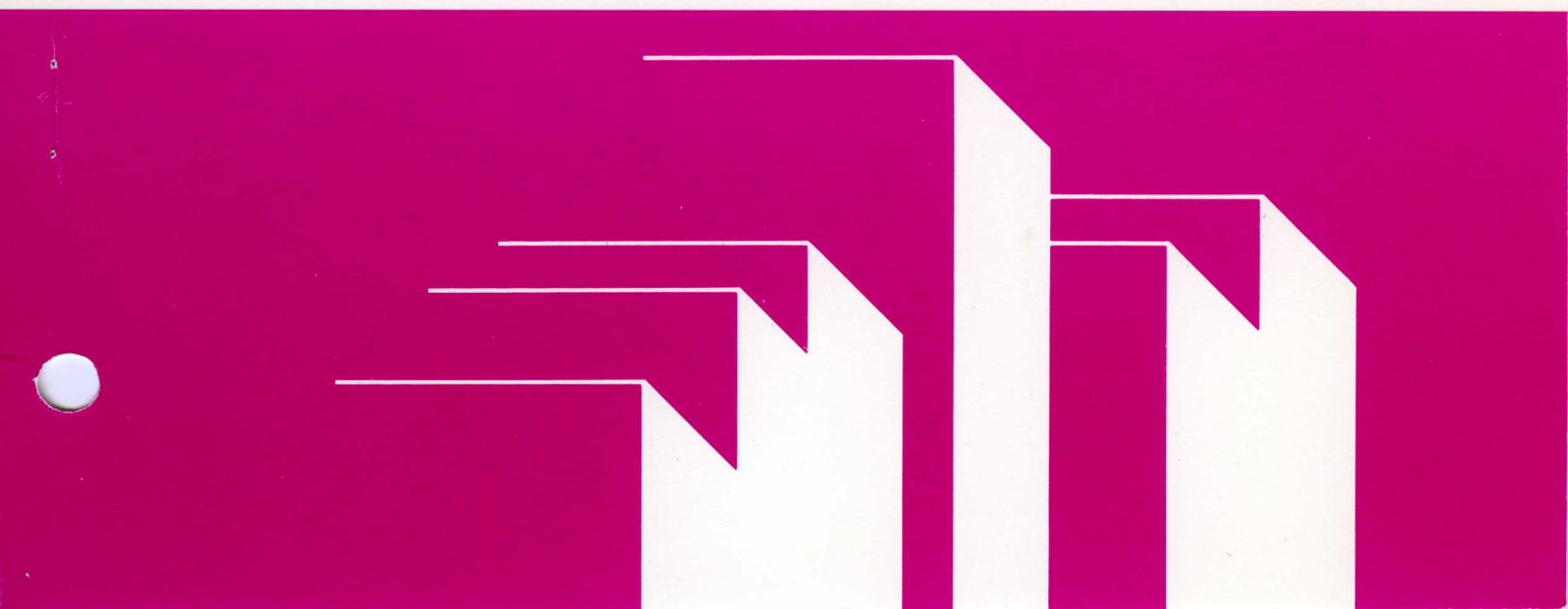
IBM System/370

Vector Operations

IBM



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This edition obsoletes the previous edition, SA22-7125-0. It contains a number of detailed changes, which are indicated by a vertical line in the margin to the left of the change.

Changes are made periodically to the information herein; before using this publication in connection with the operation of IBM equipment, refer to the latest *IBM System/370, 30xx, and 4300 Processors Bibliography*, GC20-0001, for the editions that are applicable and current.

This publication contains, for reference purposes, a detailed definition of the machine functions provided by the IBM System/370 vector facility. The vector facility operates as a compatible extension of the functions of System/370 as described in one of the Principles of Operation publications, either the facilities of the System/370 extended architecture (370-XA) in *IBM 370-XA Principles of Operation*, SA22-7085, or those of the System/370 architecture in *IBM System/370 Principles of Operation*, GA22-7000.

The publication should not be considered an introduction or a textbook. It is written as a reference for use principally by assembler-language programmers, although anyone concerned with the functional details of vector operations may find it useful. It describes each function at the level of detail needed to prepare an assembler-language program which relies on that function.

This publication does not describe all the instructions or other functions needed to write a complete program using vectors. It includes a description only of functions which are added to System/370 as part of the vector facility. The reader is assumed to be familiar with either the *IBM 370-XA Principles of Operation* or *IBM System/370 Principles of Operation*, as appropriate. Terms and concepts referred to in this publication but explained in those Principles of Operation publications are not explained again in this publication.

Writing a program in assembler language requires a familiarity with the notations and conventions of that language, as well as with the facilities of the operating system under which the program is to be run. The reader should refer to the appropriate programming publications for such information.

Terminology

As used in this publication, a *scalar* is a single data item, which may be a floating-point number, a binary integer, or a set of logical data. A *vector* is a linearly ordered collection of such scalars, where each scalar is an *element* of the vector. All elements of a single vector are of the same type: floating-point numbers (floating-point vector), binary integers (binary vector), or logical data (logical vector).

Scalar instructions are instructions which perform load, store, arithmetic, or logical operations on scalars that may reside in storage, floating-point registers, or general registers. *Vector instructions* perform similar operations on vectors that may reside in storage or in registers of the vector facility. Only vector instructions and related operations are described in this publication. Scalar instructions are described in the *IBM 370-XA Principles of Operation* or *IBM System/370 Principles of Operation*.

CHAPTER 1. INTRODUCTION

The vector facility is a compatible addition to the IBM System/370 architecture. Use of the facility may benefit applications in which a great deal of the time of the central processing unit (CPU) is spent executing arithmetic or logical instructions on data which can be treated as vectors. By replacing loops of scalar instructions with the vector instructions provided by the vector facility, such applications may take advantage of the order inherent in vector data to improve performance.

When the vector facility is provided on a CPU, it functions as an integral part of that CPU:

1. Standard System/370 instructions can be used for all scalar operations.

2. Data formats which are provided for vectors are the same as the corresponding System/370 scalar formats.

3. Long-running vector instructions are interruptible in the same manner as long-running scalar instructions; their execution can be resumed from the point of interruption after appropriate action has been taken.

4. Program interruptions due to arithmetic exceptions are handled in the same way as for scalar-arithmetic instructions, and the same fixup routines can be used with at most some minor extensions.

5. Vector data may reside in virtual storage, with access exceptions being handled in the customary manner.

COMPATIBILITY CONSIDERATIONS

Compatibility with System/370 scalar operations has been one of the major objectives of the vector architecture, so as to provide the same result data when equivalent functions are programmed on machines without the vector facility. Some departures from strict compatibility are introduced, however, for the sake of performance and to provide implementers of the vector facility more flexibility in making design choices.

Vector and Scalar Operations

Although operations on vector operands are generally compatible, element by element, with the corresponding scalar operations, there are certain differences between the vector and scalar architectures:

- Operands of vector-facility instructions must be aligned on integral boundaries; scalar-instruction operands need not be so aligned. (See the section "Vector-Instruction Operands and Results" on page 2-7.)

- Vector divide and multiply operations do not permit unnormalized floating-point operands; the corresponding scalar instructions do. Vector programs may encounter the *unnormalized operand* exception. (See the instruction descriptions and the section "Unnormalized-Operand Exception" on page 2-27.)

- Because the result of a series of floating-point additions may depend on their sequence, the results produced by the vector instructions ACCUMULATE or MULTIPLY AND ACCUMULATE, followed by SUM PARTIAL SUMS, are not necessarily identical with those produced by scalar summation loops, unless the scalar loops are written to perform the additions in exactly the same sequence as defined for the vector instructions. (See the instruction descriptions and the section "Partial-Sum Number" on page 2-2.)

- If, during execution of MULTIPLY AND ACCUMULATE, MULTIPLY AND ADD, or MULTIPLY AND SUBTRACT, the multiplication of an element pair results in an exponent underflow, a true zero is used in place of the product even when the exponent-underflow mask in the PSW is one. The vector and scalar results are the same, however, when the mask bit is zero

or when an exponent underflow occurs during the addition or subtraction. (See the instruction descriptions and the section "Exponent-Underflow Exception" on page 2-26.)

- Vector-facility instructions cannot safely be used to store into the current instruction stream, whereas all other instructions are interlocked to permit this. (See the section "Vector-Store Operations" on page 2-30.)

Model-Dependent Vector Functions

Programmers should keep the following restrictions in mind to ensure that programs will run successfully regardless of which implementation techniques have been chosen on a particular model.

The program should not depend on specific values of the model-dependent vector parameters (section size and partial-sum number). Likewise, the program should not depend on the contents of fields that are described as "reserved" or "undefined." Specifically:

- The section size should not be treated as a numeric constant. Thus, save-area sizes should be computed from the section-size value obtained at execution time. (See the section "Save-Area Requirements" on page 2-29.) The section size may be obtained by executing the instruction STORE VECTOR PARAMETERS.

- The program should not rely on reserved bits 0-14 of the vector-status register being zeros when placed in a general register by the instruction EXTRACT VECTOR MASK MODE, or on the bits being stored as zeros by SAVE VSR. (See the instruction descriptions "EXTRACT VECTOR MASK MODE" on page 3-11 and "SAVE VSR" on page 3-34.)

- The program should not depend on any particular values being stored by the instruction SAVE VMR in the undefined part of the save area for the vector-mask register; nor should the program depend on the presence or absence of access exceptions for that portion of the VMR save area when executing RESTORE VMR or SAVE VMR. (See the instruction descriptions "SAVE VMR" on page 3-33 and "RESTORE VMR" on page 3-29.)

- When a program using vector-facility instructions is interrupted, it cannot be safely resumed on another machine with a different section size or partial-sum number, unless the interruption occurred at a point that is known to be independent of the section size or partial-sum number, respectively.

- The exact result produced by the vector instructions ACCUMULATE or MULTIPLY AND ACCUMULATE, followed by SUM PARTIAL SUMS, may depend on the partial-sum number of the model because that number affects the sequence of performing the floating-point additions.

The program should not rely on receiving a specific program interruption, either operation exception or vector-operation exception, to indicate whether the vector facility is installed in any CPU of the configuration, since it depends on the model which of the two exceptions occurs. (See the section "Vector-Operation Control" on page 2-6.)

Problem-state programs should not depend on the setting of the vector change bits, which may be altered by actions of the control program that are unrelated to the actions of a problem-state program. Supervisor-state programs can depend on the accuracy of vector change bits that are zeros; vector change bits may sometimes be set to one, however, even when the corresponding vector-register pair has not been changed. Note also that the effect on the vector change bits of executing the instructions RESTORE VR and RESTORE VSR depends on whether the CPU is in the problem or supervisor state. (See the section "Vector Change Bits" on page 2-4.)

PER events for general-register alteration may or may not be recognized for vector-facility instructions.

VECTOR-FACILITY STRUCTURE

The vector facility provides:

1. The vector-facility registers:
   - 16 vector registers
   - A vector-mask register
   - A vector-status register
   - A vector-activity count
2. 171 instructions
3. The following exceptions and exception indications:
   - An unnormalized-operand exception
   - A vector-operation exception
   - An exception-extension code for arithmetic exceptions
4. A vector-control bit, bit 14 of control register 0

Figure 2-1 on page 2-2 shows the registers provided by the vector facility.

Vector-Data Registers

Vector Registers

There are 16 vector registers, numbered 0-15. They are used to hold one or more of the vector operands in most arithmetic, comparison, logical, load, and store operations. Unlike the general and floating-point registers, the vector registers are multipurpose in that vectors of floating-point, binary-integer, and logical data can all be accommodated.

Each vector register contains a number of element locations of 32 bits each. Depending on the operation, a vector operand may occupy a single vector register or an even-odd pair of registers. The element locations of a vector register are identified by consecutive element numbers, starting with 0.

Vector-Mask Register

There is one vector-mask register (VMR), which is used as:

- The target of the result of vector-compare operations,
- The source and target of logical operations on bit vectors, and
- The source of the mask for mask-controlled operations.

Vector Parameters

The section size and the partial-sum number are model-dependent parameters which control certain operations of the vector facility.

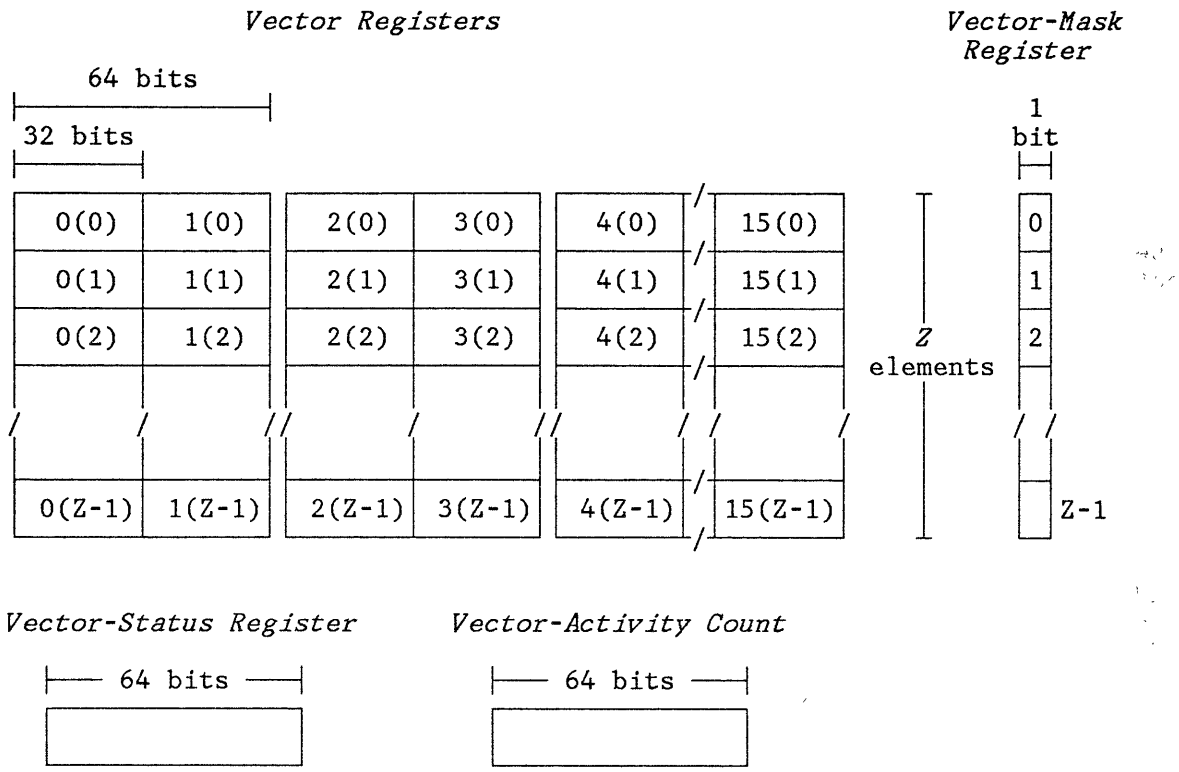
Section Size

The number of element locations in a vector register, which is also the number of bit positions in the vector-mask register, is called the section size. The section size is a power of 2; depending on the model, the section size may be 8, 16, 32, 64, 128, 256, or 512.

The element locations of a vector register, as well as the bit positions in the vector-mask register, are numbered from 0 to one less than the section size.

In a multiprocessing configuration, the section size is the same for each CPU which has the vector facility installed.

The section size of a model may be obtained by executing the instruction STORE VECTOR PARAMETERS, which places the value as a 16-bit binary integer in the left half of a word in storage.



Note: *Z* is the section size (model-dependent).

Figure 2-1. Registers of the Vector Facility

Partial-Sum Number

The partial-sum number is the number of partial sums produced when executing the instruction ACCUMULATE or MULTIPLY AND ACCUMULATE. It is also the number of vector-register elements set to zero by the instruction ZERO PARTIAL SUMS, as well as the number of vector-register elements summed by the instruction SUM PARTIAL SUMS.

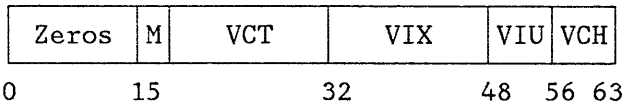
Depending on the model, the partial-sum number may range from 1 up to and including the section size.

In a multiprocessing configuration, the partial-sum number is the same for each CPU which has the vector facility installed.

The partial-sum number of a model may be obtained by executing the instruction STORE VECTOR PARAMETERS, which places the value as a 16-bit binary integer in the right half of a word in storage.

Vector-Status Register

The vector-status register (VSR) is 64 bits long and contains five fields of information, which describe the current status of the vector and vector-mask registers and of a mode of operation. The fields are arranged as follows:



The contents of the vector-status register as a whole may be examined by the instruction SAVE VSR and altered by the instruction RESTORE VSR. Bits 0-14 of the VSR are reserved for possible future use and are stored as zeros by SAVE VSR; if the instruction RESTORE VSR specifies other than all zeros for these bit positions, a specification exception is recognized.

Vector-Mask-Mode Bit

When the vector-mask-mode bit (M), bit 15 of the vector-status register, is one, the vector-mask mode is on, and arithmetic and logical instructions are executed under the control of bits in the vector-mask register. When the bit is zero, the mode is off. For details, see the section "Conditional Arithmetic" on page 2-12.

Vector Count

The vector count (VCT), bits 16-31 of the vector-status register, is a 16-bit unsigned binary integer. Together with the vector interruption index, it determines for most vector operations the number of element locations to be processed in vector registers or the number of bit positions to be processed in the vector-mask register.

Elements in register positions with element numbers less than the vector count are called the active elements of the vector register. Likewise, bits in bit positions of the vector-mask register with bit numbers less than the vector count are called the active bits of the vector-mask register. Only the active elements or bits take part in operations where the number of elements or bits processed is determined by the vector count.

The vector count may range in value from zero up to and including the section size. A specification exception is recognized if the instruction RESTORE VSR attempts to place a value in the vector-count field which exceeds the section size. The instruction EXTRACT VCT may be used to examine the vector count.

The following instructions may be used to set the vector count. If they specify a number greater than the section size, they set the vector count equal to the section size.

```
LOAD BIT INDEX
LOAD VCT AND UPDATE
LOAD VCT FROM ADDRESS
```

For information on using the vector count with vectors of any length, see the section "Vector Sectioning" on page 2-11.

Vector Interruption Index

The vector interruption index (VIX), bits 32-47 of the vector-status register, is a 16-bit unsigned binary integer. It specifies the number of the first element location in any vector register, or of the first bit position in the vector-mask register, to be processed by an interruptible vector instruction which depends on the vector interruption index. The vector interruption index is used to control resumption of the operation after such an instruction has been interrupted. It is normally zero at the start of execution, and it is set to zero at completion.

For details concerning the operation of the vector interruption index and the effect of an interruption, see the section "Vector Interruptions" on page 2-20.

The vector interruption index may range from zero to the section size. It may be examined by using the instruction SAVE VSR, and it may be set explicitly by RESTORE VSR. The instruction CLEAR VR sets the vector interruption index to zero. A specification exception is recognized if the instruction RESTORE VSR attempts to place a value in the vector-interruption-index field which exceeds the section size.

Programming Notes

1. Since the vector interruption index is always set to zero upon completion of any instruction which depends on it, the program normally need not be concerned with setting its value.

2. The vector interruption index may be set to zero explicitly by use of the instruction CLEAR VR with a zero operand.

3. If it is desired to operate on a vector in a vector register starting at other than element location 0, this may be done by first setting the vector interruption index (VIX) to the initial element number. The VIX may be set by using the instruction SAVE VSR to place the current

contents of the vector-status register (VSR) in storage, placing the initial element number in the field which corresponds to the VIX, and then returning the result to the VSR by means of RESTORE VSR. Such modification of the VSR can be performed safely when the CPU is in the problem state. If a program modifying the VSR is to be executed in the supervisor state, however, additional precautions may have to be taken; see the section "Vector Change Bits," programming note 3 on page 2-5.

Vector In-Use Bits

The eight vector in-use bits (VIU), bits 48-55 of the vector-status register, correspond to the eight vector-register pairs 0, 2, 4, 6, 8, 10, 12, and 14.

The vector in-use bits indicate which vector-register pairs are to be saved and restored by SAVE VR and RESTORE VR. These instructions ignore vector-register pairs for which the vector in-use bit is zero.

During execution of instructions which use the vector registers, the vector in-use bit associated with a vector-register pair is set to one whenever any element in either or both of the registers is loaded or modified. When a register is used as the source of an operand, its vector in-use bit remains unchanged.

The vector in-use bits are set by the instruction RESTORE VSR. If that instruction changes a vector in-use bit from one to zero, it causes the corresponding vector-register pair to be cleared to zeros. A vector in-use bit is set to zero when the instruction CLEAR VR clears the corresponding vector-register pair to zeros.

See the section "Program Switching" on page 2-28 for a discussion of the vector in-use bits.

Vector Change Bits

The eight vector change bits (VCH), bits 56-63 of the vector-status register, correspond to the eight vector-register pairs 0, 2, 4, 6, 8, 10, 12, and 14.

The vector change bits indicate which vector-register pairs are to be saved by the privileged instruction SAVE CHANGED VR. That instruction saves a vector-register pair if the corresponding vector change bit is one; it then sets the vector change bit to zero.

If the vector in-use bit associated with a vector-register pair is set to zero by the instruction CLEAR VR or RESTORE VSR, the corresponding vector change bit is also set to zero.

During execution of an instruction which uses the vector registers, the vector change bit associated with a vector-register pair is set to one whenever any element in either or both of the registers is loaded or modified. An exception is the instruction RESTORE VR; when the CPU is in the supervisor state, execution of RESTORE VR leaves the vector change bits unchanged.

When a vector register is used as the source of an operand, its vector change bit remains unchanged.

See the section "Program Switching" on page 2-28 for further discussion of the vector change bits.

Programming Notes

1. The vector change bit is always zero when the vector in-use bit is zero. When the vector change bit is set to one, the vector in-use bit is also set to one.

2. As pointed out in the section "Program Switching" on page 2-28, vector change bits are intended for use by control programs operating in the supervisor state. When the CPU is in the problem state, the value of the vector change bits stored by SAVE VSR is undefined; problem-state programs should, therefore, not depend on the value of these bits.

   A program operating in the problem state cannot set a vector change bit

to zero, except by also setting the corresponding in-use bit to zero (clearing the vector-register pair). In the problem state, the instruction RESTORE VSR sets the vector change bit to one for every pair of vector registers whose in-use bit is set to one.

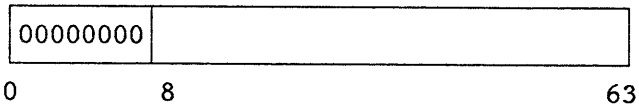
3. If a program uses the instruction RESTORE VSR to modify the contents of the vector-status register while the CPU is in the supervisor state, and the program is subject to interruptions for which the interruption handler may cause a SAVE CHANGED VR instruction to be executed, care must be taken to ensure that the vector change bits reflect all modifications of the active vector registers. A safe procedure is to supply ones in all bit positions of the operand of RESTORE VSR which correspond to the vector change bits. This precaution is unnecessary in the problem state, because RESTORE VSR then sets the vector change bits to ones regardless of the operand.

4. A program operating in the supervisor state can depend on the accuracy of vector change bits that are zeros. When the program is a guest in a virtual-machine environment, however, vector change bits may be overindicated, so that a bit may be set to one even when the corresponding vector-register pair has not been changed.

Vector-Activity Count

The vector-activity count (VAC) provides a means for measuring and scheduling the machine resources used in executing instructions of the vector facility.

The vector-activity count has this format:



Bits 8-63 are a 56-bit unsigned binary integer. In the basic form, this integer is incremented by adding a one in bit position 51 every microsecond while a vector-facility instruction is being executed. In models having a higher or lower resolution, a different bit position is incremented at such a frequency that the rate of incrementing the vector-activity count is the same as if a one were added in bit position 51 every microsecond during those periods. Bits 0-7 are zeros.

The contents of the vector-activity count may be obtained by executing the privileged instruction SAVE VAC, and they may be set by means of the privileged instruction RESTORE VAC. Bits 0-7, and any rightmost bit positions which are not incremented, are stored as zeros by SAVE VAC and are ignored by RESTORE VAC.

When incrementing the vector-activity count causes a carry to be propagated out of bit position 8, the carry is ignored, and counting continues from zero. The program is not alerted, and no interruption occurs as a result of the overflow. Except for such wraparound, or an explicit restore or reset operation, the value of the count never decreases.

The vector-activity count is not incremented during execution of the instructions RESTORE VAC and SAVE VAC. In addition, depending on the model, the count may not be incremented during execution of some other short, uninterruptible instructions of the vector facility.

The vector-activity count is incremented only when the CPU is in the operating state.

Programming Notes

1. The vector-activity count is not intended to be a precise measure of vector execution time. The count may or may not advance during the execution of a particular vector-facility instruction. In the aggregate, however, the count reflects the execution time of the vector portion of normal application programs.

2. The format of the vector-activity count has been chosen to permit the use of unnormalized scalar floating-

point instructions to perform fast addition and subtraction of VAC values.

Modes of Operation

The operation of the vector facility is independent of the architectural mode, except for the range of storage addresses which can be specified. The 370-XA architectural mode provides the choice of operating in either a 31-bit or 24-bit addressing mode; the System/370 architectural mode does not. On a CPU which provides both the 370-XA and System/370 modes, vector operations in the System/370 mode are the same as in the 370-XA mode when in the 24-bit addressing mode. Thus, an address size of 24 bits is available in either the 370-XA or System/370 mode, but vector operations with an address size of 31 bits can be performed only in the 370-XA mode. In the System/370 mode, instructions of the vector facility may be executed in both the EC and BC modes.

In both the 370-XA and System/370 modes, vector operations are governed by the vector-control bit.

Vector-Operation Control

When the vector facility is installed and available on a CPU, execution of vector-facility instructions can be completed only if bit 14 of control register 0, the vector-control bit, is one. Executing a vector-facility instruction when the vector-control bit is zero causes a vector-operation exception to be recognized and a program interruption to occur. The initial value of the vector-control bit is zero.

When the vector facility is not installed or not available on this CPU but is installed on any other CPU which is or can be placed in the configuration, executing a vector-facility instruction causes a vector-operation exception to be recognized regardless of the state of the vector-control bit.

If the vector facility is not installed on any CPU which is or can be placed in the configuration, it depends on the model whether executing a vector-facility instruction causes a vector-operation exception or an operation exception to be recognized.

A vector facility, though installed, is considered not available when it is not in the configuration, when it is in certain maintenance modes, or when its power is off.

Figure 2-2 summarizes the effect of the vector-control bit according to whether the vector facility is installed and whether vector instructions can be executed by the program.

Vector Facility Installed on Another CPU	Vector Facility on This CPU			
			Effect of Vector-Facility Instruction	
	In-stalled	Avail-able	VC = 0	VC = 1
Yes or No	Yes	Yes	VOP	Exe-cute
Yes or No	Yes	No	VOP	VOP
Yes	No	(NA)	VOP	VOP
No	No	(NA)	VOP or OP	VOP or OP

Explanation:

NA Not applicable
OP Operation exception
VC Vector-control bit (control register 0, bit 14)
VOP Vector-operation exception

Figure 2-2. Vector Control

Programming Notes

1. The control program may use the vector-control bit to defer enabling of the CPU for vector operations and to delay allocation of a vector-save area until a program attempts to use the facility by executing its first vector instruction. Because the resulting vector-operation exception nullifies the operation, the instruction address does not need to be adjusted in order to resume the program.

2. The control program may also keep the vector-control bit set to zero

to prevent a program from examining or changing the contents of the vector-facility registers. This may be useful when a program that does not use the vector facility is to be run after a program that does use the facility has been interrupted. If the next program to use the vector registers is the original program, then running the intervening program with the vector-control bit set to zero may eliminate the need for information held in the vector facility to be saved and later restored.

A possible exception is the vector-activity count (VAC). When the vector-control bit is zero, the VAC may or may not be incremented during the brief period of detecting that an instruction requires the vector-operation exception to be recognized. The number of times that the VAC might be stepped in this way is small, however, compared to the counts accumulated during execution of a vector-application program.

3. When a machine check indicating vector-facility failure occurs, the machine has made a previously available vector facility unavailable. Until the cause of the failure is removed and the facility is made available again, attempting to execute a vector instruction causes a vector-operation exception to be recognized even though the vector-control bit is one. (See the section "Vector-Facility Failure" on page 2-31.)

VECTOR-INSTRUCTION OPERANDS AND RESULTS

The vector facility provides for operations on vectors of short (32-bit) and long (64-bit) floating-point numbers, 32-bit signed binary integers, and 32-bit logical data. A few operations deal with vectors of 16- and 64-bit signed binary integers. There are also operations on vectors of individual bits, which are generally used as mask bits.

All binary-arithmetic vector operations treat elements of 32-bit binary integers as signed; any fixed-point-overflow exceptions are recognized. Binary-comparison operations also deal with 32-bit signed binary integers. Logical vector operations, including shifts, treat elements as 32-bit logical data.

Most instructions which operate on floating-point, binary-integer, or logical vectors use a format that explicitly designates three operands: two source operands and one target operand. The operands may be:

- In storage,
- In a vector register, or a pair of vector registers, or
- In a scalar (general or floating-point) register.

Instructions which use mask bits generally designate an implicit operand in the vector-mask register, and they also may explicitly designate storage, vector-register, and scalar-register operands.

All vector operands in storage must be aligned on integral boundaries. When an instruction requires boundary alignment and the storage operand is not designated on the appropriate boundary, a specification exception is recognized.

An instruction which processes operands in vector or scalar registers must designate a valid register number for each such operand. If an invalid register number is designated, a specification exception is recognized.

Figure 2-3 on page 2-8 summarizes the vector-data formats, the associated operations, and the boundary-alignment and register-number requirements.

Vectors of 16-, 32-, and 64-bit elements containing arithmetic or logical data are collectively referred to as arithmetic vectors. Arithmetic vectors in storage must be on integral boundaries. The elements of arithmetic vectors have the same formats as scalar data of the same data type.

Vectors of individual bits are referred to as bit vectors (see the section "Bit Vectors" on page 2-10).

Data Type	Width in Bits				Alignment Required In Storage	Valid Register Numbers	
	1	16	32	64		Scalar Register	Vector Register
Floating point							
Short			A		Word	Even FR	Any VR
Long				A	Doubleword	Even FR	Even VR
Binary integer							
16-bit signed		S			Halfword	--	Any VR
32-bit signed			B		Word	Any GR	Any VR
64-bit signed				P	--	--	Even VR
Logical			L		Word	Any GR	Any VR
Bit	M				Byte	--	--

Explanation:

-- Does not apply
A All arithmetic, load, and store operations
B Some arithmetic and all load and store operations
FR Floating-point register
GR General register
L Logical and shift operations
M Logical operations on bits in storage and in vector-mask register; comparison results
P 64-bit binary integers, which occur only as the result of a binary multiply operation
S Only load and store operations, which convert between 16 bits in storage and 32 bits in a vector register
VR Vector register

Figure 2-3. Types of Vector Data

Programming Note

Logical-data elements may also be considered as 32-bit unsigned binary integers, but no arithmetic or comparison operations are provided to process such vectors.

Arithmetic Vectors in Storage

Arithmetic vectors in storage may be loaded and stored in one of two ways:

- By sequential addressing (contiguously or with stride)
- By indirect element selection

Most arithmetic, comparison, and logical instructions may also access one of the vector operands directly from storage by sequential addressing. Indirect element selection is available only for load and store operations.

Access by Sequential Addressing

Vector elements are most often accessed in storage in a regular sequence of addresses. The instruction specifies a general register containing the starting address and, optionally, another general register containing the stride. The stride, which is a 32-bit signed binary integer, is the number of element locations by which the operation advances when proceeding from one element to the next. The maximum number of elements to be accessed is specified by the vector count.

A stride of one specifies a contiguous vector, for which successive elements are in adjacent storage locations; this stride is the default when no general register is specified for the stride. A stride of zero causes the same element to be used repeatedly as the storage

operand. A negative stride causes elements to be accessed in a descending sequence of addresses.

During the execution of instructions which access an arithmetic vector in storage sequentially, the starting address contained in the general register is updated as successive elements in storage are accessed. At the end of instruction execution, or at the time of any interruption, the contents of the general register have been updated to the storage address of the next vector element due to be processed if instruction execution had not ended or been interrupted. Likewise, when instructions process a bit vector in storage, the starting address in the general register is updated by the number of bytes accessed during execution.

Such automatic updating of vector addresses is used to process a vector in sections when the vector has more elements than will fit into a vector register. It also assists in resuming instruction execution after an interruption.

For more details on sequential addressing, see the section "Class-IM and Class-IC Instructions" on page 2-15. For more information on sectioning, see the section "Vector Sectioning" on page 2-11.

Programming Note

A contiguous vector is implied when zero is specified in the instruction field that designates the general register containing the stride. This differs from a zero stride, which is specified by placing a value of zero in the general register containing the stride, and which causes reuse of the same element in storage. A zero stride is generally not desired because the scalar form of an instruction is usually faster than repeated use of the same storage location. (See the section "Operands in Scalar Registers" on page 2-10.)

Access by Indirect Element Selection

Indirect element selection permits vector elements to be loaded or stored in an arbitrary sequence. With the instructions used for indirect element selection, LOAD INDIRECT and STORE INDIRECT, the locations of the individual operand elements to be loaded or stored are designated by a vector of element numbers in a vector register. Each such element number indicates the position of the corresponding operand element relative to the start of the operand vector. The number of operand elements accessed, which is also the number of element numbers used for indirect element selection, is equal to or less than the vector count.

The element numbers used for indirect element selection are 32-bit signed binary integers. They may be positive, negative, repeated, and in any order. Successive operand elements are located in storage at addresses $A + w*E(0)$, $A + w*E(1)$, $A + w*E(2)$, ..., where A is the origin of the operand vector in storage, w is the width in bytes (4 or 8) of each element, and $E(0)$, $E(1)$, $E(2)$, ... are the successive element numbers in a vector register.

General-register address updating does not apply to the instructions LOAD INDIRECT and STORE INDIRECT.

Programming Notes

1. For a discussion of address updating, see the programming notes under "Vector Sectioning" on page 2-11.

2. Vectors of element numbers may be stored as 16-bit signed binary integers when the element numbers remain within the range of such integers. The vector instructions LOAD HALFWORD and STORE HALFWORD perform the conversion between the 16-bit and 32-bit formats.

3. Accessing vectors in storage in the arbitrary sequence permitted by indirect element selection may be significantly slower than accessing contiguous vector elements.

Arithmetic Vectors in Registers

Operands in Vector Registers

Any vector register can be designated for a vector of short floating-point numbers, 32-bit signed binary integers, or 32-bit logical data. Even-odd vector-register pairs are coupled to hold long floating-point numbers or the 64-bit signed binary integers which result from binary multiplication.

When a vector register is modified, those elements in the vector register beyond the last element to be modified are left unchanged.

Most operations on floating-point, binary, or logical vectors which may be performed with one vector operand in storage and one operand in a vector register may also be performed with both operands in vector registers. When both operands are in vector registers, the corresponding pairs of elements from each vector-register operand generally have the same element number (but see the descriptions of ACCUMULATE and MULTIPLY AND ACCUMULATE for an exception to this rule).

Operands in Scalar Registers

Operations on floating-point, binary, or logical vectors may specify as one source operand the contents of a scalar register, that is, of a floating-point or general register, the other operand being a vector. This scalar operand is used repeatedly and treated as a vector of identical elements of the same length as the vector operand.

Some vector instructions which obtain one of the source operands from a scalar register also produce a scalar result, which replaces the contents of the same scalar register.

Bit Vectors

A group of bits in contiguous bit positions is called a bit vector. Bit vectors are the operands of logical operations where one of the operands is in the vector-mask register. They are used in operations on arithmetic vectors under mask control.

A bit vector in storage must begin on a byte boundary, but it may end at any bit position, the remaining bits of the rightmost byte being ignored. When the instruction STORE VMR stores a bit vector with the vector count specifying a number of bits that is not a multiple of 8, the final byte stored is padded on the right with zeros.

When used for the control of load and store operations or for arithmetic and logical operations in the vector-mask mode, the appropriate bit vector must first be placed in the vector-mask register. Each bit in the vector-mask register corresponds sequentially, one for one, to an element of one or both of the vector-register operands.

Bit vectors in the vector-mask register are generated or altered by the following vector instructions:

AND TO VMR
COMPARE
COMPLEMENT VMR
EXCLUSIVE OR TO VMR
LOAD VMR
LOAD VMR COMPLEMENT
OR TO VMR

Programming Notes

1. Examples of the use of bit vectors for mask control are shown in Appendix A.

2. Since the section size is a multiple of 8 and bit vectors start on a byte boundary, every section of a bit vector also starts on a byte boundary. Thus, after an instruction has completed processing a full section of bits, the next bit is always the leftmost bit of the byte specified by the updated address.

3. When a bit vector is used as a mask to identify selected elements of an arithmetic vector with one bits and the remaining elements with zero bits, the bit vector is logically equivalent to a vector containing a set of element numbers in ascending sequence, which may be used for indirect selection of the arithmetic-vector elements. The vector of element numbers consists merely of the bit indexes (bit

numbers) of the one bits in the bit vector.

A bit vector may be converted to a vector of element numbers by the instruction LOAD BIT INDEX. This instruction operates directly on a bit vector in storage and produces a vector of element numbers in a vector register; the vector-mask register is not used.

Vector Sectioning

Vector sectioning is a programming technique for processing vectors the length of which may exceed the section size. Such vectors are processed by dividing them into smaller sections and using a loop of instructions, referred to as a sectioning loop, which repeats the appropriate sequence of instructions for all consecutive sections of the specified vectors. To assist with such sectioning, addresses of vector operands in storage and bit-vector parameters are automatically updated, and the instruction LOAD VCT AND UPDATE is provided.

The LOAD VCT AND UPDATE instruction specifies a general register that has initially been loaded with the total number of vector elements to be processed. The instruction sets the vector count to the lesser of the section size and the general-register contents. It also subtracts this value from the current contents of the general register, which then contains the number of elements remaining to be processed during subsequent passes through the sectioning loop.

LOAD VCT AND UPDATE sets the condition code to provide the program with an indication of whether a complete vector has been processed. The program may use the instruction BRANCH ON CONDITION for loop control to repeat the sequence of instructions for each section. A sectioning loop may also be closed by testing the residual count in the general register for zero and branching back to the start of the loop if not zero.

For most vector operations, the program can be written such that sectioning is independent of the section size. There are occasions, however, when knowledge of the actual section size is desirable; this value is available to the program by executing the instruction STORE VECTOR PARAMETERS.

Programming Notes

1. Examples of sectioning are shown in Appendix A.

2. One method of controlling the vector count for sectioning is to place the instruction LOAD VCT AND UPDATE at the beginning of the loop and an appropriate BRANCH ON CONDITION instruction at the end of the loop. This is usually sufficient because most vector-facility instructions do not set the condition code. If the sectioning loop does contain an instruction that modifies the condition code, the final BRANCH ON CONDITION instruction could be preceded by a LOAD AND TEST instruction to test the general register containing the residual vector count.

   Appendix A also illustrates other techniques.

3. If a sectioning loop contains more than one reference to the same vector in storage, such as a load followed later by a store, the program must ensure, by retaining a copy of the current address, that all addresses within the loop which specify the same vector refer to the same section.

4. The instructions which provide indirect element selection, LOAD INDIRECT and STORE INDIRECT, progress one section of element numbers at a time. But sectioning of the vector of element numbers used for addressing is performed by a preceding instruction which loaded or generated the element numbers by means of sequential addressing. The indirect-selection instructions themselves do not provide for address updating. Each element address is computed separately from an element number and from the specified starting address, which remains unchanged.

Conditional Arithmetic

Vector-Mask Mode

The vector-mask mode allows for conditional execution of arithmetic and logical instructions, depending on the mask bits in the vector-mask register.

When the vector-mask mode is in effect, operand elements are processed if they are in positions which correspond to mask bits that are ones. In positions which correspond to zero mask bits, the target locations remain unchanged, no arithmetic or operand-access exceptions are recognized for those positions, the corresponding change bits in storage remain unchanged, and no PER event for storage alteration is indicated. When the vector-mask mode is not in effect, the mask bits are ignored, and all active elements are processed.

The arithmetic and logical vector instructions which are under the control of the vector-mask mode are:

ACCUMULATE
ADD
AND
DIVIDE
EXCLUSIVE OR
LOAD COMPLEMENT
LOAD NEGATIVE
LOAD POSITIVE
MAXIMUM ABSOLUTE
MAXIMUM SIGNED
MINIMUM SIGNED
MULTIPLY
MULTIPLY AND ACCUMULATE
MULTIPLY AND ADD
MULTIPLY AND SUBTRACT
OR
SHIFT LEFT SINGLE LOGICAL
SHIFT RIGHT SINGLE LOGICAL
SUBTRACT

Except for LOAD COMPLEMENT, LOAD NEGATIVE, and LOAD POSITIVE, which are considered arithmetic instructions for this purpose, load and store instructions are not controlled by the vector-mask mode; neither are instructions which modify the vector-mask register, such as COMPARE. LOAD EXPANDED, LOAD MATCHED, STORE COMPRESSED, and STORE MATCHED do depend on the vector-mask register for their execution, but this is independent of the mode setting.

For more details, see the section "Class-IM and Class-IC Instructions" on page 2-15.

Instructions Controlling the Vector-Mask Mode

The instruction SET VECTOR MASK MODE (VSVMM) turns the vector-mask mode on or off. EXTRACT VECTOR MASK MODE (VXVMM) places the current value of the mode in a general register.

Programming Notes

1. The vector-mask mode is useful when arithmetic vector operations depend on the result of a vector comparison. Only elements which are to be processed are subject to arithmetic and access exceptions.

2. Since loading, comparing, and storing are operations which are not subject to the vector-mask mode, it is frequently possible to leave the vector-mask mode in effect while performing the arithmetic for an entire sectioning loop.

COMMON INSTRUCTION DESCRIPTIONS

Many vector-facility instructions have common characteristics and obey common rules for accessing the elements of their vector operands. This section describes the common aspects, which are not repeated in individual instruction descriptions.

Some instructions contain fields that vary slightly from the basic format, and in some instructions, the operation performed does not follow the general rules stated in this section. Any exceptions to these rules are noted in the individual instruction descriptions, as are the rules for instruction formats and types not covered in this section.

The rules are grouped according to instruction classes and formats.

Programming Note

Many load and all store operations on vectors are the same for binary and short floating-point operands, so that only a single set of operation codes is provided for them. However, for programming convenience, both binary and short floating-point mnemonics are assigned to these operation codes.

Separate operation codes are provided for short floating-point and binary operands when the operation must distinguish between floating-point and general registers, as in loading or extracting an element, or when the operation depends on the data type, such as LOAD COMPLEMENT.

Instruction Classes

Vector-facility instructions are classified into one of nine classes: IM, IC, IG, IP, IZ, NC, NZ, N1, and N0. The properties of these nine instruction classes are summarized in Figure 2-4.

Instruction Class	Number of Elements or Bits	Execution Interruptible?	Vector-Mask Mode Control?
IM	VCT - VIX	Yes	Yes
IC	VCT - VIX	Yes	No
IG	GR and VIX	Yes	No
IP	PSN - VIX	Yes	No
IZ	SS	Yes	No
NC	VCT	No	No
NZ	SS	No	No
N1	One	No	No
N0	None	No	No

Explanation:

GR	Number of bits determined by contents of a general register
PSN	Number of elements determined by partial-sum number
SS	Section size
VCT	Vector count
VIX	Vector interruption index

Figure 2-4. Vector-Facility Instruction Classes

The instruction classes distinguish:

- Whether the instruction is interruptible (I_) or not interruptible (N_),
- Whether instruction execution depends on the vector interruption index (IM, IC, IG, IP),
- Whether instruction execution depends on the setting of the vector-mask mode (IM),
- Whether the number of vector elements or bits processed is variable and is controlled by the vector count (IM, IC, NC) or by a general register (IG),
- Whether the number of vector elements or bits processed is the partial-sum number (IP) or the section size (IZ, NZ),
- Whether just one vector element is processed (N1) or none (N0).

Instruction Formats

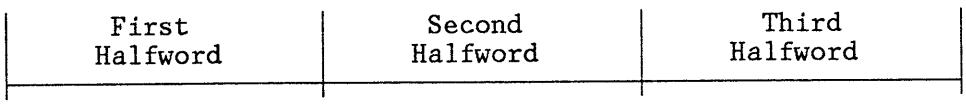
The instruction formats used by vector-facility instructions are shown in Figure 2-5 on page 2-14. The first four are the base formats — QST, QV, VST, and VV, where Q indicates that the format provides for a scalar-register operand, ST indicates a storage operand (with stride), and V indicates a vector-register operand. Most of the arithmetic instructions are available in all four of these base formats. For the vector-comparison instructions, the VR_1 field of the base formats is interpreted as a modifier (M_1).

Bit positions which are shown in instruction formats as shaded (////) are unassigned.

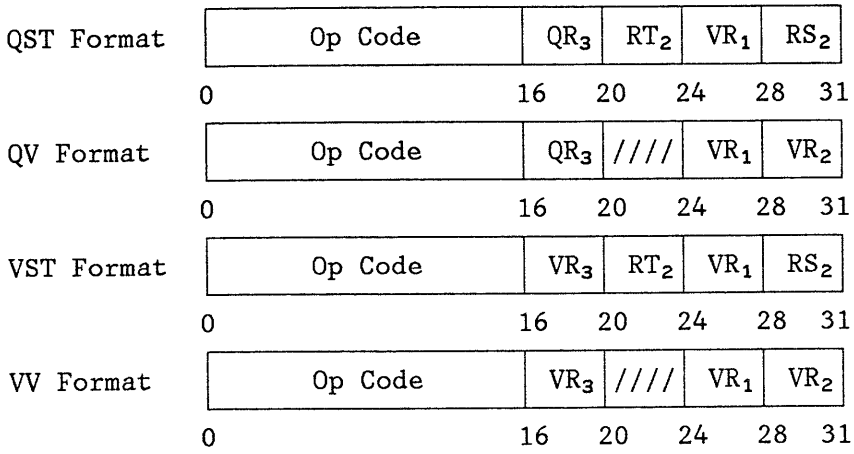
Field Designations

The field designations in the instruction formats indicate the use of the field and the type of operation in which the field participates.

B_2 and D_2 Fields: B_2 designates a base register, and D_2 is a displacement. They are used for addressing in the same way as with scalar instructions.



Base Formats



Other Formats

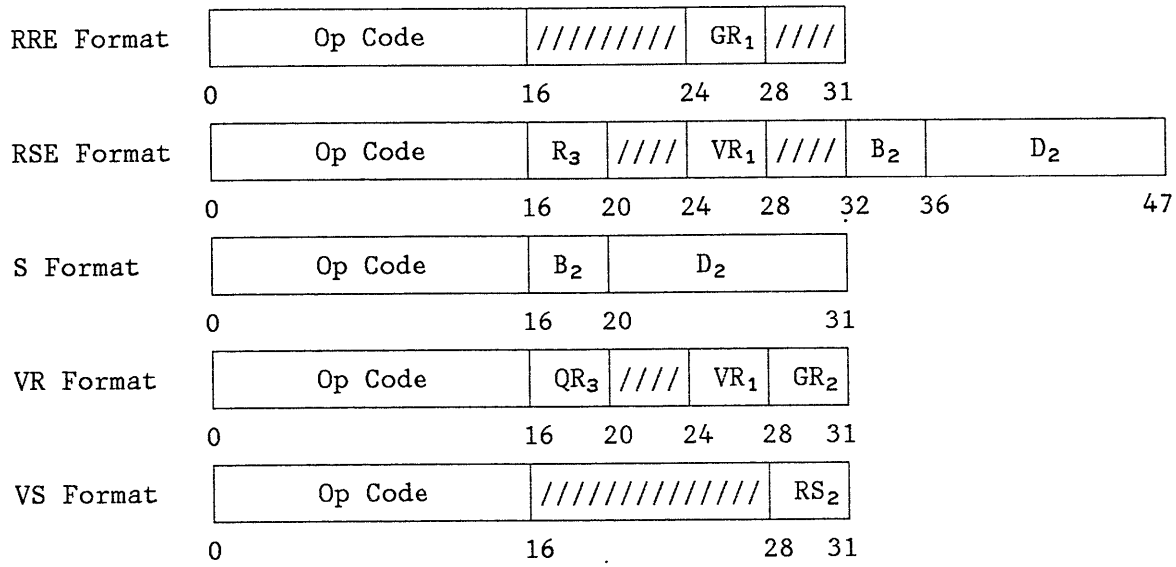


Figure 2-5. Vector-Facility Instruction Formats

FR_3 Field: FR_3 designates a (scalar) floating-point register. It is a more specific description of the QR_3 field used in some instruction descriptions, and the same rules and restrictions apply as for QR_3.

GR Field: GR designates a (scalar) general register or a pair of general registers. Unless otherwise indicated in the individual instruction definitions, the contents of the general registers designated by the GR_1 and GR_2 fields are called the first operand and second operand, respectively. When designating the third operand (GR_3), it is a more specific indication of the QR_3 field used in some instruction descriptions, and the same rules and restrictions apply as for QR_3.

QR_3 Field: QR_3 designates a scalar register, with the operation code determining whether it is a floating-point or general register. In the QST format, the QR_3 field must not designate a general register which is the same as that designated by the RS_2 field; otherwise, a specification exception is recognized. For instructions in the QV or VR formats with only two operands, one a vector and one a scalar, the scalar operand is called the second operand and is designated by a QR_2 field.

R_3 Field: R_3 is shown in individual instruction descriptions as either VR_3, to designate a vector register, or GR_3, to designate a general register.

RS_2 Field: RS_2 designates a general register containing a storage-operand address. The address is updated during execution. The RS_2 field cannot designate the same general register as the RT_2 field or, in the QST format, as the GR_3 or QR_3 field. (Note that the field can designate general register 0.)

RT_2 Field: RT_2 designates a general register containing a stride. The field cannot designate general register 0; if the RT_2 field is zero, a stride of 1 is specified. It also cannot designate the same general register as the RS_2 field.

VR Field: VR designates a vector register or a pair of vector registers. The VR_1, VR_2, and VR_3 fields designate the first, second, and third operands, respectively, in vector registers or pairs of vector registers, as required for the data type specified by the operation code.

Three-Operand Instruction Formats

All nonstore vector instructions which explicitly specify three operands in the QST, QV, RSE, VST, and VV formats use the first-operand location as the target for the result and the second- and third-operand locations for the source operands. These three-operand operations may be shown symbolically as:

Operand 1 = Operand 3 • Operand 2

where • represents an arithmetic or logical operation. Operand 1 is always in vector registers. Operand 2 is in storage or in vector registers. Operand 3 is either in vector registers or in a scalar register. An instruction may specify the same or different vector registers for the target and source operands.

Vector-comparison instructions are similar to these three-operand instructions, except that they designate a modifier (M_1) instead of a first operand (VR_1), and they place the result in the vector-mask register.

Summary of Instructions by Class and Format

Figure 2-6 on page 2-16 briefly lists all instructions of the vector facility according to class and format within the class.

Class-IM and Class-IC Instructions

Most vector instructions are in either class IM or IC. Instructions in both classes are interruptible, the number of elements processed is determined by the vector count, and they depend on the vector interruption index. Class-IM instructions are also under the control of the vector-mask mode; class-IC instructions are independent of the vector-mask mode.

For both classes, the elements of each operand are processed in sequence from element *X*, where *X* is the initial value of the vector interruption index (normally zero), to *C*-1, where *C* is the vector count.

The number of elements that are processed for each operand is called the net count. If *C* is greater than *X*, then the net count is *C*-*X*; otherwise the net count is zero. For vector instructions which combine vector operands with a scalar operand, the scalar operand is considered to be replicated as many times as indicated by the net count.

If the net count is zero at the start of instruction execution, the vector interruption index is set to zero, and execution is completed immediately. No elements are processed, no operand-access exceptions occur, the change bits for any storage operand remain unchanged, and no PER event for storage

Instructions	Class	Instruction Formats When Operands Are				Total
		Long	Short	Binary	Other	
ADD, SUBTRACT	IM	Four[1]	Four[1]	Four[1]		24
AND, EXCLUSIVE OR, OR	IM			Four[1]		12
DIVIDE	IM	Four[1]	Four[1]			8
MULTIPLY	IM	Four[1]	Four[12]	Four[1]		12
MULTIPLY AND ADD	IM	QST/QV/VST	QST/QV/VST[2]			6
MULTIPLY AND SUBTRACT	IM	QST/QV/VST	QST/QV/VST[2]			6
MULTIPLY AND ACCUMULATE	IM	VST/VV	VST/VV[2]			4
ACCUMULATE	IM	VST/VV	VST/VV[2]			4
LOAD COMPLEMENT	IM	VV	VV	VV		3
LOAD NEGATIVE, LOAD POSITIVE	IM	VV	VV	VV		6
SHIFT LEFT SINGLE LOGICAL	IM			RSE		1
SHIFT RIGHT SINGLE LOGICAL	IM			RSE		1
MAXIMUM ABSOLUTE	IM	VR	VR			2
MAXIMUM SIGNED, MINIMUM SIGNED	IM	VR	VR			4
COMPARE	IC	Four[1]	Four[1]	Four[1]		12
LOAD, LOAD MATCHED	IC	QV/VST/VV	QV/VST[3]/VV[3]	QV		14
STORE, STORE MATCHED	IC	VST	VST[3]			4
LOAD EXPANDED, STORE COMPRESSED	IC	VST	VST[3]			4
LOAD INTEGER VECTOR	IC			VST		1
LOAD HALFWORD, STORE HALFWORD	IC			VST		2
LOAD ZERO	IC	VV	VV[3]			2
LOAD INDIRECT, STORE INDIRECT	IC	RSE	RSE[3]			4
LOAD BIT INDEX	IG			RSE		1
SUM PARTIAL SUMS	IP	VR				1
ZERO PARTIAL SUMS	IP	VR				1
RESTORE VR	IZ				RRE	1
SAVE VR, SAVE CHANGED VR	IZ				RRE	2
RESTORE VSR	IZ				S	1
CLEAR VR	IZ				S	1

Figure 2-6 (Part 1 of 2). Summary of Vector-Facility Instructions by Class and Format

alteration is indicated. Vector, floating-point, and general registers that are due to be modified, the vector in-use bits, and the vector change bits remain unchanged.

If the instruction is interrupted during execution, *Y-X* pairs of elements have been processed, where *X* and *Y* are the values of the vector interruption index at the beginning of execution and at the time of interruption, respectively. *Y* is then the element number of the next element, if any, to be processed for each operand.

When a class-IM or class-IC instruction designates a scalar register as the location of the third operand (in the QST or QV format), and the scalar register is a floating-point register, the instruction must designate register 0, 2, 4, or 6 in the third-operand field; otherwise, a specification exception is recognized.

Instructions	Class	Instruction Formats When Operands Are				Total
		Long	Short	Binary	Other	
COUNT LEFT ZEROS IN VMR	NC				RRE	1
COUNT ONES IN VMR	NC				RRE	1
COMPLEMENT VMR, TEST VMR	NC				RRE	2
AND TO VMR, EXCLUSIVE OR TO VMR	NC				VS	2
LOAD VMR, LOAD COMPLEMENT VMR	NC				VS	2
OR TO VMR, STORE VMR	NC				VS	2
RESTORE VMR, SAVE VMR	NZ				S	2
EXTRACT ELEMENT, LOAD ELEMENT	N1	VR	VR	VR		6
EXTRACT VCT	NO				RRE	1
EXTRACT VECTOR MASK MODE	NO				RRE	1
LOAD VCT AND UPDATE	NO				RRE	1
LOAD VCT FROM ADDRESS	NO				S	1
RESTORE VAC, SAVE VAC, SAVE VSR	NO				S	3
SET VECTOR MASK MODE	NO				S	1
STORE VECTOR PARAMETERS	NO				S	1
Totals		53	51	41	26	171

Explanation:

1 Four instruction formats are provided: QST, QV, VST, and VV.
2 Operand 1 is in the long format; operands 2 and 3 are in the short format.
3 Instruction in this format may be used for both short and binary operands.

Figure 2-6 (Part 2 of 2). Summary of Vector-Facility Instructions by Class and Format

Class-IM Instructions

For instructions in class IM, all elements are processed as described above when the vector-mask mode is off. When the vector-mask mode is on, however, operand elements are fetched from storage or from operand registers, and result elements are placed in the target register, only for those elements which correspond to ones in the vector-mask register. Element positions in the target register corresponding to zeros remain unchanged; no arithmetic or operand-access exceptions are recognized for those positions, the corresponding change bits in storage remain unchanged, and no PER event for storage alteration is indicated.

The first mask bit used, when the vector-mask mode is on, is bit *X* of the vector-mask register, corresponding to the first vector-register element *X*. The last mask bit and vector-register element processed are numbered *C*-1, if the instruction is completed, or *Y*-1, if the instruction is interrupted during execution.

Class-IM instructions in the QST and VST formats have the storage address in the RS_2 register updated during execution for every element position, regardless of whether the corresponding mask bit is one or zero (see the section "Storage Operands for QST and VST Formats" on page 2-18).

Class-IC Instructions

Execution of instructions in class IC is independent of the vector-mask mode. The following instructions depend on mask bits in the vector-mask register, but their execution is the same whether the vector-mask mode is on or off: LOAD EXPANDED, LOAD MATCHED, STORE COMPRESSED, and STORE MATCHED. The first

mask bit used for those instructions is bit *X*, corresponding to the first vector-register element *X*. The last mask bit and vector-register element processed are numbered *C*-1, if the instruction is completed, or *Y*-1, if the instruction is interrupted during execution.

Storage Operands for QST and VST Formats

In the QST and VST formats, the RS_2 field designates a general register containing the starting address, that is, the address of the first element of the vector operand in storage which is to be processed. The RT_2 field, if not zero, designates a general register containing the stride; if the RT_2 field is zero, general register 0 is not used, and a stride of one is assumed.

The addresses of successive vector elements in storage are *A*, *A*+*wT*, *A*+2*wT*, ..., where *A* is the starting address, *T* is the stride, and *w* is the size of each element in bytes. The value of *w* is 2, 4, or 8, depending on whether the operation code specifies the storage-operand elements to be halfwords, words, or doublewords.

Each address may be obtained by adding to the previous address the value *wT*, which is the stride *T* shifted to the left by one, two, or three bit positions. Any carries or ones shifted out of bit position 0 are ignored. Depending on whether the address size is 31 or 24 bits, the rightmost 31 or 24 bits of the sum are used as the storage address, which is also returned to the general register containing the initial address; the leftmost one or eight bit positions, respectively, of the register are set to zeros. The register is thus updated after each unit of operation to hold the address of the next element, whether an element of the storage operand has been accessed or not. All bits in the general register containing the stride take part in the operation, with the contents of the stride register remaining unchanged.

A stride of zero (*T*=0) means that the same element location is used repeatedly. When storing with a zero stride, only the last element stored is retained in the addressed location.

The RT_2 field must be zero and must not designate the same general register as the RS_2 field; likewise, the third-operand field of a QST-format instruction must not designate the same general register as the RS_2 field. Otherwise, a specification exception is recognized, and the operation is suppressed.

No storage accesses are made for elements that are skipped when the stride is not one. If no elements are processed because the net count is zero at the start of instruction execution, no access exceptions are recognized for the storage operand, the change bits for the operand remain unchanged, and no PER event for storage alteration is indicated.

The contents of the RS_2 register remain unchanged when the address is not updated because the net count is zero. When the net count is not zero and one or more elements have been accessed, the address is updated, and the leftmost bits of the RS_2 register, depending on the address size, are set to zeros, even if the stride is zero.

For the instructions LOAD EXPANDED and STORE COMPRESSED, when the net count is not zero and the active bits of the vector-mask register starting with bit X are all zeros, X being the initial value of the vector interruption index, no operand storage accesses are made and the address in the RS_2 register is not updated. It is undefined in that case whether the leftmost one or eight bits of the RS_2 register, depending on the address size, are set to zeros or remain unchanged.

When class-IM instructions are executed with the vector-mask mode on, no access exceptions are recognized for elements corresponding to zeros in the vector-mask register.

Programming Notes

1. For instructions which produce a vector result, result elements corresponding to ones in the vector-mask register are the same whether the vector-mask mode is on or off. The vector-mask mode does affect the results produced by instructions which reduce vector operands to a partial sum (ACCUMULATE and MULTIPLY

AND ACCUMULATE) or to a single scalar result, because those results may depend on the presence or absence of each operand element.

2. The address-updating operation consists of unsigned shifts and additions of binary integers without overflow. Nevertheless, it is useful to consider the stride as a signed quantity, because adding the two's complement of an integer to an unsigned binary number is the same as subtracting that integer.

Class-NC Instructions

Class-NC instructions process a variable number of bits in the vector-mask register but do not process any arithmetic-vector elements. The number of bits processed is determined by the vector count. The instructions are not interruptible and do not depend on the vector interruption index.

Class-NC instructions use the RRE or VS format. Class-NC instructions in the RRE format operate on bits in the vector-mask register. Class-NC instructions in the VS format operate on bits in the vector-mask register and on a bit vector in storage.

When instruction execution is completed for an operation that modifies the contents of the vector-mask register, any remaining rightmost bits of the register are set to zeros.

When the vector count is zero, execution of the instruction is completed without any bits being processed. For an instruction of a type that modifies bits in the vector-mask register when the vector count is not zero, a vector count of zero causes all bits of the vector-mask register to be set to zeros. Any general register due to be modified remains unchanged.

VS-Format Instructions

The VS format is used for instructions which operate on bit vectors in storage and in the vector-mask register. All VS-format instructions are in class NC.

The RS_2 field designates a general register that contains the storage address of the first byte of the second operand, the leftmost bit of which is the first bit of the storage operand to be processed. The first bit in the vector-mask register is the leftmost bit, bit 0. The operation proceeds with successive bits in contiguous bit locations of the second operand and in the vector-mask register.

When instruction execution is completed, the address of what would have been the next byte of the second operand is placed in the general register designated by RS_2; that address is the integral part of the expression $A + (C+7)/8$, where A is the starting address in the RS_2 register and C is the vector count. The updated address occupies the rightmost 31 or 24 bit positions of the RS_2 register, depending on the address size; the leftmost bit or eight bits, respectively, are set to zeros.

If the vector count is not a multiple of 8, the remaining bits in the last byte used in storage are ignored on fetching and set to zeros on storing.

If no bits are processed because the vector count is zero, the contents of the RS_2 register remain unchanged, no access exceptions are recognized for the storage operand, the change bits for the operand remain unchanged, and no PER event for storage alteration is indicated.

Programming Note

Only class-NC instructions which modify the vector-mask register set bits beyond the active bits to zeros. This contrasts with COMPARE (class IC), which leaves bits in the vector-mask register beyond the active bits unchanged, and RESTORE VMR (class NZ), which ignores the vector count and replaces all the bits.

Instructions In Other Classes

Details of instructions in classes IG, IP, IZ, NZ, N1, and N0 are contained in the individual instruction definitions.

VECTOR INTERRUPTIONS

Interruptible Vector Instructions

All instructions which can operate on multiple elements of arithmetic vectors in storage or in vector registers are interruptible. Their execution generally consists of multiple units of operation with interruptions being permitted between these units of operation.

Vector instructions which can operate on only one arithmetic-vector element, or on none at all, are not interruptible; that is, the entire execution consists of one unit of operation. They include instructions which operate on multiple bits in the vector-mask register but not on elements of arithmetic vectors.

Conceptually, vector instructions are executed sequentially, elements of the vector operands of a single vector instruction are processed sequentially, and any resulting exceptions are recognized sequentially. Any program interruption is due to the first exception which is recognized and for which interruptions are allowed.

At the time of an interruption, changes to register contents, which are due to be made by an interruptible vector instruction beyond the point of interruption, have not yet been made. Changes to storage locations, however, which are due to be made by an interruptible vector instruction beyond the point of interruption, may have occurred for one or more storage locations beyond the location containing the element identified by the interruption parameters, but not for any location beyond the last element specified by the instruction and not for any locations for which access exceptions exist. Changes to storage locations or register contents which are due to be made by instructions following the interrupted instruction have not yet been made at the time of interruption.

If an instruction is due to cause more than one program interruption other than for PER events, only the first one is indicated.

Units of Operation

The execution of an interruptible vector instruction is considered to be divided into units of operation, such that an interruption is permitted between these units of operation.

The unit of operation for program interruptions, other than for PER events alone, is one vector element. After the last vector element has been processed without a program interruption, the instruction is completed in a final unit of operation. This final unit of operation consists in advancing the instruction address to the next instruction, setting the vector interruption index to zero if the instruction depends on the vector interruption index, and, for some instructions, setting the condition code.

Performing the final unit of operation cannot create any program-interruption conditions. If a program interruption occurs while processing the last element of a vector, the instruction remains partially completed, because the final unit of operation has not yet been performed. Thus, all elements of a vector are processed alike, including the recognition of any program exceptions.

Only the final unit of operation of advancing the instruction address, setting the vector interruption index to zero, and possibly setting the condition code is performed without processing any elements, when an interruptible instruction which depends on the vector interruption index is executed in the following situations:

- For class-IM and class-IC instructions, the vector interruption index equals or exceeds the vector count.
- For the class-IP instructions SUM PARTIAL SUMS and ZERO PARTIAL SUMS, the vector interruption index equals or exceeds the partial-sum number.
- For the class-IG instruction LOAD BIT INDEX, the specified bit count is zero, or the vector interruption index equals the section size.

For interruptions due to an asynchronous condition (external, I/O, repressible machine-check, or restart), the unit of operation may be one or more elements,

depending on the model, the particular instruction, and the condition causing the interruption. If a PER event is held pending at the time an instruction is due to be interrupted by such an asynchronous condition, a program interruption for the PER event occurs first, and the other interruptions occur subsequently (subject to the mask bits in the new PSW) in the normal priority order.

PER events alone do not normally cause execution of a vector instruction to be interrupted prematurely. For possible exceptions, see the subsection "Priority of Indication" of the section "Program-Event Recording" in Chapter 4, "Control," of *IBM 370-XA Principles of Operation* and *IBM System/370 Principles of Operation*.

Operand Parameters

Execution of interruptible vector instructions involves the updating of information referred to as the operand parameters. The operand parameters include:

- The vector interruption index, for instructions which depend on that index,
- The storage address in a general register, for instructions in the QST and VST formats,
- The bit index and bit count in a general register, for LOAD BIT INDEX,
- The floating-point scalar operand, for MAXIMUM ABSOLUTE, MAXIMUM SIGNED, MINIMUM SIGNED, and SUM PARTIAL SUMS,
- The element numbers in a general-register pair, if specified, for MAXIMUM ABSOLUTE, MAXIMUM SIGNED, and MINIMUM SIGNED,
- The vector in-use bits, for CLEAR VR and RESTORE VSR, and
- The save-area address and element number in general registers, for RESTORE VR, SAVE CHANGED VR, and SAVE VR.

Upon interruption, the operand parameters are adjusted so as to indicate the extent to which instruction execution has been completed. If the instruction is reexecuted after the interruption, execution resumes from the point of interruption.

Arithmetic Exceptions

The arithmetic exceptions which may be caused by interruptible vector instructions are:

Exponent overflow
Exponent underflow
Fixed-point overflow
Floating-point divide
Significance
Unnormalized operand

In the following respects, the arithmetic exceptions are the same for vector instructions as for the corresponding scalar instructions: the program mask in the PSW controls the occurrence of a program interruption for fixed-point overflow, exponent underflow, or significance; the result for the current target element is the same as the result for the corresponding scalar operation; and bits 8-15 of the program-interruption code indicate the type of exception.

The binary ADD, LOAD COMPLEMENT, LOAD POSITIVE, and SUBTRACT instructions for vectors do not indicate fixed-point overflow when a program interruption is disallowed by the fixed-point-overflow mask in the PSW, unlike the corresponding scalar instructions which can indicate overflow by setting the condition code. Other differences, including the definition of the unnormalized-operand exception, which does not apply to scalar instructions, are described in the following sections.

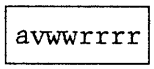
Exception-Extension Code

When an arithmetic exception is recognized during execution of an interruptible vector instruction, a nonzero exception-extension code is stored in bits 0-7 of the program-interruption code. The exception-extension code indicates whether the interruption was due to a noninterruptible scalar instruction or an interruptible vector instruction, whether the result, if any, was placed in a scalar or vector reg-

ister, the width of the result, and the number of the register.

The arithmetic-partial-completion bit, bit 0 of the program-interruption code, indicates that the exception-extension code has been stored. If the arithmetic exception is due to an interruptible vector instruction and causes an interruption which leaves instruction execution partially completed, bit 0 is set to one, and bits 1-7 contain further information. If a scalar instruction was executed, bits 0-7 are set to all zeros.

If not all zeros, the information in the exception-extension code is as follows:



Bit 0 (a) is the arithmetic-partial-completion bit; when one, it indicates that the interrupted instruction was partially completed and that bits 1-7 have the meaning shown below. If bit 0 is zero, bits 1-7 are also zeros.

Bit 1 (v), when one, indicates that the arithmetic result is in vector registers. When bit 1 is zero, the arithmetic result is in a scalar register.

Bits 2-3 (ww) contain the width of the arithmetic result:

01 4-byte result (short or binary)
10 8-byte result (long or binary multiply)

Bits 4-7 (rrrr) contain the register number of the result register designated by the interrupted instruction.

Types of Ending for Units of Operation

When execution of an interruptible vector instruction is interrupted, the current unit of operation may end in one of five ways: completion, inhibition, nullification, suppression, or termination. Termination of a unit of operation of a vector instruction causes termination of the instruction; it can occur only as the result of an exigent machine check and will not be discussed further.

When an interruption occurs after completion, inhibition, nullification, or suppression of a unit of operation, all prior units of operation have been completed. The effect of the interruption on the instruction address in the old PSW stored during the interruption, on the operand parameters, and on the result location for the current unit of operation is as follows:

Completion: The instruction address in the old PSW designates the interrupted instruction or an EXECUTE instruction, as appropriate. The result location for the current unit of operation contains the new result, as defined for the type of exception. The operand parameters are adjusted such that, if the instruction is reexecuted, execution of the interrupted instruction is resumed with the next unit of operation.

Inhibition: Same as completion, except that the result location for the current unit of operation remains unchanged. The exception-extension code is stored the same as if a result had been placed in that location.

Nullification: The instruction address in the old PSW designates the interrupted instruction or an EXECUTE instruction, as appropriate. The result location for the current unit of operation remains unchanged. The operand parameters are adjusted such that, if the instruction is reexecuted, execution of the interrupted instruction is resumed with the current unit of operation. Interruption occurs before any arithmetic operation on the current element has started. Because access exceptions which nullify execution may be recognized for elements beyond the current unit of operation, access to the current element may or may not be the cause of the exception.

Suppression: Same as nullification, except that the instruction address in the old PSW designates the next sequential instruction. Because access exceptions which suppress execution may be recognized for elements beyond the current unit of operation, access to the current element may or may not be the cause of the exception.

The following chart summarizes the differences between the four types of ending for a unit of operation:

Unit of Operation Is	Instruction Address	Operand Parameters At	Current Result Location
Completed	Current Instruct.	Next Element	Changed
Inhibited	Current Instruct.	Next Element	Unchanged
Nullified	Current Instruct.	Current Element	Unchanged
Suppressed	Next Instruction	Current Element	Unchanged

Programming Notes

1. After a program interruption due to an arithmetic exception, an interruption handler may perform any desired fixup of the result before resuming execution of the program.

2. When an instruction which depends on the vector interruption index is interrupted because of an arithmetic exception for the last element to be processed by the instruction, and the instruction is later reexecuted, it is completed by advancing the instruction address, setting the vector interruption index to zero, and possibly setting the condition code, without further processing or program interruptions for this instruction. The same may happen after the vector interruption index has been set to too high a value by the instruction RESTORE VSR.

   If the last element processed before an interruption due to an arithmetic exception is the last element of the vector register, then the vector interruption index contains the section size.

3. The floating-point-divide and unnormalized-operand exceptions are defined to inhibit execution of the current unit of operation. Inhibition differs from completion only in that no result is defined for these exceptions, and that the result location for the current element remains unchanged. Inhibition differs from nullification in that an arithmetic operation has been performed for the current element and the operand parameters have been adjusted to point to the next element.

4. When an arithmetic exception is recognized and bit 1 of the exception-extension code is one, the number of the associated result element in the vector registers is always one less than the current vector interruption index, since all arithmetic exceptions cause either completion or inhibition of the current unit of operation.

Effect of Interruptions During Execution

Interruptions occurring before instruction execution has begun, or after completion of the entire instruction, are the same as for nonvector instructions.

The effect of interruptions which occur during execution of vector-facility instructions depends on the type of ending. Figure 2-7 on page 2-24 shows the effect for each interruption type that can occur during execution.

Setting of Instruction Address

The instruction address in the old PSW designates the interrupted vector-facility instruction or an EXECUTE instruction, as appropriate, after completion, inhibition, or nullification of a unit of operation. The instruction address designates the next sequential instruction after suppression of a unit of operation.

Setting of Instruction-Length Code

When a program interruption occurs during the execution of an interruptible vector instruction, the instruction-length code (ILC) that is stored is 2 or 3, depending on whether the instruction length is two or three halfwords, respectively. When the vector instruction is executed under the control of an

Type of Interruption	Type of Ending	Except. Extens. Code Stored?
Program		
Addressing	S	No
Exponent overflow	C	Yes
Exponent underflow	C	Yes
Fixed-point overflow	C	Yes
Floating-point divide	I	Yes
Page translation	N	No
Protection	S	No
Segment translation	N	No
Significance	C	Yes
Translation specification	S	No
Unnormalized operand	I	Yes
PER event alone	C	No
PER event with another exception	E	E
External, I/O, Repressible Machine Check, and Restart		
All	C	No

Explanation:

C Completed unit of operation
E Action determined by the exception reported with the PER event
I Inhibited unit of operation
N Nullified unit of operation
S Suppressed unit of operation

Figure 2-7. Interruptions during Execution of Interruptible Vector-Facility Instructions

EXECUTE instruction, the ILC is always 2.

The ILC is stored as described regardless of whether the instruction address is advanced to the next instruction (the unit of operation is suppressed) or the instruction address designates the interrupted instruction (the unit of operation is completed, inhibited, or nullified).

For information on the ILC setting for a program interruption that occurs while fetching the instruction, see the section "Instruction-Length Code" in Chapter 6, "Interruptions," of *IBM 370-XA Principles of Operation* and *IBM System/370 Principles of Operation*.

Programming Note

Unless an interruption occurs during instruction fetching and prevents interpretation of the instruction, the instruction-length code is determined entirely by the leftmost two bits of the operation code. The ILC value does not depend on whether the operation code is assigned, or whether the instruction is installed or executed. Thus, the ILC is set to 2 or 3 for a vector instruction, depending on the instruction length, even when a vector-operation exception or an operation exception is recognized.

Setting of Storage Address

When a vector-facility instruction which updates a vector-operand address in a general register is interrupted, the address in the general register has been updated to the point of interruption.

After completion or inhibition of a unit of operation, the updated address designates the next operand element in storage following the one causing the interruption.

After nullification or suppression of a unit of operation, the updated address designates the current operand element; this may or may not be the same as the element that caused the interruption, because of access exceptions which may be recognized for elements beyond the last one processed. If the exception occurs before the first element has been processed, the entire instruction is nullified or suppressed, and the general register containing the storage address remains unchanged.

When the entire instruction has been completed before an interruption takes place, the updated address designates the operand element following the last element processed.

Setting of Vector Interruption Index

At the start of execution of an interruptible vector instruction which depends on the vector interruption index, the vector interruption index contains the number of the next element to be processed in the designated vector registers or the vector-mask register. When such an instruction is interrupted, the vector interruption index is set to indicate the element within the registers at which execution may subsequently be resumed.

After completion or inhibition of a unit of operation, the vector interruption index identifies the next element, if any, to be processed after the one causing the interruption.

After nullification or suppression of a unit of operation, the vector interruption index identifies the current element; this may or may not be the element which caused the interruption, because of access exceptions which may be recognized for elements beyond the last one processed.

During the final step of completing the entire instruction, the vector interruption index is set to zero. This final step cannot cause any further interruptions.

When the entire instruction is nullified or suppressed, the vector interruption index remains unchanged. It also remains unaffected by the interruption of interruptible vector-facility instructions which do not depend on the vector interruption index and which do not set it explicitly. The vector interruption index is explicitly set to zero by CLEAR VR and to a specified value by RESTORE VSR.

Programming Notes

1. Proper resumption of an interrupted instruction depends on the vector interruption index and the appropriate general registers being left unchanged.

2. If it is desired not to resume a program that was interrupted during execution of a vector-facility instruction but, instead, to store the current vector-register contents by means of vector-store instructions, or to load different data using vector-load instructions, care must be taken to set the vector interruption index to zero explicitly. This may be done with a CLEAR VR instruction; specifying a second operand of zeros leaves the vector-register contents unchanged.

Program-Interruption Conditions

When the vector facility is installed, two additional program exceptions can occur: unnormalized operand and vector operation. A vector-operation exception may also occur on CPUs without the vector facility. All arithmetic exceptions for vector instructions cause an exception-extension code to be stored as part of the program-interruption code. There are also modifications to access exceptions and to some of the arithmetic exceptions, and additional causes for the specification exception.

Access Exceptions for Vector Operands

When a vector-facility instruction specifies an arithmetic or bit vector in storage, access exceptions may be recognized for one or more storage locations beyond the location containing the element being processed, but not for any location beyond the last element specified by the instruction.

For contiguous operands, that is, for arithmetic vectors which are addressed sequentially with a stride of one and for bit vectors, access exceptions are not recognized more than 2K bytes beyond the current location. For noncontiguous operands, that is, for vectors which are addressed sequentially with a stride not equal to one and those which are loaded or stored by indirect element selection, access exceptions are not recognized more than seven element locations beyond the current one.

No access exceptions are recognized for the storage location of an operand when:

- No vector elements are to be processed because the net count is zero,

- The instruction operates under the control of the vector-mask register and the location of a vector element

in storage corresponds to a zero mask bit,

- For the instruction LOAD BIT INDEX, the specified bit count is zero or the vector interruption index equals the section size,
- For the instructions RESTORE VR and SAVE VR, the vector in-use bit associated with the specified vector-register pair is zero, or
- For the instruction SAVE CHANGED VR, the vector change bit associated with the specified vector-register pair is zero.

Programming Note

Interruptible nonvector instructions, such as MOVE LONG, permit access exceptions to be recognized no more than 2K byte locations beyond the location of the byte being processed, which permits access exceptions for a maximum of four operand pages, two for each operand. This is in addition to access exceptions during instruction fetching of up to four pages when the instruction is the target of EXECUTE. Interruptible vector instructions permit access exceptions to be recognized for up to eight operand pages, in addition to a possible four instruction pages. The eight operand pages are not necessarily contiguous.

Exponent-Overflow Exception

If, during execution of a MULTIPLY AND ACCUMULATE, MULTIPLY AND ADD, or MULTIPLY AND SUBTRACT instruction, the multiplication of an element pair results in an exponent overflow, only the multiplication part of the unit of operation is completed, and the addition or subtraction part is not performed. The unit of operation is completed by placing the overflowed product, as defined for the corresponding scalar floating-point multiply instruction, in the result location.

Exponent-Underflow Exception

If, during execution of a MULTIPLY AND ACCUMULATE, MULTIPLY AND ADD, or MULTIPLY AND SUBTRACT instruction, the multiplication of an element pair results in an exponent underflow, no interruption occurs, regardless of the value of the exponent-underflow mask in the PSW. In this case, a true zero is added in place of the product, and the operation continues.

Floating-Point-Divide Exception

When a floating-point-divide exception is recognized during execution of a vector floating-point DIVIDE instruction, the unit of operation is inhibited.

Specification Exception

Specification exceptions are recognized for the following causes in addition to the causes listed in the section "Specification Exception" of Chapter 6, "Interruptions," of *IBM 370-XA Principles of Operation* and *IBM System/370 Principles of Operation*.

- An invalid vector-register number is designated by a VR field of a vector instruction.
- The stride of an instruction in the QST or VST format is specified to be in the same general register as the storage address.
- The third operand of an instruction in the QST format is specified to be in the same general register as the storage address.
- The instruction RESTORE VSR attempts to load values into the vector-status register that are
  1. Other than all zeros in bits 0-14,
  2. Greater than the section size in the vector-count field (bits 16-31), or
  3. Greater than the section size in the vector-interruption-index field (bits 32-47).

- The instruction RESTORE VR, SAVE CHANGED VR, or SAVE VR specifies a number in the element-number field that is equal to or greater than the section size, or a number in the VR-pair field that is other than an even number from 0 to 14.

- The instruction EXTRACT ELEMENT or LOAD ELEMENT specifies an element number in the second operand that is equal to or greater than the section size.

Unnormalized-Operand Exception

An unnormalized-operand exception is recognized when, in a vector floating-point divide or multiply operation, a source-operand element has a nonzero fraction with a leftmost hexadecimal digit of zero. The vector floating-point instructions which may cause an unnormalized-operand exception to be recognized are DIVIDE, MULTIPLY, MULTIPLY AND ACCUMULATE, MULTIPLY AND ADD, and MULTIPLY AND SUBTRACT.

The unnormalized-operand exception is recognized for one operand element even when there is another operand that is zero, except that the floating-point-divide exception, which takes precedence, is recognized instead when the zero element is the divisor of a vector DIVIDE instruction.

The unit of operation is inhibited.

The instruction-length code is 2.

The interruption code is XX1E hex, or XX9E hex with a concurrent PER event, where XX is the exception-extension code.

Vector-Operation Exception

A vector-operation exception is recognized when a vector-facility instruction is executed while bit 14 of control register 0 is zero on a CPU which has the vector facility installed and available. The vector-operation exception is also recognized when a vector-facility instruction is executed and the vector facility is not installed or available on this CPU, but the facility can be made available to the program either on this CPU or on another CPU in the configuration.

When a vector-facility instruction is executed, and the vector facility is not installed on any CPU which is or can be placed in the configuration, it depends on the model whether a vector-operation exception or an operation exception is recognized.

The operation is nullified when the vector-operation exception is recognized.

The instruction-length code is 2 or 3.

The interruption code is 0019 hex, or 0099 hex with a concurrent PER event.

Programming Note

The definition permits a vector-operation exception to occur even when no CPU in the configuration has the vector facility installed. See the section "Vector-Operation Control" on page 2-6 for more information.

Priority of Vector Interruptions

Multiple program-interruption conditions for vector-facility instructions are recognized, one after another, according to the same priority rules as apply to other instructions, together with the following rules:

- The unnormalized-operand exception has the same priority with respect to the nonarithmetic exceptions as the other arithmetic exceptions which can occur for vector instructions (exponent overflow, exponent underflow, fixed-point overflow, floating-point divide, and significance).

  When more than one arithmetic-exception condition is recognized at the same time, unnormalized operand takes precedence over the exponent-overflow and exponent-underflow exceptions; the floating-point-divide exception takes precedence over the unnormalized-operand exception.

- The vector-operation exception has the same priority as the operation

exception; the two exceptions are mutually exclusive.

- An access exception caused by the operand of RESTORE VSR takes precedence over a specification exception caused by the same operand.

See also the section "Multiple Program-Interruption Conditions" in Chapter 6, "Interruptions," of *IBM 370-XA Principles of Operation* and *IBM System/370 Principles of Operation*.

PROGRAM SWITCHING

The following instructions are provided to save, restore, and clear the vector-facility registers when switching from one program to another. The instructions marked "privileged" are restricted to programs operating in the supervisor state.

```
CLEAR VR
RESTORE VAC (privileged)
RESTORE VMR
RESTORE VR
RESTORE VSR
SAVE CHANGED VR (privileged)
SAVE VAC (privileged)
SAVE VMR
SAVE VR
SAVE VSR
```

Saving and restoring of the vector registers is further assisted by their associated vector in-use bits and vector change bits. When the vector in-use bit for a vector-register pair is zero, the saving and subsequent restoring of those registers are eliminated, thus reducing the program-switching time, because the registers are known to contain all zeros.

For programs operating in the supervisor state, the vector change bits may serve to reduce switching time still further by permitting the saving of a vector-register pair to be eliminated when its vector in-use bit is one but its vector change bit is zero. Although such a vector-register pair is in use, its contents are known not to have been changed if its vector change bit has remained zero since it was last restored from its save area; consequently, the previously saved information is still valid.

The vector change bits do not affect the restoring of vector registers and, therefore, do not help to reduce the restore time. When an interruption-handling portion of the control program restores previously saved registers, restoring the contents of a pair of vector registers is not considered a change. Hence, executing RESTORE VR in the supervisor state is defined not to alter the vector change bits. Executing RESTORE VR in the problem state, however, sets the vector change bit of the affected vector-register pair to one, so as to protect the integrity of its use by the control program.

Program Use of the Restore and Save Instructions

The instructions RESTORE VR, SAVE CHANGED VR, and SAVE VR are defined to be interruptible and to restore or save only a single pair of vector registers each time they are executed. When more than one vector-register pair is to be restored or saved, the appropriate instruction must be used in a programming loop as follows.

First, the even general register to be specified by the instruction should be set to the beginning of the save area for the vector registers, and the odd general register should be set to zeros. Then the restore or save instruction should be executed. It should be followed by a BRANCH ON CONDITION with a mask of 5 back to the restore or save instruction. This causes each vector-register pair, in turn, to be restored or saved if its vector in-use bit (or vector change bit for SAVE CHANGED VR) is one, or to be skipped if the bit is zero.

Restore Operations

To restore the vector-status register and the vector registers, the instruction RESTORE VSR should be executed before the above programming loop for RESTORE VR. A complete set of restore operations also includes RESTORE VMR and RESTORE VAC. RESTORE VAC should be the last restore instruction executed to avoid having the others advance the vector-activity count unnecessarily.

Save Operations

A complete set of save operations consists of the instruction SAVE VAC, followed by a loop that uses either SAVE VR or SAVE CHANGED VR, and then the instructions SAVE VMR and SAVE VSR.

SAVE VAC is executed first, so as to avoid having the vector-activity count advanced by the other save operations, especially at a time when no vector operations were performed since the last time that the registers were restored.

Programs running in either the problem state or the supervisor state may use the instruction SAVE VR in the loop to save the entire contents of all vector-register pairs for which the vector in-use bits are ones.

Alternatively, when a program using vector-facility instructions is interrupted and the vector registers are to be placed back into an area from which they were previously restored, an interruption handler in the supervisor state may use the privileged instruction SAVE CHANGED VR in the loop. SAVE VSR should be executed only after the vector registers have been saved, so that the vector change bits, which SAVE CHANGED VR sets to zeros, are saved as zeros.

SAVE VR should be used instead of SAVE CHANGED VR when the vector information is to be saved in an area which may not be the one from which the vector registers were last restored. Thus, SAVE VR is the appropriate instruction for a machine-check-interruption handler.

Clear Operations

The instruction CLEAR VR may be used to clear all or selected pairs of vector registers and to make sure that the vector interruption index is set to zero.

CLEAR VR may be executed by the control program to ensure that all vector registers are cleared before turning over the vector facility to a new program requesting vector operations. It should also be executed by the vector program to clear a vector-register pair that is not needed again soon. Both measures serve to avoid unnecessary saving and restoring.

When a vector-register pair has been cleared by means of CLEAR VR, and the corresponding vector in-use bit is zero, all elements in those registers contain zeros. The zero elements in a cleared register are valid operands. Such use of a cleared vector register or register pair as a source of all zeros does not set the associated vector in-use bit to one. One or more individual elements of a cleared vector-register pair may be replaced by an instruction such as LOAD ELEMENT, but as soon as any element in either or both registers of the pair has been changed, its vector in-use bit and vector change bit are set to ones, and the register pair is no longer considered cleared. The vector registers are considered to have been changed even when the value loaded is all zeros.

The instruction RESTORE VSR also clears a vector-register pair when it finds that the associated vector in-use bit is one and must be set to zero.

When either CLEAR VR or RESTORE VSR finds a vector in-use bit that is already zero, the instruction does not clear the vector-register pair again. If either instruction is interrupted and later reexecuted, instruction execution is resumed from the beginning, but the instruction skips over registers that were cleared before the interruption and have remained cleared.

Save-Area Requirements

To make programs that save and restore registers of the vector facility model-independent, the sizes and addresses of the save areas should be computed at execution time using the current section size, as obtained by the instruction STORE VECTOR PARAMETERS.

Figure 2-8 on page 2-30 shows the save-area sizes and the boundary alignment for RESTORE VR, SAVE CHANGED VR, and SAVE VR as a function of the section size. Boundary alignment requires that the address of a vector-register save area be a multiple of the integral boundary shown in the second column (8 times the section size). The save-area size is given as the number of bytes required to save all 16 vector registers; when fewer consecutive vector registers are to be saved, this area may be

reduced correspondingly. The figure also shows the vector-mask register (VMR), which requires $4Z$ bits ($Z/2$ bytes), where Z is the section size; the VMR save area has no alignment requirement.

Section Size (Z)	Vector Registers		Bytes for Vector-Mask Register ($Z/2$)
	Integral Boundary ($8Z$)	Bytes for 16 VRs ($64Z$)	
8	64	512	4
16	128	1,024	8
32	256	2,048	16
64	512	4,096	32
128	1,024	8,192	64
256	2,048	16,384	128
512	4,096	32,768	256

Figure 2-8. Save-Area Requirements

RELATIONSHIP TO OTHER FACILITIES

Program-Event Recording (PER)

The following PER events are recognized for instructions of the vector facility:

Instruction fetching
Storage alteration

Whether PER general-register-alteration events are recognized for vector-facility instructions is undefined.

When the net count is zero for IC- or IM-class instructions, when the vector count is zero for NC-class instructions, or when all active bits in the vector-mask registers are zeros for the STORE MATCHED instruction, no PER storage-alteration events are recognized.

When an interruptible vector instruction is interrupted and PER storage alteration applies to storage locations corresponding to vector elements that are due to be changed by the instruction beyond the point of interruption, PER storage alteration is indicated if any such storage change actually occurred and may be indicated even if such a change did not occur. PER storage alteration is only recognized if no access exception exists for such locations at the time that the instruction is executed.

Vector-Store Operations

As for nonvector instructions, the processing of vector-facility instructions generally appears to a program running on the same CPU to follow the conceptual sequence: The execution of one instruction appears to precede the execution of the following instruction, the processing of one vector element appears to precede the processing of the following vector element, and an interruption takes place between instructions or between units of operation of interruptible instructions. As discussed below, however, this conceptual sequence is not necessarily observed by programs on other CPUs, by channel programs, or when vector-facility instructions are used to store into the instruction stream.

Storage-Operand Consistency

For all vector-facility instructions, multiple accesses may be made to all or some of the bytes of a storage operand.

Thus, unlike instructions which make only single-access references, intermediate results of a vector-facility store instruction may be observed by channel programs and by other CPU programs accessing the same storage location concurrently.

When an interruptible store-type vector instruction is interrupted and its execution is later resumed, a store performed by the instruction before its interruption may be repeated when execution is resumed.

(See the section "Storage-Operand Consistency" in Chapter 5, "Program Execution," of *IBM 370-XA Principles of Operation* and *IBM System/370 Principles of Operation*.)

Storing into Instruction Stream

When a vector-facility instruction is executed that causes storing into a location from which subsequent instructions have been prefetched, the copies of the prefetched instructions are not necessarily changed. (See the section

"Instruction Fetching" in Chapter 5, "Program Execution," of *IBM 370-XA Principles of Operation* and *IBM System/370 Principles of Operation* for a complete list of functions which cause all copies of prefetched instructions to be discarded.)

Resets

In regard to the operation of the vector facility, CPU reset terminates execution of the current vector instruction and any manual operation. Pending machine-check-interruption conditions affecting the vector facility and check-stop states are cleared. All copies of prefetched vector-facility instructions or operands are discarded.

Initial CPU reset initializes the vector-control bit, bit 14 of control register 0, to zero.

The registers of the vector facility (vector-status register, vector-mask register, vector-activity count, and all vector registers) are cleared to zero by clear reset and power-on reset. The section size and partial-sum number remain unaffected.

Machine-Check Handling

Two bits of the machine-check-interruption code are associated with the vector facility: vector-facility failure and vector-facility source. The vector-facility-failure bit indicates to the program that vector-facility instructions should no longer be used. The vector-facility-source bit is a modifier to instruction-processing damage, which indicates that the vector facility is the error source.

These bits may be set to ones regardless of whether the vector-control bit, bit 14 of control register 0, is one or zero.

Vector-Facility Failure

Bit 6 (VF) of the machine-check-interruption code, when one, indicates that the vector facility has failed to such an extent that the service processor has made the facility not available.

This bit is not meaningful when system damage, bit 0 of the machine-check-interruption code, is one.

Vector-facility failure is a repressible condition, which has no subclass mask.

Vector-Facility Source

Bit 13 (VS) of the machine-check-interruption code, when one, indicates that the vector facility is the source of the reported machine-check condition. Vector-facility source is reported together with instruction-processing damage. When this bit is one, the contents of vector-facility registers may have been damaged or may contain incorrect information with no preserved error.

This bit is not meaningful when vector-facility failure, bit 6, is one.

Validation of Vector-Facility Registers

The following procedure can be used to validate the registers associated with the vector facility. The program should first execute RESTORE VSR, specifying all vector in-use bits as ones. This validates the vector-status register by setting it without first inspecting the previous contents. The program should then execute RESTORE VAC, RESTORE VMR, and RESTORE VR to load and validate the vector-activity count, the vector-mask register, and the vector registers.

Programming Notes

1. When a vector-facility-failure condition is indicated, the program should stop using any functions associated with the vector facility. Thus, no vector-facility instructions should be executed; the vector-control bit, bit 14 of control register 0, should be set or remain set to zero; and the registers associated with the vector facility should not be validated or saved.

2. Although the purpose of the vector-facility-source bit is to indicate that the vector facility is the source of the instruction-processing

damage, it is possible in some situations that the bit may be set to one when failures have occurred both in the vector facility and in other parts of the CPU.

3. Since a vector-facility-source condition may imply that vector-facility registers have been damaged, the registers should be validated before further use is attempted. If the vector-control bit is zero, it must be set to one to perform the validation.

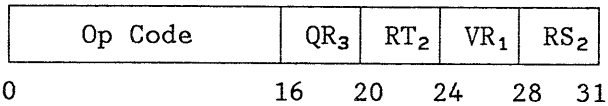
4. The instruction RESTORE VR is the only instruction which validates the vector registers, and then only if their vector in-use bits are ones. In particular, the instruction CLEAR VR should not be used for validation, because this instruction may be implemented for performance reasons such that the registers are not actually cleared unless the program subsequently attempts to load or modify them. With this design, when the program next loads the vector register following a CLEAR VR instruction, only those elements which are not loaded, if any, are actually cleared at that time. Except for the possible effect on machine-check handling, this implementation gives the same results as if the instruction actually cleared the registers.

Complete lists of vector-facility instructions and their mnemonics, formats, and operation codes are contained in Appendix B, "Lists of Instructions." The lists also indicate when the condition code is set and the exceptional conditions in operand designations, data, or results that cause a program interruption.

When, for a vector instruction, the operation on each element of the vector is the same as for a counterpart scalar instruction, the vector instruction description does not repeat these details. The complete definition in these cases can be obtained from the definition for the counterpart scalar instruction.

In many cases, several related vector operations are described under a single name. For example, MULTIPLY in the QST format is described as follows:

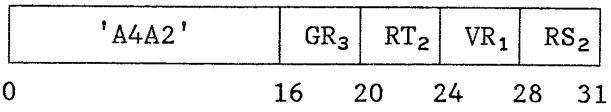
Mnemonic $VR_1,QR_3,RS_2(RT_2)$ [QST]



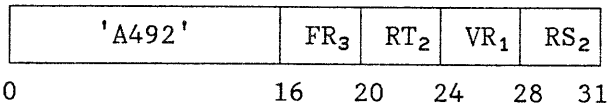
Mnemonic	Op Code	Operands
VMS	'A4A2'	Binary
VMDS	'A492'	Long
VMES	'A482'	Short multiplier and multiplicand, long product

This figure is a "shorthand" representation for three different instructions, one binary and two floating-point multiply instructions. It replaces the following set of three figures:

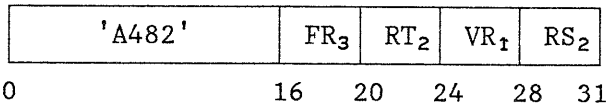
VMS $VR_1,GR_3,RS_2(RT_2)$
[QST, Binary operands]



VMDS $VR_1,FR_3,RS_2(RT_2)$
[QST, Long operands]



VMES $VR_1,FR_3,RS_2(RT_2)$
[QST, Short multiplier and multiplicand, long product]



Thus, the term "Binary" under the heading "Operands" for the first instruction indicates that the vector elements are 32-bit signed binary integers, that the scalar operand is taken from a general register, and that the operation on each element pair is performed in the same manner as the scalar MULTIPLY instruction described in Chapter 7, "General Instructions," of *IBM 370-XA Principles of Operation* and *IBM System/370 Principles of Operation*.

Likewise, the terms "Short" or "Long" under the heading "Operands" for the second and third instructions indicate that the vector elements are floating-point numbers in the short or long floating-point format, respectively, that the scalar operand is taken from a floating-point register, and that the operation on each element pair is performed in the same manner as the corresponding scalar MULTIPLY instruction described in Chapter 9, "Floating-Point Instructions," of *IBM 370-XA Principles of Operation* and *IBM System/370 Principles of Operation*.

Except for the new suffixes Q and S, which indicate scalar-vector operations, each mnemonic for a vector instruction is generally the same as the mnemonic for the counterpart scalar instruction prefixed with a "V."

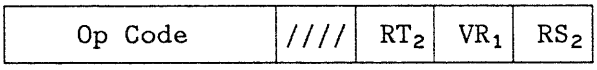
For several of the load and store instructions, the same instruction is used for vectors in the short floating-point format and in the 32-bit binary-integer or logical format. Separate mnemonics are assigned to the short and binary-logical formats for programming convenience, but the op codes for the two mnemonics are the same when the function is the same.

Programming Note

Programming notes in this section, as well as the examples in Appendix A, assume normal execution of vector instructions. In particular, they assume that the program does not alter the vector interruption index, so that each interruptible vector instruction begins its operation on the first element or element pair with the vector interruption index set to zero. If the instruction is interrupted for a cause other than an arithmetic exception, and if its execution is subsequently resumed, the vector interruption index and all other parameters are assumed to have been restored to the value they had at the time of interruption, so that the result is the same as if the interruption had not occurred.

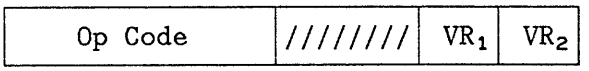
ACCUMULATE

Mnemonic $VR_1,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VACD	'A417'	Long operand and sum
VACE	'A407'	Short operand, long sum

Mnemonic VR_1,VR_2 [VV]



Mnemonic	Op Code	Operands
VACDR	'A517'	Long operand and sum
VACER	'A507'	Short operand, long sum

Partial sums of the elements of the second-operand vector are accumulated by adding the second-operand elements to the contents of element positions 0 to p-1 of the first operand. The partial-sum number p depends on the model.

The operation proceeds in an ascending sequence of element numbers. The I-th element of the second operand is added to the first-operand element at a position which is the remainder of dividing I by p, where I varies from X to C-1, X is the initial vector interruption index (normally zero), and C is the vector count. The operation accumulates C-X elements of the second operand.

Thus, second-operand elements 0, p, $2p$, ... are accumulated into position 0 of the first operand; second-operand elements 1, p+1, $2p$+1, ... are accumulated into position 1; and so forth. The contents of first-operand element positions above p-1 remain unchanged.

Every addition is performed in the same manner as for the scalar ADD NORMALIZED (ADR) instruction, where the second-operand elements for VACE and VACER are extended on the right with 32 zeros, except that the condition code is not set.

A specification exception is recognized when the VR_1 field designates an invalid register number. In the VST format, a specification exception is also recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

ACCUMULATE is a class-IM instruction: it is interruptible, the vector count and vector interruption index determine the

number of elements processed, and its execution is under the control of the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2 in VST format)
Exponent overflow (with exception-extension code)
Exponent underflow (with exception-extension code)
Operation
Significance (with exception-extension code)
Specification
Vector operation

Programming Notes

1. ACCUMULATE is used, together with ZERO PARTIAL SUMS and SUM PARTIAL SUMS, to produce the scalar sum of the elements of a vector in a manner similar to the example in Appendix A ("Sum of Products" on page A-3) of using MULTIPLY AND ACCUMULATE to produce a sum of products.

2. The short-format ACCUMULATE instructions (VACE and VACER) add floating-point vector elements in the short format to produce a floating-point sum in the long format. This creates a result of higher precision than would an equivalent loop with the scalar short-format ADD instructions (AE or AER, respectively), which produces a sum in the short format.

ADD

Mnemonic $VR_1,QR_3,RS_2(RT_2)$ [QST]

Op Code	QR_3	RT_2	VR_1	RS_2
0	16	20	24	28 31

Mnemonic	Op Code	Operands
VAS	'A4A0'	Binary
VADS	'A490'	Long
VAES	'A480'	Short

Mnemonic VR_1,QR_3,VR_2 [QV]

Op Code	QR_3	////	VR_1	VR_2
0	16	20	24	28 31

Mnemonic	Op Code	Operands
VAQ	'A5A0'	Binary
VADQ	'A590'	Long
VAEQ	'A580'	Short

Mnemonic $VR_1,VR_3,RS_2(RT_2)$ [VST]

Op Code	VR_3	RT_2	VR_1	RS_2
0	16	20	24	28 31

Mnemonic	Op Code	Operands
VA	'A420'	Binary
VAD	'A410'	Long
VAE	'A400'	Short

Mnemonic VR_1,VR_3,VR_2 [VV]

Op Code	VR_3	////	VR_1	VR_2
0	16	20	24	28 31

Mnemonic	Op Code	Operands
VAR	'A520'	Binary
VADR	'A510'	Long
VAER	'A500'	Short

Element by element, the second-operand vector is added to the third operand, and the result is placed in the first-operand location.

The operation is performed on each pair of elements in the same manner as the corresponding scalar operation, except that the condition code is not set. For floating-point operands, the scalar equivalent is ADD NORMALIZED.

A specification exception is recognized when a VR or QR field designates an

invalid register number. In the QST and VST formats, a specification exception is recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field. For the VAS instruction, a specification exception is also recognized when the QR_3 field designates the same general register as the RS_2 field.

ADD is a class-IM instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is under the control of the vector-mask mode.

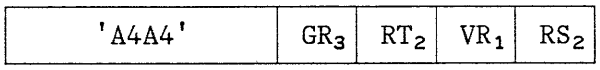
Condition Code: The code remains unchanged.

Program Exceptions:

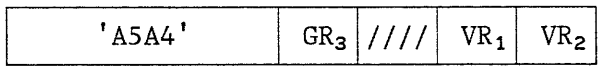
Access (fetch, operand 2 in QST and VST formats)
Exponent overflow (with exception-extension code; floating-point operands only)
Exponent underflow (with exception-extension code; floating-point operands only)
Fixed-point overflow (with exception-extension code; binary operands only)
Operation
Significance (with exception-extension code; floating-point operands only)
Specification
Vector operation

AND

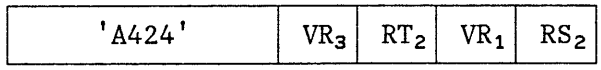
VNS $VR_1,GR_3,RS_2(RT_2)$ [QST]



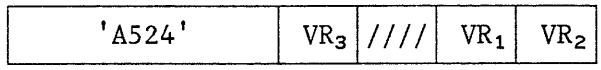
VNQ VR_1,GR_3,VR_2 [QV]



VN $VR_1,VR_3,RS_2(RT_2)$ [VST]



VNR VR_1,VR_3,VR_2 [VV]



Element by element, the AND of the second and third operands is placed in the first-operand location.

The operation is performed on each pair of 32-bit elements in the same manner as the corresponding scalar operation, except that the condition code is not set.

For the VN and VNS instructions, a specification exception is recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field. For the VNS instruction, a specification exception is also recognized when the GR_3 field designates the same general register as the RS_2 field.

AND is a class-IM instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is under the control of the vector-mask mode.

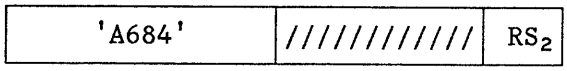
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2 in QST and VST formats)
Operation
Specification
Vector operation

AND TO VMR

VNVM RS_2 [VS]



The AND of the second-operand bit vector and of the active bits of the vector-mask register is placed in the vector-mask register. Bits beyond the active bits are set to zeros.

AND TO VMR is a class-NC instruction: it is not interruptible, the vector count determines the number of elements processed, and its execution is not affected by the vector-mask mode.

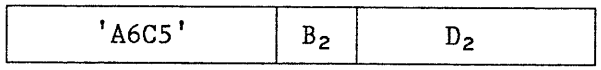
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2)
Operation
Vector operation

CLEAR VR

VRCL $D_2(B_2)$ [S]



The specified pairs of vector registers are cleared, the associated vector in-use bits and vector change bits are set to zeros, and the vector interruption index is set to zero.

The second-operand address is not used to address storage. Instead, bits 24-31 of the second-operand address, called the second-operand bits, control which vector registers are cleared. The eight second-operand bits are associated with the eight even-numbered vector-register pairs from 0 to 14, and with the corresponding vector in-use bits and vector change bits. The leftmost bits of the address are ignored.

The vector interruption index is set to zero first, after which the eight second-operand bits are examined in any order. If a second-operand bit and the corresponding vector in-use bit are both ones, all element positions of the associated pair of vector registers are cleared to zeros; the corresponding vector in-use bits and vector change bits are then set to zeros. If a second-operand bit or the corresponding vector in-use bit is zero, the associated registers and bits remain unchanged.

The instruction is interruptible. If it is interrupted before the operation is completed, the instruction address in the current PSW identifies this instruction. If execution is resumed, then vector-register pairs, which were cleared and had their vector in-use bits and vector change bits set to zeros, are not cleared again, provided that their vector in-use bits are still zeros.

The vector count is not used by the instruction and remains unchanged.

CLEAR VR is a class-IZ instruction: it is interruptible, the section size determines the number of elements processed, and its execution is not affected by the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

Operation
Vector operation

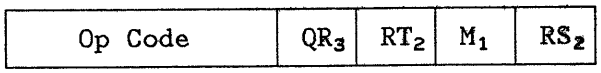
Programming Notes

1. When a vector in-use bit is zero, execution time of CLEAR VR is saved because the corresponding vector-register pair is already cleared, and the instruction does not clear those registers again.

2. CLEAR VR with a zero operand (VRCL 0) merely sets the vector interruption index to zero.

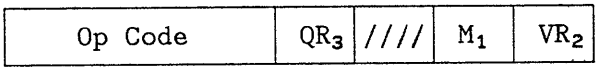
COMPARE

Mnemonic $M_1,QR_3,RS_2(RT_2)$ [QST]



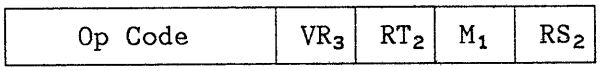
Mnemonic	Op Code	Operands
VCS	'A4A8'	Binary
VCDS	'A498'	Long
VCES	'A488'	Short

Mnemonic M_1,QR_3,VR_2 [QV]



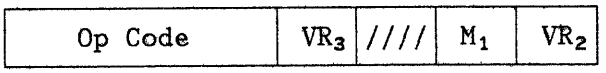
Mnemonic	Op Code	Operands
VCQ	'A5A8'	Binary
VCDQ	'A598'	Long
VCEQ	'A588'	Short

Mnemonic $M_1,VR_3,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VC	'A428'	Binary
VCD	'A418'	Long
VCE	'A408'	Short

Mnemonic M_1,VR_3,VR_2 [VV]



Mnemonic	Op Code	Operands
VCR	'A528'	Binary
VCDR	'A518'	Long
VCER	'A508'	Short

The third operand is compared with the second-operand vector, element by element. The corresponding bit in the vector-mask register is set to one or zero, depending on the comparison result and on the value of a modifier in bits 24-26 of the instruction.

The comparison is algebraic and is performed on each element pair in the same manner as the corresponding scalar operation, except for the way in which the result is indicated. The condition code is not set; instead, a single result bit is set in the vector-mask register for each element pair. The value of the result bit is selected from one of the modifier bits according to the comparison of the third-operand element with the second-operand element, as follows:

Result of Comparison	Modifier Bit Whose Value Is Selected
Operands equal	M0 (bit 24)
Operand 3 low	M1 (bit 25)
Operand 3 high	M2 (bit 26)

Modifier bit M3, bit 27 of the instruction, is ignored.

Bits in the vector-mask register which do not correspond to elements being compared remain unchanged.

A specification exception is recognized when a VR or QR field designates an invalid register number. In the QST and VST formats, a specification exception is recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and

designates the same general register as the RS_2 field. For the VCS instruction, a specification exception is also recognized when the QR_3 field designates the same general register as the RS_2 field.

COMPARE is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2 in QST and VST formats)
Operation
Specification
Vector operation

Programming Notes

1. To obtain ones in the resultant bit vector when a desired comparison condition is found for an element of operand 3, the modifier bits should be specified as follows:

Modifier Bits				Result Is One If Operand-3 Comparison Is
M0	M1	M2	M3	
0	0	0	-	— (always 0)
0	0	1	-	High
0	1	0	-	Low
0	1	1	-	Not equal
1	0	0	-	Equal
1	0	1	-	Not low
1	1	0	-	Not high
1	1	1	-	Any (always 1)

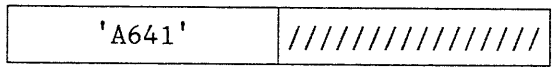
2. The modifier bits of the vector COMPARE instruction correspond to the condition codes of the scalar COMPARE instruction when an element of vector operand 3 is the same as the scalar operand 1 and the corresponding element of vector operand 2 is the same as the scalar operand 2. Thus, the value of the leftmost three bits of the mask field of the BRANCH ON CONDITION instruction, which causes branching when used to test the condition code of the scalar COMPARE, is the same as the modifier value of the vector COMPARE instruction, which sets a vector-mask bit to one for the same comparison condition.

3. The comparison instructions are the only ones which both modify the vector-mask register and are interruptible. They do not change those bits in the vector-mask register which lie beyond the last bit processed. This contrasts with the non-interruptible instructions which load or perform logical operations on the vector-mask register; they set to zeros all bits which lie beyond the last bit processed.

4. Unlike the related arithmetic and logical vector instructions, the comparison instructions are not executed under control of the vector-mask mode.

COMPLEMENT VMR

VCVM [RRE]



The active bits of the vector-mask register (VMR) are complemented. Bits beyond the active bits of the vector-mask register are set to zeros.

COMPLEMENT VMR is a class-NC instruction: it is not interruptible, the vector count determines the number of elements processed, and its execution is not affected by the vector-mask mode.

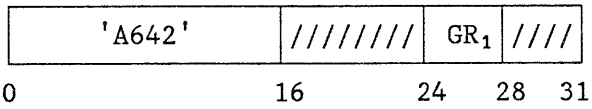
Condition Code: The code remains unchanged.

Program Exceptions:

Operation
Vector operation

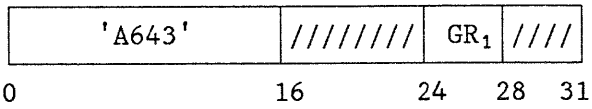
COUNT LEFT ZEROS IN VMR

VCZVM GR_1 [RRE]



COUNT ONES IN VMR

VCOVM GR_1 [RRE]



Selected bits among the active bits of the vector-mask register (VMR) are counted, and the count is added to the contents of the general register designated by GR_1. For the COUNT LEFT ZEROS IN VMR instruction, the selected bits are the zero bits to the left of the leftmost one bit. For the COUNT ONES IN VMR instruction, the selected bits are the one bits.

The general-register contents are treated as a 32-bit unsigned binary integer. Any carry out of the leftmost bit of the sum is ignored; there is no overflow indication.

Condition code 0, 1, or 3 is set according to whether the active bits are all zeros, mixed zeros and ones, or all ones. When the vector count is zero, the general register is not altered, and condition code 0 is set.

COUNT LEFT ZEROS IN VMR and COUNT ONES IN VMR are class-NC instructions: they are not interruptible, the vector count determines the number of elements processed, and their execution is not affected by the vector-mask mode.

Resulting Condition Code:

0 Active bits all zeros
1 Active bits mixed zeros and ones
2 --
3 Active bits all ones

Program Exceptions:

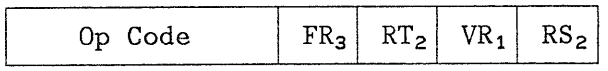
Operation
Vector operation

Programming Note

When only the condition-code result of COUNT LEFT ZEROS IN VMR or COUNT ONES IN VMR is required, but not the actual bit counts, the instruction TEST VMR may be used instead.

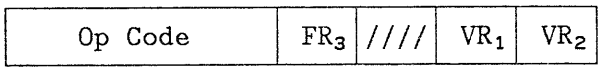
DIVIDE

Mnemonic $VR_1,FR_3,RS_2(RT_2)$ [QST]



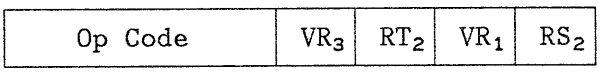
Mnemonic	Op Code	Operands
VDDS	'A493'	Long
VDES	'A483'	Short

Mnemonic VR_1,FR_3,VR_2 [QV]



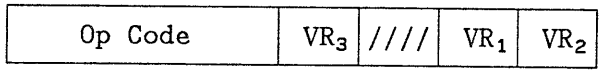
Mnemonic	Op Code	Operands
VDDQ	'A593'	Long
VDEQ	'A583'	Short

Mnemonic $VR_1,VR_3,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VDD	'A413'	Long
VDE	'A403'	Short

Mnemonic VR_1,VR_3,VR_2 [VV]



Mnemonic	Op Code	Operands
VDDR	'A513'	Long
VDER	'A503'	Short

Element by element, the third operand is divided by the second-operand vector, and the result is placed in the first-operand location.

The operation is performed on each pair of elements in the same manner as the corresponding scalar operation, except for two changes. When the fraction part of a divisor element is zero, so that a floating-point-divide exception is recognized, the unit of operation is inhibited. Also, the operands are not first normalized; when one or both of the source-operand elements have a nonzero fraction with a leftmost hexadecimal digit of zero, an unnormalized-operand exception is recognized, and the unit of operation is inhibited.

The floating-point-divide exception takes precedence over the unnormalized-operand exception, and both take precedence over the exponent overflow and exponent underflow exceptions.

A specification exception is recognized when a VR or QR field designates an invalid register number. In the QST and VST formats, a specification exception is recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

DIVIDE is a class-IM instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is under the control of the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2 in QST and VST formats)
Exponent overflow (with exception-extension code)
Exponent underflow (with exception-extension code)
Floating-point divide (with exception-extension code)
Operation
Specification
Unnormalized operand (with exception-extension code)
Vector operation

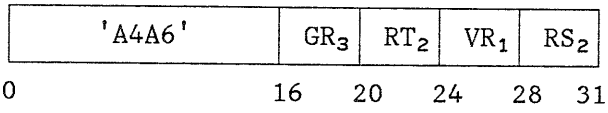
Programming Notes

1. The QST and QV formats provide for dividing a scalar operand by a vector. The operation of dividing a vector by a scalar can usually be replaced by the (generally faster) operation of multiplying the vector operand by the reciprocal of the scalar operand.

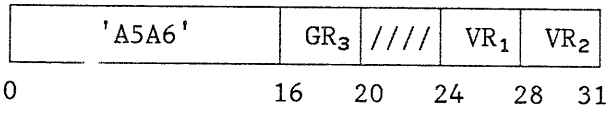
2. An unnormalized-operand exception is recognized whenever a divisor element is unnormalized, even if the corresponding dividend element is zero.

EXCLUSIVE OR

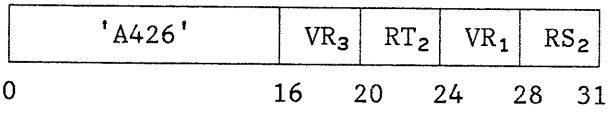
VXS $VR_1,GR_3,RS_2(RT_2)$ [QST]



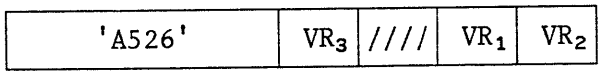
VXQ VR_1,GR_3,VR_2 [QV]



VX $VR_1,VR_3,RS_2(RT_2)$ [VST]



VXR VR_1,VR_3,VR_2 [VV]



Element by element, the EXCLUSIVE OR of the second and third operands is placed in the first-operand location.

The operation is performed on each pair of 32-bit elements in the same manner as the corresponding scalar operation, except that the condition code is not set.

For the VX and VXS instructions, a specification exception is recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field. For the VXS instruction, a specification exception is also recognized when the GR_3 field designates the same general register as the RS_2 field.

EXCLUSIVE OR is a class-IM instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is under the control of the vector-mask mode.

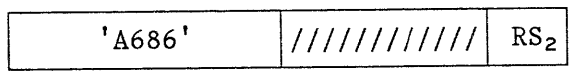
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2 in QST and VST formats)
Operation
Specification
Vector operation

EXCLUSIVE OR TO VMR

VXVM RS_2 [VS]



The EXCLUSIVE OR of the second-operand bit vector and of the active bits of the vector-mask register is placed in the vector-mask register. Bits beyond the active bits are set to zeros.

EXCLUSIVE OR TO VMR is a class-NC instruction: it is not interruptible, the vector count determines the number of elements processed, and its execution is not affected by the vector-mask mode.

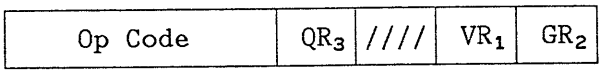
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2)
Operation
Vector operation

EXTRACT ELEMENT

Mnemonic VR_1,QR_3,GR_2 [VR]



Mnemonic	Op Code	Operands
VXEL	'A629'	Binary or logical
VXELD	'A619'	Long
VXELE	'A609'	Short

The element from the vector register or vector-register pair designated by VR_1, which has the element number contained in the general register designated by GR_2, is placed in the general or floating-point register designated by QR_3.

The element number is a 32-bit unsigned binary integer which must be less than the section size.

For VXELE, the rightmost 32 bits of the floating-point register designated by QR_3 remain unchanged.

For VXEL, if the GR_2 and QR_3 fields designate the same general register, the element number is obtained from that register before it is replaced by the specified vector element.

A specification exception is recognized when the VR_1 or QR_3 field designates an

invalid register number, or when the element number is equal to or greater than the section size.

EXTRACT ELEMENT is a class-N1 instruction: it is not interruptible, one element is processed, and its execution is not affected by the vector-mask mode. The vector count and vector interruption index are not used by the instruction and remain unchanged.

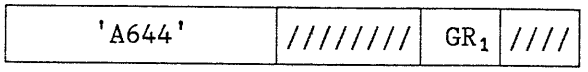
Condition Code: The code remains unchanged.

Program Exceptions:

Operation
Specification
Vector operation

EXTRACT VCT

VXVC GR_1 [RRE]



The vector count, with 16 zeros appended on the left, is placed in the general register designated by GR_1.

EXTRACT VCT is a class-N0 instruction: it is not interruptible, no elements are processed, and its execution is not affected by the vector-mask mode.

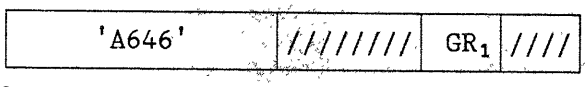
Condition Code: The code remains unchanged.

Program Exceptions:

Operation
Vector operation

EXTRACT VECTOR MASK MODE

VXVMM GR_1 [RRE]



Bits 16-31 of the general register designated by GR_1 are set to the value of bits 0-15 of the vector-status register. Thus, bit 31 of the general register indicates the current setting of the vector-mask mode. Bits 0-15 of the general register are set to zeros.

EXTRACT VECTOR MASK MODE is a class-N0 instruction: it is not interruptible, no elements are processed, and its execution is not affected by the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

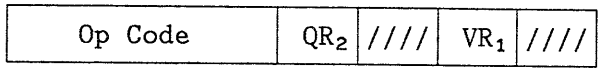
Operation
Vector operation

Programming Note

The program should not rely on bits 16-30 of the general register being set to zeros. Those bits correspond to unassigned bits of the vector-status register, which are reserved for possible future use.

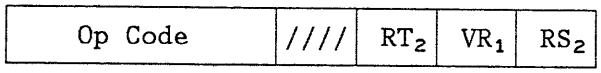
LOAD

Mnemonic VR_1,QR_2 [QV]



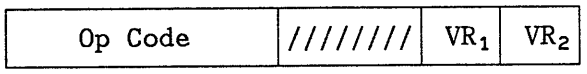
Mnemonic	Op Code	Operands
VLQ	'A5A9'	Binary or logical
VLDQ	'A599'	Long
VLEQ	'A589'	Short

Mnemonic $VR_1,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VL	'A409'	Binary or logical
VLD	'A419'	Long
VLE	'A409'	Short

Mnemonic VR_1,VR_2 [VV]



Mnemonic	Op Code	Operands
VLR	'A509'	Binary or logical
VLDR	'A519'	Long
VLER	'A509'	Short

Element by element, the second operand is placed unchanged in consecutive first-operand locations.

A specification exception is recognized when a VR or QR field designates an invalid register number. In the VST format, a specification exception is also recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

LOAD is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

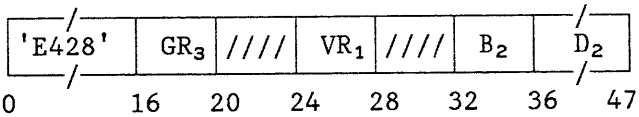
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2 in VST format)
Operation
Specification
Vector operation

LOAD BIT INDEX

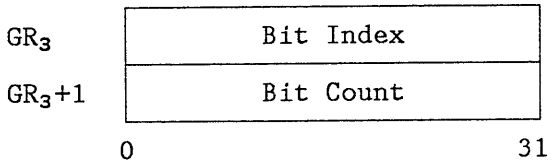
VLBIX $VR_1,GR_3,D_2(B_2)$ [RSE]



Bit by bit, the second operand is converted from a bit vector to a vector of element numbers, the result vector is placed in the first-operand location, and the number of elements in the result vector is placed in the vector count.

The result-vector elements are 32-bit signed binary integers, which give the positions of the one bits in the second operand, relative to the starting address of the second operand and in sequence from left to right. No result-vector elements are generated for zero bits.

The GR_3 field must designate an even register number to specify an even-odd pair of general registers. The registers contain a bit index and a bit count, as follows:



Both are treated as 32-bit signed binary integers. The bit index identifies the first bit of the second operand to be processed. The bit count gives the number of bits to be processed. If the bit count is zero or less than zero, no bits are processed. Upon completion or interruption of the instruction, the bit index identifies the next bit to be processed, and the bit count, if greater than zero, gives the number of bits remaining.

The address of the byte location containing the current bit to be processed is the sum, modulo the address size, of the second-operand address and of a number obtained by shifting bits 0-28 of the current bit index right by three bit positions, with bits equal to bit 0 being shifted into the leftmost three bit positions (without changing the contents of the general register). The rightmost three bits of the current bit index designate the bit within the byte.

Execution of the instruction consists of a repetition of the following procedure:

The current value of the vector interruption index is placed in the vector count. Then, if the vector count is equal to the section size, or if the bit count is zero or less than zero, the

vector interruption index is set to zero, and instruction execution is completed. Otherwise, the second-operand bit designated by the current bit index is selected. If the selected bit is one, the value of the bit index is placed in the first-operand element location designated by the vector interruption index, and the vector interruption index is then incremented by one. Next, regardless of the value of the selected bit, one is added algebraically to the bit index, and one is subtracted from the bit count. The procedure is then repeated.

Execution of the instruction may be interrupted, but only upon return to the starting point of the repetitive procedure.

When 31-bit addressing is in effect, incrementing the bit index beyond the value $2^{31}-1$ may cause an overflow, which is not signaled to the program. The result of incrementing the bit index beyond $2^{31}-1$ is undefined.

A specification exception is recognized when the GR_3 field designates an invalid register number.

The B_2 field should not designate the same general register as either of the pair of registers designated by the GR_3 field. The result fields (bit count, bit index, condition code, vector count, vector interruption index, and vector register) are undefined if B_2 is nonzero and $B_2 = GR_3$ or $B_2 = GR_3+1$.

LOAD BIT INDEX is a class-IG instruction: it is interruptible, a general register and the vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

Resulting Condition Code:

0 Vector count zero; bit count zero
1 Vector count zero; bit count less than zero
2 Vector count equal to section size; bit count greater than zero
3 Vector count greater than zero; bit count zero or less than zero

Program Exceptions:

Access (fetch, operand 2)
Operation
Specification
Vector operation

Programming Notes

1. Example of LOAD BIT INDEX:

   Bit Positions: 012345678

   Bit Vector: 010001101

   Result Vector: 1 5 6 8

2. The bit index in the even register should normally be set to zero by the program before entering a sectioning loop that contains the instruction. An initial nonzero value may be useful to shorten a bit vector that would otherwise contain a large number of leading zeros.

3. Assuming normal use of the instruction with the vector interruption index initially set to zero, LOAD BIT INDEX sets the vector count to the number of result elements generated. The vector count is then available to control subsequent vector instructions.

   If condition code 2 is set, the vector count has been set to the section size; a full section of element numbers has been loaded by the instruction, and more bits remain to be processed. If condition code 3 is set, the vector count has been set to a value equal to or less than the section size; the last or only section of element numbers has been loaded, and no more bits remain to be processed. If condition code 0 or 1 is set, the vector count is zero, and there were no bits to be processed and no element numbers to be loaded.

4. If all bits in the second operand are zeros, no result elements are generated, and the vector count is set to the initial vector interruption index, which normally is zero. This may also occur for the last pass through a sectioning loop using this instruction, if the number of one bits in the second

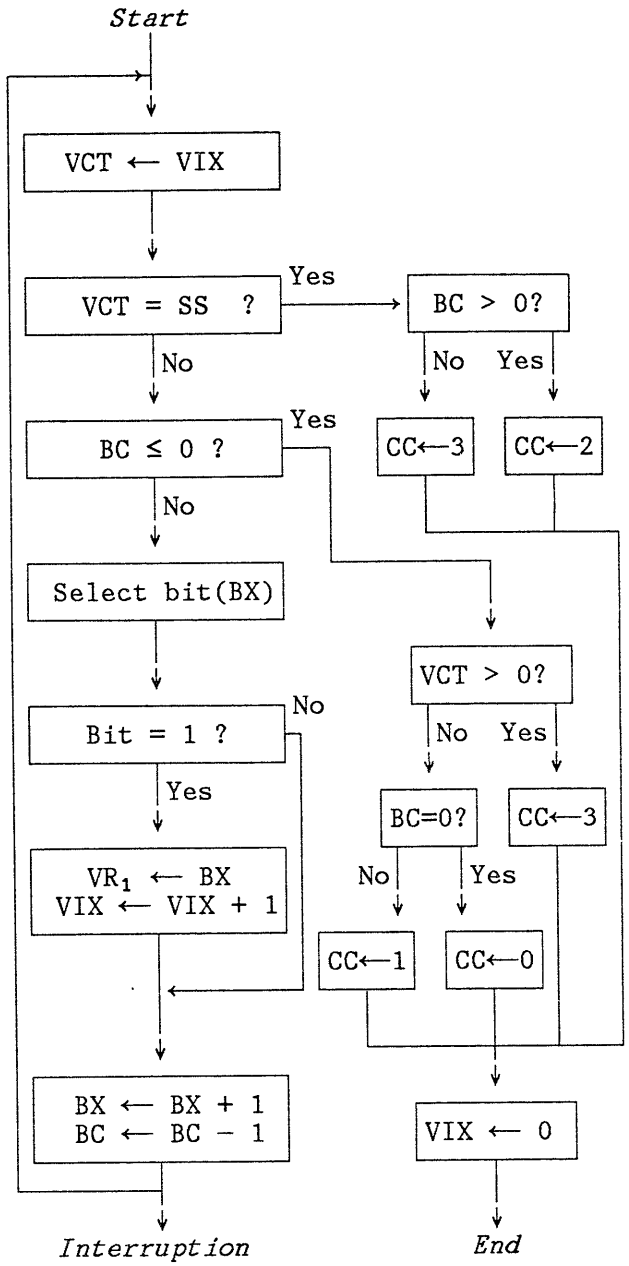
operand happens to be a multiple of the section size, thus generating one or more full sections, with the remainder of the second operand containing only zero bits. Subsequent vector instructions will still function correctly, because no elements are processed when the vector count is zero.

5. The effect on the result fields of specifying the same general register for the base register of the second operand and for the bit index or bit count is unpredictable; it may depend on the model, on the occurrence of asynchronous interruptions such as I/O, or on other events that are not under the direct control of the program.

6. Programs using extremely large values of the bit index when 31-bit addressing is in effect must limit those values so that they cannot exceed $2^{31}-1$, which corresponds to a byte location of $2^{28}-1$ relative to the second-operand address. Allowing the instruction to increment the bit index to the next value may or may not cause overflow; the next byte location might be either 2^{28} or -2^{28} relative to the second-operand address. The result may not be repeatable from one instruction execution to the next.

   When 24-bit addressing is in effect, byte addresses in storage are computed modulo 2^{24}, so that the possibility of overflow at a bit index of $2^{31}-1$ does not affect the resultant address.

7. Figure 3-1 is a summary of the operation.

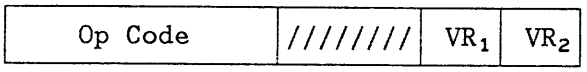


BC: Bit count in GR_3+1
BX: Bit index in GR_3
CC: Condition code
SS: Section size
VCT: Vector count
VIX: Vector interruption index

Figure 3-1. Execution of LOAD BIT INDEX

LOAD COMPLEMENT

Mnemonic VR_1,VR_2 [VV]



Mnemonic	Op Code	Operands
VLCR	'A562'	Binary
VLCDR	'A552'	Long
VLCER	'A542'	Short

Element by element, the second-operand vector is placed in the first-operand location with the opposite sign. For VLCR, each result element is the two's complement of the corresponding source element. For VLCDR and VLCER, each result element is the corresponding source element with the sign bit inverted.

The operation is performed on each element in the same manner as the corresponding scalar operation, except that the condition code is not set.

A specification exception is recognized when a VR field designates an invalid register number.

LOAD COMPLEMENT is a class-IM instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is under the control of the vector-mask mode.

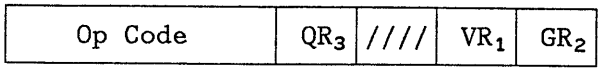
Condition Code: The code remains unchanged.

Program Exceptions:

Fixed-point overflow (with exception-extension code; VLCR only)
Operation
Specification
Vector operation

LOAD ELEMENT

Mnemonic VR_1,QR_3,GR_2 [VR]



Mnemonic	Op Code	Operands
VLEL	'A628'	Binary or logical
VLELD	'A618'	Long
VLELE	'A608'	Short

The element in the vector register or vector-register pair designated by VR_1, which has the element number contained in the general register designated by GR_2, is replaced by the scalar operand in the general or floating-point register designated by QR_3.

The element number is a 32-bit unsigned binary integer which must be less than the section size.

A specification exception is recognized when the VR_1 or QR_3 field designates an invalid register number, or when the element number is equal to or greater than the section size.

LOAD ELEMENT is a class-N1 instruction: it is not interruptible, one element is processed, and its execution is not affected by the vector-mask mode. The vector count and vector interruption index are not used and remain unchanged.

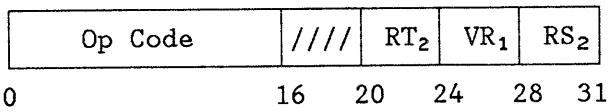
Condition Code: The code remains unchanged.

Program Exceptions:

Operation
Specification
Vector operation

LOAD EXPANDED

Mnemonic $VR_1,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VLY	'A40B'	Binary or logical
VLYD	'A41B'	Long
VLYE	'A40B'	Short

Element by element, successive elements of the second-operand vector are placed unchanged in the element locations of the first operand that correspond to ones in the active bits of the vector-mask register. Element locations of the first operand that correspond to zeros in the active bits of the vector-mask register remain unchanged, and there are no corresponding second-operand locations in storage.

A specification exception is recognized when the VR_1 field designates an invalid register number, when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

When the active bits of the vector-mask register are all zeros, no access exceptions are recognized for the storage location specified by the second operand.

LOAD EXPANDED is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2)
Operation
Specification
Vector operation

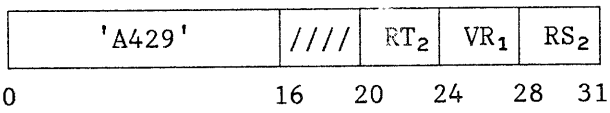
Programming Notes

1. The number of vector elements which are loaded from storage and the amount by which the address in the general register designated by RS_2 is updated correspond to the number of ones among the active bits of the vector-mask register.

2. The operation performed by LOAD EXPANDED is the opposite of STORE COMPRESSED.

LOAD HALFWORD

VLH $VR_1,RS_2(RT_2)$ [VST]



Element by element, the second operand is extended from a vector of 16-bit signed binary integers to a vector of 32-bit signed binary integers, and the result is placed in consecutive first-operand locations.

Each second-operand element is two bytes in length. The element is extended upon loading to 32 bits by setting each of the 16 leftmost bit positions of the first-operand element equal to the sign bit of the second-operand element.

A specification exception is recognized when the second operand is not designated on a halfword boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

LOAD HALFWORD is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

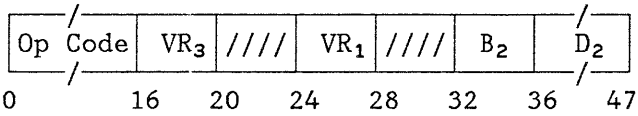
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2)
Operation
Specification
Vector operation

LOAD INDIRECT

Mnemonic $VR_1,VR_3,D_2(B_2)$ [RSE]



Mnemonic	Op Code	Operands
VLI	'E400'	Binary or logical
VLID	'E410'	Long
VLIE	'E400'	Short

Element by element, the third operand is used to select elements of the second-operand vector in storage and place them unchanged in the element positions of the first operand which correspond to those of the third operand.

The third operand is a vector of 32-bit signed binary integers. The address of each second-operand element is computed as the sum of the second-operand origin and the offset obtained from each element of the third operand, as follows.

The second-operand origin is generated from the base-address (B_2) and displacement (D_2) fields using the normal rules of address generation. The offset is obtained by shifting the current third-operand element to the left by two bits (for VLI or VLIE) or three bits (for VLID), with zeros appended on the right. The origin and offset are added. The rightmost 31 or 24 bits of the sum, depending on the address size, are used as the storage address. The second-operand element is fetched from that address and loaded into the first-operand location at the same element position as that from which the third-operand element was obtained.

During the shift and addition operations, any carries or shifts into or out of the unused bit positions on the left are ignored.

A specification exception is recognized when the VR_1 field designates an invalid register number, or when the second operand is not designated on an integral boundary.

LOAD INDIRECT is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2)
Operation
Specification
Vector operation

Programming Note

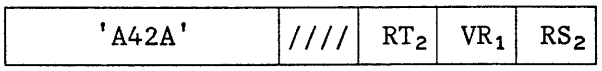
LOAD INDIRECT is used to load a vector by indirect element selection. The instruction fetches elements from storage in the following sequence of addresses: $A + w*VR_3(0)$, $A + w*VR_3(1)$, $A + w*VR_3(2)$, ..., where A is the origin of the vector in storage, w is the width of each element, and $VR_3(0)$, $VR_3(1)$, $VR_3(2)$, ... are the successive element numbers contained in the vector register designated by the VR_3 field of the instruction.

The origin is $A = (B_2)+D_2$, where (B_2) represents the contents of the base register designated by the B_2 field, and D_2 is the displacement designated by the D_2 field.

The element width w is 4 for VLI or VLIE and 8 for VLID. The storage elements are loaded successively into element positions $VR_1(0)$, $VR_1(1)$, $VR_1(2)$, ... of the target register.

LOAD INTEGER VECTOR

VLINT $VR_1,RS_2(RT_2)$ [VST]



Element by element, a vector of uniformly spaced integers, as specified by the second-operand designation, is placed in consecutive first-operand locations.

If the vector interruption index X is less than the vector count, the contents of the general register designated by RS_2 replace element X of the first operand (normally X = 0 at the start). Then, the contents of that general register are incremented by adding the contents of the general register designated by RT_2 (the stride), both being treated as 32-bit binary integers. Any overflow during the addition is ignored. The vector interruption index X is then incremented by one.

These steps are repeated for each successive first-operand element until incrementing X causes it to equal the vector count. The vector interruption index is then set to zero.

The general register designated by RT_2 remains unchanged. If the RT_2 field of the instruction is zero, general register 0 is not used for the increment; instead, the increment is +1, so that consecutive integers are loaded.

A specification exception is recognized when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

LOAD INTEGER VECTOR is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

Operation
Specification
Vector operation

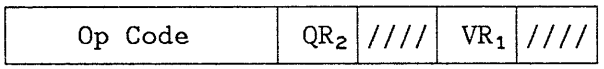
Programming Note

The operation resembles the generation of storage addresses for QST- and VST-format instructions, except that the element size is w = 1, no storage references for operands take place, no access exceptions for operands are recognized, and all 32 bits of both general registers participate in the operation. The result is independent of the address size.

Performing a LOAD INTEGER VECTOR operation also resembles the execution of a loop using the nonvector instruction LOAD ADDRESS. They differ in that LOAD INTEGER VECTOR does not depend on the address size; it does not set to zeros the leftmost one or eight bit positions. LOAD INTEGER VECTOR can generate negative numbers, which LOAD ADDRESS cannot.

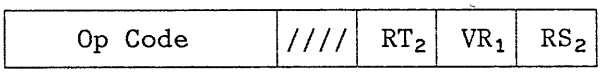
LOAD MATCHED

Mnemonic VR_1,QR_2 [QV]



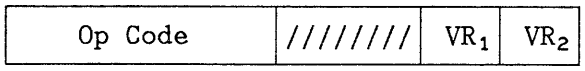
Mnemonic	Op Code	Operands
VLMQ	'A5AA'	Binary or logical
VLMDQ	'A59A'	Long
VLMEQ	'A58A'	Short

Mnemonic $VR_1,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VLM	'A40A'	Binary or logical
VLMD	'A41A'	Long
VLME	'A40A'	Short

Mnemonic VR_1,VR_2 [VV]



Mnemonic	Op Code	Operands
VLMR	'A50A'	Binary or logical
VLMDR	'A51A'	Long
VLMER	'A50A'	Short

Element by element, elements of the second operand corresponding to ones in the active bits of the vector-mask register are placed unchanged in the corresponding element locations of the first operand. Elements of the second operand corresponding to zeros in the active bits of the vector-mask register are not loaded, and the corresponding element locations of the first operand remain unchanged.

A specification exception is recognized when a VR or QR field designates an invalid register number. In the VST format, a specification exception is also recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

No access exceptions are recognized for elements of the second operand which correspond to zeros in the active bits of the vector-mask register; however, the general register designated by the RS_2 field is updated for each of those elements.

LOAD MATCHED is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2 in VST format)
Operation
Specification

Vector operation

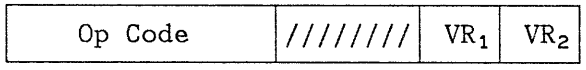
Programming Notes

1. LOAD MATCHED functions the same as LOAD for those elements which correspond to ones in the active bits of the vector-mask register: each such element is loaded from the same storage location into the same vector-register position. It differs in that elements in storage corresponding to zeros in the active bits of the vector-mask register are skipped.

2. LOAD, LOAD EXPANDED, and LOAD MATCHED function the same, for corresponding formats, when all active bit positions of the vector-mask register contain ones.

LOAD NEGATIVE

Mnemonic VR_1,VR_2 [VV]



Mnemonic	Op Code	Operands
VLNR	'A561'	Binary
VLNDR	'A551'	Long
VLNER	'A541'	Short

Element by element, the negative of the absolute value of the second-operand vector is placed in the first-operand location.

The operation is performed on each element in the same manner as the corresponding scalar operation, except that the condition code is not set.

A specification exception is recognized when a VR field designates an invalid register number.

LOAD NEGATIVE is a class-IM instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is under the control of the vector-mask mode.

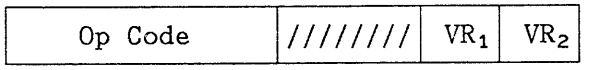
Condition Code: The code remains unchanged.

Program Exceptions:

Operation
Specification
Vector operation

LOAD POSITIVE

Mnemonic VR_1,VR_2 [VV]



Mnemonic	Op Code	Operands
VLPR	'A560'	Binary
VLPDR	'A550'	Long
VLPER	'A540'	Short

Element by element, the absolute value of the second-operand vector is placed in the first-operand location.

The operation is performed on each element in the same manner as the corresponding scalar operation, except that the condition code is not set.

A specification exception is recognized when a VR field designates an invalid register number.

LOAD POSITIVE is a class-IM instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is under the control of the vector-mask mode.

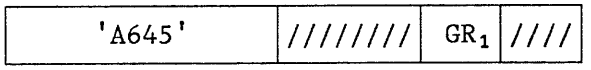
Condition Code: The code remains unchanged.

Program Exceptions:

Fixed-point overflow (with exception-extension code; binary operand only)
Operation
Specification
Vector operation

LOAD VCT AND UPDATE

VLVCU GR_1 [RRE]



If the operand in the general register designated by the GR_1 field is greater than zero, the vector count (VCT) is replaced by the lesser of the section size and the operand. If the operand is zero or less than zero, the vector count is set to zero. The general register is then updated by subtracting the new vector count from the register contents.

The register contents are treated as a 32-bit signed binary integer. The vector count and section size are treated as 16-bit unsigned binary integers.

LOAD VCT AND UPDATE is a class-NO instruction: it is not interruptible, no elements are processed, and its execution is not affected by the vector-mask mode.

Resulting Condition Code:

0 Vector count zero; register result zero
1 Vector count zero; register result less than zero
2 Vector count equal to section size; register result greater than zero
3 Vector count greater than zero; register result zero

Program Exceptions:

Operation
Vector operation

Programming Notes

1. LOAD VCT AND UPDATE may be used at the start of a sectioning loop to determine the number of vector elements to be processed during each pass through the loop. Before entering the loop, the program initializes the general-register operand to the total number of elements in the vector. The end of the loop may simply be a BRANCH ON CONDITION instruction, if the condition

code has not been changed since the start of the loop, or the branch may be preceded by LOAD AND TEST specifying the general register as both the first and second operand.

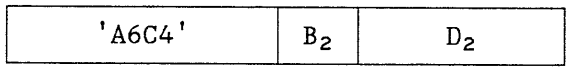
If LOAD VCT AND UPDATE sets condition code 2, the vector count has been set to the section size; a full section of vector elements are to be processed, and more remain to be processed. If it sets condition code 3, the vector count has a value equal to or less than the section size, and the last or only section is to be processed. If it sets condition code 0 or 1, the vector count is zero, and there are no vector elements to be processed.

2. If LOAD AND TEST is used instead at the end of the loop, condition code 2 simply indicates that the general register contents are greater than zero, and there are more elements to be processed. Any other condition code means that there are no more elements.

3. The general-register operand remains greater than zero at the end of instruction execution only if condition code 2 is set. For the other condition codes, the final register contents are zero or negative.

LOAD VCT FROM ADDRESS

VLVCA $D_2(B_2)$ [S]



If the second-operand-address value is greater than zero, the vector count (VCT) is replaced by the lesser of the section size and the address value. If the second-operand-address value is zero or less than zero, the vector count is set to zero.

If the B_2 field of the instruction is not zero, the second-operand-address value is formed by adding the contents of the general register designated by the B_2 field and the contents of the 12-bit D_2 field of the instruction. All 32 bits in the general register designated by the B_2 field participate in the addition, which is independent of the address size. The result of the addition is used as the operand itself and not to address storage. It is treated as a 32-bit signed binary integer.

If the B_2 field of the instruction is zero, general register 0 is not used; instead, the address value consists of the D_2 field with 20 zero bits appended on the left.

No storage references for operands take place, and the address value is not inspected for boundary alignment or access exceptions.

LOAD VCT FROM ADDRESS is a class-NO instruction: it is not interruptible, no elements are processed, and its execution is not affected by the vector-mask mode.

Resulting Condition Code:

0 Vector count zero; second-operand address zero
1 Vector count zero; second-operand address less than zero
2 Vector count equal to section size; second-operand address greater than section size
3 Vector count greater than zero; second-operand address less than or equal to section size and greater than zero

Program Exceptions:

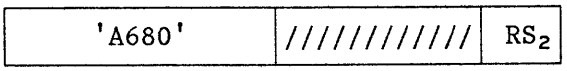
Operation
Vector operation

Programming Note

LOAD VCT FROM ADDRESS may be used to set the vector count to the section size by specifying a B_2 field of zero and placing a value greater than 511 in the D_2 field.

LOAD VMR

VLVM RS_2 [VS]



The second-operand bit vector replaces the active bits of the vector-mask register (VMR). Bits beyond the active bits are set to zeros.

LOAD VMR is a class-NC instruction: it is not interruptible, the vector count determines the number of elements processed, and its execution is not affected by the vector-mask mode.

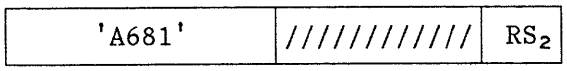
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2)
Operation
Vector operation

LOAD VMR COMPLEMENT

VLCVM RS_2 [VS]



The complement of the bits from the second-operand bit vector replaces the active bits of the vector-mask register (VMR). Bits beyond the active bits are set to zeros.

LOAD VMR COMPLEMENT is a class-NC instruction: it is not interruptible, the vector count determines the number of elements processed, and its execution is not affected by the vector-mask mode.

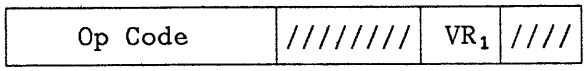
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2)
Operation
Vector operation

LOAD ZERO

Mnemonic VR_1 [VV]



Mnemonic	Op Code	Operands
VLZR	'A50B'	Binary or logical
VLZDR	'A51B'	Long
VLZER	'A50B'	Short

The first-operand vector is cleared to zero. Only element positions numbered less than the vector count are set to zero. Any element positions numbered equal to or greater than the vector count remain unchanged.

A specification exception is recognized when the VR_1 field designates an invalid register number.

LOAD ZERO is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of element positions set to zero, and its execution is not affected by the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

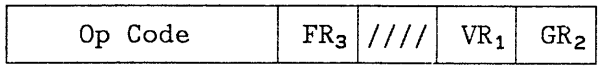
Operation
Specification
Vector operation

Programming Note

The instruction LOAD ZERO is equivalent to LOAD (VLQ, VLDQ, or VLEQ) with an implied scalar source operand of zero. It provides the fastest way to set a vector register to zero.

MAXIMUM ABSOLUTE

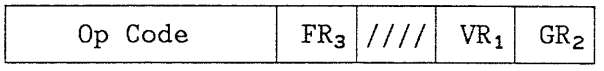
Mnemonic VR_1,FR_3,GR_2 [VR]



Mnemonic	Op Code	Operands
VMXAD	'A612'	Long
VMXAE	'A602'	Short

MAXIMUM SIGNED

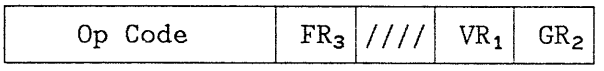
Mnemonic VR_1,FR_3,GR_2 [VR]



Mnemonic	Op Code	Operands
VMXSD	'A610'	Long
VMXSE	'A600'	Short

MINIMUM SIGNED

Mnemonic VR_1,FR_3,GR_2 [VR]



Mnemonic	Op Code	Operands
VMNSD	'A611'	Long
VMNSE	'A601'	Short

The scalar third operand and all first-operand vector elements are compared to determine the maximum or minimum value, which replaces the third operand. The instruction MAXIMUM ABSOLUTE compares absolute values to select the maximum. The instructions MAXIMUM SIGNED and MINIMUM SIGNED compare signed values to select the maximum or minimum, respectively.

The comparison of each pair of absolute or signed operand values is performed in the same manner as the scalar floating-point COMPARE instruction for the same format, except that the result is the selection of one element of the pair instead of a condition-code setting.

The scalar third operand is compared with each element of the first operand in turn to determine the selected (maximum absolute, maximum signed, or minimum signed) value. If the comparison is unequal and the first-operand element is the selected value, the first-operand element replaces the third operand; otherwise, no change takes place. The operation then continues with the next element of the first operand in the sequence of element numbers.

The GR_2 field must be zero or even. When nonzero, it designates an even-odd pair of general registers. The contents of the odd general register are treated as a 32-bit unsigned binary integer, which is incremented by one after each first-operand element has been processed; any carry out of bit position 0 is ignored. Each time a new selected value replaces the third operand, the current contents of the odd general register, before it is incremented, are placed in the even general register.

When the GR_2 field is zero, the action associated with the general registers is not performed, and their contents remain unchanged.

For VMXAE, VMXSE, and VMNSE, the rightmost 32 bits of the floating-point register designated by FR_3 remain unchanged.

A specification exception is recognized when the VR_1, GR_2, or FR_3 field designates an invalid register number.

MAXIMUM ABSOLUTE, MAXIMUM SIGNED, and MINIMUM SIGNED are class-IM instructions: they are interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is under the control of the vector-mask mode. When the vector-mask mode is on, no selection takes place for first-operand elements corresponding to zero mask bits: the third operand and the even general register remain unchanged. However, when the GR_2 field is nonzero, the odd general register is incremented

by one for every first-operand element, regardless of the mode and mask bits.

Condition Code: The code remains unchanged.

Program Exceptions:

Operation
Specification
Vector operation

Programming Notes

1. Because the current third operand is compared with every element of the first operand, including element 0, these instructions can be used in a sectioning loop to find the selected value of a vector of any length. Before starting the first, or only, section, the program should initialize the third operand as follows.

   MAXIMUM ABSOLUTE: zero
   MAXIMUM SIGNED: largest negative value
   MINIMUM SIGNED: largest positive value

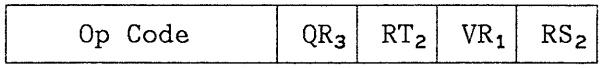
2. If the GR_2 field is not zero, and the program initializes both of the specified pair of general registers to zero before executing the instruction, the even register will contain the number of the selected element, counting from the start (element 0) of the first section. If no element was selected, the even register will retain its initial contents. The odd register will contain the cumulative number of elements processed.

   When the first operand contains two or more elements that could equally qualify as the selected element, the instruction selects the first one.

3. Since the element values are floating-point numbers, the rules for floating-point comparison apply, and two or more elements with different bit patterns may satisfy the test for maximum or minimum value. For example, elements with zero fractions compare equal even though their sign and characteristic may differ. (See also the programming notes for the COMPARE instruction in Chapter 9, "Floating-Point Instructions," of *IBM 370-XA Principles of Operation* and *IBM System/370 Principles of Operation*.)

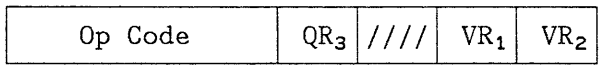
MULTIPLY

Mnemonic $VR_1,QR_3,RS_2(RT_2)$ [QST]



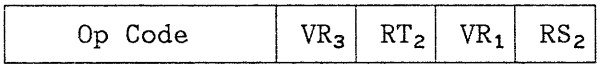
Mnemonic	Op Code	Operands
VMS	'A4A2'	Binary
VMDS	'A492'	Long
VMES	'A482'	Short multiplier and multiplicand, long product

Mnemonic VR_1,QR_3,VR_2 [QV]



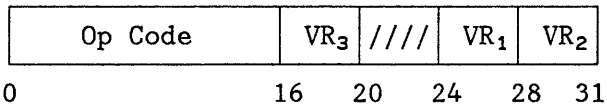
Mnemonic	Op Code	Operands
VMQ	'A5A2'	Binary
VMDQ	'A592'	Long
VMEQ	'A582'	Short multiplier and multiplicand, long product

Mnemonic $VR_1,VR_3,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VM	'A422'	Binary
VMD	'A412'	Long
VME	'A402'	Short multiplier and multiplicand, long product

Mnemonic VR_1,VR_3,VR_2 [VV]



Mnemonic	Op Code	Operands
VMR	'A522'	Binary
VMDR	'A512'	Long
VMER	'A502'	Short multiplier and multiplicand, long product

Element by element, the product of the second operand and the third operand is placed in the first-operand location. The operation is performed on each pair of elements in the same manner as the corresponding scalar operation, except for the following differences:

1. For binary operands, the third-operand location is any vector register; each element of the third operand is a 32-bit signed binary integer, as is each element of the second operand. The first-operand location is a vector-register pair, which receives product elements consisting of 64-bit signed binary integers.

2. For floating-point operands, the operands are not first normalized. When one or both of the source-operand elements have a nonzero fraction with a leftmost hexadecimal digit of zero, an unnormalized-operand exception is recognized, and the unit of operation is inhibited.

A specification exception is recognized when a VR or QR field designates an invalid register number. In the QST and VST formats, a specification exception is recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field. For the VMS instruction, a specification exception is also recognized when the QR_3 field designates the same general register as the RS_2 field.

MULTIPLY is a class-IM instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is under the control of the vector-mask mode.

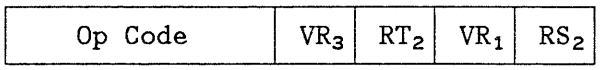
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2 in QST and VST formats)
Exponent overflow (with exception-extension code; floating-point operands only)
Exponent underflow (with exception-extension code; floating-point operands only)
Operation
Specification
Unnormalized operand (with exception-extension code; floating-point operands only)
Vector operation

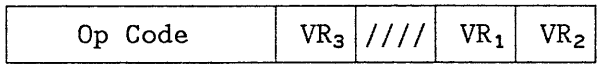
MULTIPLY AND ACCUMULATE

Mnemonic $VR_1,VR_3,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VMCD	'A416'	Long
VMCE	'A406'	Short multiplier and multiplicand; long first operand, product, and sum

Mnemonic VR_1,VR_3,VR_2 [VV]



Mnemonic	Op Code	Operands
VMCDR	'A516'	Long
VMCER	'A506'	Short multiplier and multiplicand; long first operand, product, and sum

Partial sums of the products of corresponding elements of the second and third operands are accumulated by adding the products to the contents of element positions 0 to p-1 of the first operand. The partial-sum number p depends on the model.

The operation proceeds in an ascending sequence of element numbers. The product of the I-th elements of the second and third operands is added to the first-operand element at a position which is the remainder of dividing I by p, where I varies from X to C-1, X is the initial vector interruption index (normally zero), and C is the vector count. The operation accumulates C-X element products.

Thus, the products formed from second- and third-operand elements 0, p, $2p$, ... are accumulated into position 0 of the first operand; products from elements 1, p+1, $2p$+1, ... are accumulated into position 1; etc. The contents of first-operand element positions above p-1 remain unchanged.

Every multiplication is performed in the same manner as the corresponding scalar floating-point, short or long, MULTIPLY instruction, except that the operand elements are not first normalized. Every addition is performed in the same manner as the scalar instruction ADD NORMALIZED (ADR), except that the condition code is not set.

When one or both of a pair of second- and third-operand elements have a nonzero fraction with a leftmost hexadecimal digit of zero, an unnormalized-operand exception is recognized, and the unit of operation is inhibited.

If the multiplication of an element pair results in an exponent underflow, a true zero is used in place of the product in the addition operation, and no exception is recognized. If the multiplication results in an exponent overflow, the product replaces the corresponding partial-sum element, and an exponent overflow is recognized. Exceptions in the addition are recognized in the same manner as for the scalar instruction ADD NORMALIZED (ADR).

A specification exception is recognized when a VR field designates an invalid register number. In the VST format, a specification exception is also recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

MULTIPLY AND ACCUMULATE is a class-IM instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is under the control of the vector-mask mode.

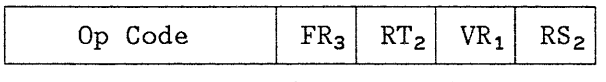
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2 in VST format)
Exponent overflow (with exception-extension code)
Exponent underflow (with exception-extension code)
Operation
Significance (with exception-extension code)
Specification
Unnormalized operand (with exception-extension code)
Vector operation

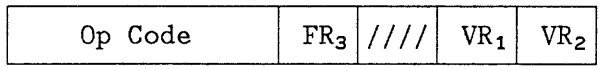
MULTIPLY AND ADD

Mnemonic $VR_1,FR_3,RS_2(RT_2)$ [QST]



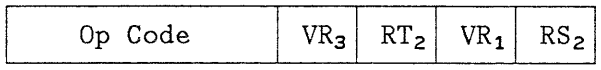
Mnemonic	Op Code	Operands
VMADS	'A494'	Long operands and sum
VMAES	'A484'	Short multiplier and multiplicand; long first operand, product, and sum

Mnemonic VR_1,FR_3,VR_2 [QV]



Mnemonic	Op Code	Operands
VMADQ	'A594'	Long operands and sum
VMAEQ	'A584'	Short multiplier and multiplicand; long first operand, product, and sum

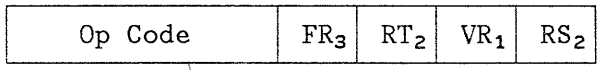
Mnemonic $VR_1,VR_3,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VMAD	'A414'	Long operands and sum
VMAE	'A404'	Short multiplier and multiplicand; long first operand, product, and sum

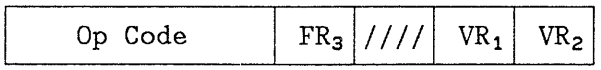
MULTIPLY AND SUBTRACT

Mnemonic $VR_1,FR_3,RS_2(RT_2)$ [QST]



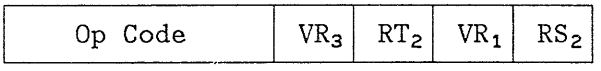
Mnemonic	Op Code	Operands
VMSDS	'A495'	Long operands and difference
VMSES	'A485'	Short multiplier and multiplicand; long first operand, product, and difference

Mnemonic VR_1,FR_3,VR_2 [QV]



Mnemonic	Op Code	Operands
VMSDQ	'A595'	Long operands and difference
VMSEQ	'A585'	Short multiplier and multiplicand; long first operand, product, and difference

Mnemonic $VR_1,VR_3,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VMSD	'A415'	Long operands and difference
VMSE	'A405'	Short multiplier and multiplicand; long first operand, product, and difference

Element by element, the third operand is multiplied by the second-operand vector, and the product is added to, or subtracted from, the first-operand vector. The sum or difference is placed in the first-operand location.

Every multiplication is performed in the same manner as the corresponding scalar floating-point, short or long, MULTIPLY instruction, except that the operand elements are not first normalized. Every addition or subtraction is performed in the same manner as the scalar instruction ADD NORMALIZED (ADR) or SUBTRACT NORMALIZED (SDR), respectively, except that the condition code is not set.

When one or both of a pair of second- and third-operand elements have a nonzero fraction with a leftmost hexadecimal digit of zero, an

unnormalized-operand exception is recognized, and the unit of operation is inhibited.

If the multiplication of an element pair results in an exponent underflow, a true zero is used in place of the product in the addition or subtraction operation, and no exception is recognized. If the multiplication of an element pair results in an exponent overflow, the corresponding product replaces the first-operand element, and an exponent overflow is recognized. Exceptions in the addition or subtraction are recognized in the same manner as for the scalar instruction ADD NORMALIZED (ADR) or SUBTRACT NORMALIZED (SDR), respectively.

A specification exception is recognized when a VR or FR field designates an invalid register number. In the QST and VST formats, a specification exception is also recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

MULTIPLY AND ADD and MULTIPLY AND SUBTRACT are class-IM instructions: they are interruptible, the vector count and vector interruption index determine the number of elements processed, and their execution is under the control of the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2 in QST and VST formats)
Exponent overflow (with exception-extension code)
Exponent underflow (with exception-extension code)
Operation
Significance (with exception-extension code)
Specification
Unnormalized operand (with exception-extension code)
Vector operation

Programming Notes

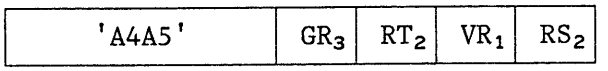
1. The MULTIPLY AND ADD and MULTIPLY AND SUBTRACT operations may be summarized as:

   $op_1 = op_1 \pm op_3 * op_2$

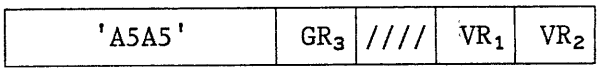
2. If the constant 1.0 is placed in the third-operand location, MULTIPLY AND ADD (VMAES or VMAEQ) and MULTIPLY AND SUBTRACT (VMSES or VMSEQ) may be used to add (subtract) a vector in the short format to (from) a vector in the long format.

OR

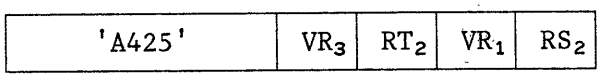
VOS $VR_1,GR_3,RS_2(RT_2)$ [QST]



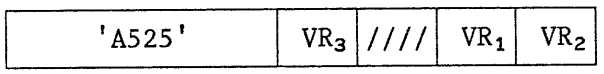
VOQ VR_1,GR_3,VR_2 [QV]



VO $VR_1,VR_3,RS_2(RT_2)$ [VST]



VOR VR_1,VR_3,VR_2 [VV]



Element by element, the OR of the second and third operands is placed in the first-operand location.

The operation is performed on each pair of 32-bit elements in the same manner as the corresponding scalar operation,

except that the condition code is not set.

For the VO and VOS instructions, a specification exception is recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field. For the VOS instruction, a specification exception is also recognized when the GR_3 field designates the same general register as the RS_2 field.

OR is a class-IM instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is under the control of the vector-mask mode.

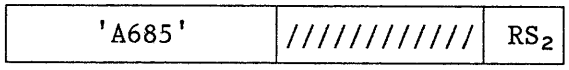
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2 in QST and VST formats)
Operation
Specification
Vector operation

OR TO VMR

VOVM RS_2 [VS]



The OR of the second-operand bit vector and of the active bits of the vector-mask register is placed in the vector-mask register. Bits beyond the active bits are set to zeros.

OR TO VMR is a class-NC instruction: it is not interruptible, the vector count determines the number of elements processed, and its execution is not affected by the vector-mask mode.

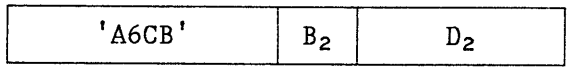
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2)
Operation
Vector operation

RESTORE VAC

VACRS $D_2(B_2)$ [S]



Bits 8-63 of the vector-activity count (VAC) are replaced by bits 8-63 of the doubleword designated by the second-operand address; bits 0-7 of the VAC are set to zeros. Execution of this instruction does not increment the vector-activity count and leaves the loaded value unchanged.

The operand must be designated on a doubleword boundary; otherwise, a specification exception is recognized.

RESTORE VAC is a class-NO instruction: it is not interruptible, no elements are processed, and its execution is not affected by the vector-mask mode.

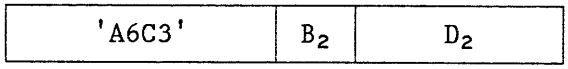
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2)
Operation
Privileged operation
Specification
Vector operation

RESTORE VMR

VMRRS $D_2(B_2)$ [S]



The second operand replaces the entire contents of the vector-mask register (VMR).

The length of the second operand is $4Z$ bits ($Z/2$ bytes), where Z is the section size. The contents of only the first Z bits are necessarily fetched and placed in the VMR; additional bits may or may not be fetched from the second operand, and access exceptions may or may not be recognized for that portion of the operand.

RESTORE VMR is a class-NZ instruction: it is not interruptible, the section size determines the number of elements processed, and its execution is not affected by the vector-mask mode. The vector count and vector interruption index are not used by the instruction and remain unchanged.

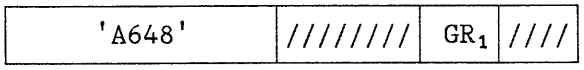
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2)
Operation
Vector operation

RESTORE VR

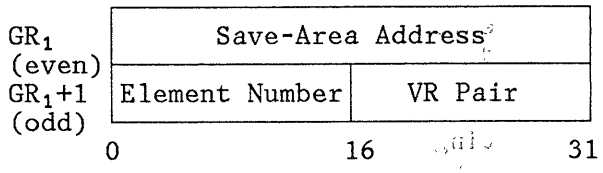
VRRS GR_1 [RRE]



If the vector in-use bit associated with a specified pair of vector registers is one, the contents of those vector registers are replaced by consecutive doublewords from a storage area called the save area of the vector-register pair. If the vector in-use bit is zero, the vector registers remain unchanged. In either case, the address of the save area is incremented to the location of the save area of the next pair of vector registers.

The GR_1 field must designate an even register number to specify an even-odd pair of general registers. The even general register contains a save-area address, which specifies the storage location of the first element pair in the save area. The odd general register contains two unsigned binary integers: bits 0-15 of the register contain an element number, which designates the location of the first element pair in the vector registers; bits 16-31 designate the vector-register (VR) pair.

Graphically, the general-register contents may be represented as follows:



Depending on the address size, the rightmost 31 or 24 bits of the contents of the even general register are used as the save-area address. When the general register is updated to the address of the next location, the leftmost one or eight bit positions, respectively, of the general register are set to zeros.

The instruction is interruptible. When an interruption occurs, the save-area-address and element-number fields have been updated to indicate the next element to be processed in the current save area and vector registers.

At the completion of the instruction, the save-area-address field is updated to the storage location of the next pair of vector registers, the element-number field is set to zero, and the VR-pair field is incremented by 2. If vector-register pair 14 was just restored, the VR-pair field is set to 16, and the save-area-address field is set to the next address following the end of the save area of vector-register pair 14.

At the start of execution, the VR-pair field must be an even number from 0 to 14, and the element-number field must be less than the section size; also, whether or not the storage location will be accessed, the starting address of the save area for the current VR pair must be on a boundary which is a multiple of 8 times the section size.

The starting addresses of the save areas for the current and next pair of vector registers are given in the following formulas:

```
SAC = SAF - 8*ENF
SAN = SAC + 8*SS
```

evaluated modulo the address size, where:

ENF Contents of the element-number field at the beginning of the operation (normally zero)

SAC Starting address of save area for the current VR pair

SAF Contents of the save-area-address field at the beginning of the operation

SAN Starting address of save area for the next VR pair

SS Section size

If the vector in-use bit examined was associated with vector-register pair 14 and 15, condition code 0 or 2 is set according to whether the bit was zero or one, respectively. If the vector in-use bit examined was associated with any other register pair, condition code 1 or 3 is set according to whether the bit was zero or one, respectively.

When the CPU is in the problem state, and the vector in-use bit of the specified pair of vector registers is one, execution of this instruction sets the vector change bit of the vector-register pair to one; execution in the supervisor state does not alter the vector change bits.

A specification exception is recognized when at the start of execution:

- The GR_1 field designates an odd register number.
- The starting address of the save area is not a multiple of 8 times the section size.
- The element number is equal to or greater than the section size.
- The VR-pair field contains other than an even number from 0 to 14.

RESTORE VR is a class-IZ instruction: it is interruptible, the section size and element-number field determine the number of elements processed, and its execution is not affected by the vector-mask mode. The vector count and vector interruption index are not used and remain unchanged.

Resulting Condition Code:

0 VRs 14 and 15 examined and not restored
1 VR pair other than 14 and 15 examined and not restored
2 VRs 14 and 15 restored
3 VR pair other than 14 and 15 restored

Program Exceptions:

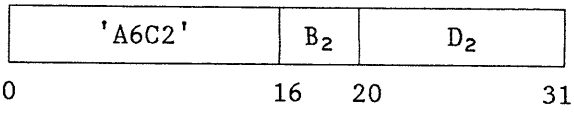
Access (fetch, save-area location)
Operation
Specification
Vector operation

Programming Note

See the section "Program Use of the Restore and Save Instructions" on page 2-28 for a discussion of the use of the instructions RESTORE VR, SAVE CHANGED VR, and SAVE VR.

RESTORE VSR

VSRRS $D_2(B_2)$ [S]



The contents of the vector-status register (VSR) are replaced by the doubleword designated by the second-operand address, and vector registers may be cleared depending on the vector in-use bits.

The vector in-use bits, bits 48-55 of the vector-status register, and the vector change bits, bits 56-63 of the register, are set in pairs sequentially from left to right, a vector in-use bit being set together with the corresponding vector change bit.

If the second operand specifies that a vector in-use bit is to be set to one, it is set to one. The setting of the corresponding vector change bit depends on whether the instruction is executed in the supervisor or problem state. If the vector in-use bit is set to one while in the supervisor state, the vector change bit is set to the value

specified by the second operand. If the vector in-use bit is set to one while in the problem state, the vector change bit is set to one, ignoring the second operand.

If the second operand specifies that a vector in-use bit is to be set to zero, the old setting of the vector in-use bit is first tested before it is changed. If the old setting was one, all element positions of the associated pair of vector registers are cleared to zeros, and both the vector in-use bit and the corresponding vector change bit are then set to zeros. If the old setting was zero, both the vector in-use bit and the corresponding vector change bit are simply set to zeros.

The instruction is interruptible. If it is interrupted before the operation is completed, the instruction address in the current PSW identifies this instruction. If the interrupted instruction is reissued, it is again executed from the beginning; vector-register pairs which were cleared and had their vector in-use bits and vector change bits set to zeros are not cleared again, provided that their vector in-use bits are still zeros.

A specification exception is recognized if any of the following is true:

- The second operand is not designated on a doubleword boundary.
- The value to be placed in bit positions 0-14 of the vector-status register is not all zeros.
- The value to be placed in the vector count, bits 16-31 of the vector-status register, is greater than the section size.
- The value to be placed in the vector interruption index, bits 32-47 of the vector-status register, is greater than the section size.

RESTORE VSR is a class-IZ instruction: it is interruptible, the section size determines the number of elements processed, and its execution is not affected by the vector-mask mode. The vector count and vector interruption index are loaded with values obtained from the second operand.

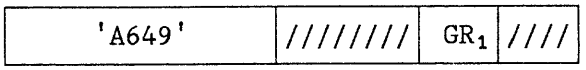
Condition Code: The code remains unchanged.

Program Exceptions:

Access (fetch, operand 2)
Operation
Specification
Vector operation

SAVE CHANGED VR

VRSVC GR_1 [RRE]



If the vector change bit associated with a specified pair of vector registers is one, the contents of those vector registers are placed in consecutive doublewords of a storage area called the save area of the vector-register pair, and the vector change bit is then set to zero. If the vector change bit is already zero, the vector registers are not stored. In either case, the address of the save area is incremented to the location of the save area of the next pair of vector registers.

If the vector change bit examined was associated with vector-register pair 14 and 15, condition code 0 or 2 is set according to whether the bit was zero or one, respectively. If the vector change bit examined was associated with any other register pair, condition code 1 or 3 is set according to whether the bit was zero or one, respectively.

The operand parameters and their updating are the same as for the instruction RESTORE VR.

A specification exception is recognized when at the start of execution:

- The GR_1 field designates an odd register number.
- The starting address of the save area is not a multiple of 8 times the section size.
- The element number is equal to or greater than the section size.

- The VR-pair field contains other than an even number from 0 to 14.

SAVE CHANGED VR is a class-IZ instruction: it is interruptible, the section size and element-number field determine the number of elements processed, and its execution is not affected by the vector-mask mode. The vector count and vector interruption index are not used and remain unchanged.

Resulting Condition Code:

0 VRs 14 and 15 examined and not saved
1 VR pair other than 14 and 15 examined and not saved
2 VRs 14 and 15 saved
3 VR pair other than 14 and 15 saved

Program Exceptions:

Access (store, save-area location)
Operation
Privileged operation
Specification
Vector operation

Programming Notes

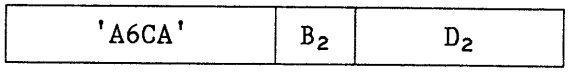
1. The operation is the same as for SAVE VR, except that the instruction is privileged, the vector change bit takes the place of the vector in-use bit, and the vector change bit is set to zero after a vector-register pair is saved. The effect is that a vector-register pair is saved only if it has been loaded or modified since the last use of SAVE CHANGED VR designating this pair.

   If the vector in-use bit is zero, the vector change bit is also zero, so that neither instruction will perform a save operation.

2. See the section "Program Use of the Restore and Save Instructions" on page 2-28 for a discussion of the use of the instructions RESTORE VR, SAVE CHANGED VR, and SAVE VR.

SAVE VAC

VACSV $D_2(B_2)$ [S]



The current value of the vector-activity count (VAC) is stored at the doubleword designated by the second-operand address. Execution of this instruction does not increment the vector-activity count and leaves its value unchanged.

The operand must be designated on a doubleword boundary; otherwise, a specification exception is recognized.

SAVE VAC is a class-NO instruction: it is not interruptible, no elements are processed, and its execution is not affected by the vector-mask mode.

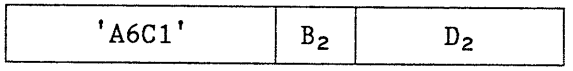
Condition Code: The code remains unchanged.

Program Exceptions:

Access (store, operand 2)
Operation
Privileged operation
Specification
Vector operation

SAVE VMR

VMRSV $D_2(B_2)$ [S]



The contents of the entire vector-mask register (VMR) are placed unchanged in storage at the second-operand location.

The length of the second operand is $4Z$ bits ($Z/2$ bytes), where Z is the section size. Only the first Z bits of the result are defined to be the VMR contents; the remaining $3Z$ bits of the result are undefined, and storing of that part of the result may or may not take place.

SAVE VMR is a class-NZ instruction: it is not interruptible, the section size determines the number of elements processed, and its execution is not affected by the vector-mask mode. The vector count and vector interruption index are not used and remain unchanged.

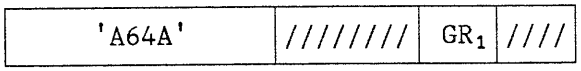
Condition Code: The code remains unchanged.

Program Exceptions:

Access (store, operand 2)
Operation
Vector operation

SAVE VR

VRSV GR_1 [RRE]



If the vector in-use bit associated with a specified pair of vector registers is one, the contents of those vector registers are placed in consecutive doublewords of a storage area called the save area of the vector-register pair. If the vector in-use bit is zero, the vector registers are not stored. In either case, the address of the save area is incremented to the location of the save area of the next pair of vector registers.

The operand parameters, their updating, and the condition-code setting are the same as for the instruction RESTORE VR.

A specification exception is recognized when at the start of execution:

- The GR_1 field designates an odd register number.
- The starting address of the save area is not a multiple of 8 times the section size.
- The element number is equal to or greater than the section size.
- The VR-pair field contains other than an even number from 0 to 14.

SAVE VR is a class-IZ instruction: it is interruptible, the section size and element-number field determine the number of elements processed, and its execution is not affected by the vector-mask mode. The vector count and vector interruption index are not used and remain unchanged.

Resulting Condition Code:

0 VRs 14 and 15 examined and not saved
1 VR pair other than 14 and 15 examined and not saved
2 VRs 14 and 15 saved
3 VR pair other than 14 and 15 saved

Program Exceptions:

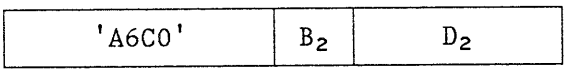
Access (store, save-area location)
Operation
Specification
Vector operation

Programming Note

See the section "Program Use of the Restore and Save Instructions" on page 2-28 for a discussion of the use of the instructions RESTORE VR, SAVE CHANGED VR, and SAVE VR.

SAVE VSR

VSRSV $D_2(B_2)$ [S]



The contents of the vector-status register (VSR) are placed in storage at the doubleword location designated by the second-operand address, except that, when the CPU is in the problem state, the value of the vector change bits stored by the instruction is undefined.

A specification exception is recognized when the second operand is not designated on a doubleword boundary.

SAVE VSR is a class-N0 instruction: it is not interruptible, no elements are processed, and its execution is not affected by the vector-mask mode.

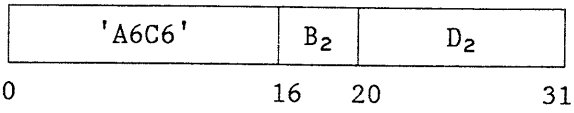
Condition Code: The code remains unchanged.

Program Exceptions:

Access (store, operand 2)
Operation
Specification
Vector operation

SET VECTOR MASK MODE

VSVMM $D_2(B_2)$ [S]



The vector-mask mode is set on or off, depending on whether the rightmost bit, bit 31, of the second-operand address is one or zero, respectively. The second-operand address is not used to address data, and all address bits other than bit 31 are ignored.

SET VECTOR MASK MODE is a class-NO instruction: it is not interruptible, no elements are processed, and its execution is not affected by the vector-mask mode.

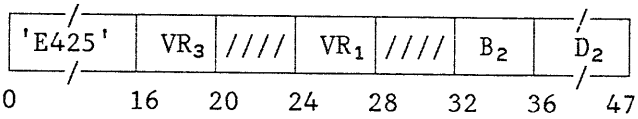
Condition Code: The code remains unchanged.

Program Exceptions:

Operation
Vector operation

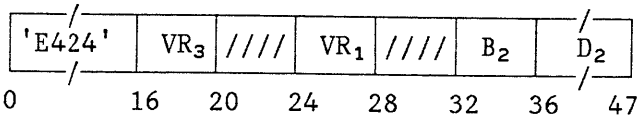
SHIFT LEFT SINGLE LOGICAL

VSLL $VR_1,VR_3,D_2(B_2)$ [RSE]



SHIFT RIGHT SINGLE LOGICAL

VSRL $VR_1,VR_3,D_2(B_2)$ [RSE]



One by one, the elements in the third-operand vector are shifted left (VSLL) or right (VSRL) by the number of bits specified by the second-operand address, and the result is placed in the first-operand location.

The operation is performed on each element in the same manner as the corresponding scalar operation.

SHIFT LEFT SINGLE LOGICAL and SHIFT RIGHT SINGLE LOGICAL are class-IM instructions: they are interruptible, the vector count and vector interruption index determine the number of elements processed, and their execution is under the control of the vector-mask mode.

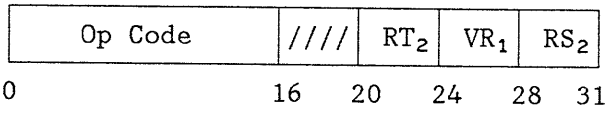
Condition Code: The code remains unchanged.

Program Exceptions:

Operation
Vector operation

STORE

Mnemonic $VR_1,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VST	'A40D'	Binary or logical
VSTD	'A41D'	Long
VSTE	'A40D'	Short

Element by element, the first-operand vector is placed unchanged in storage at the second-operand location.

A specification exception is recognized when the VR_1 field designates an invalid register number, when the second operand

is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

STORE is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

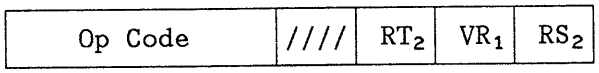
Condition Code: The code remains unchanged.

Program Exceptions:

Access (store, operand 2)
Operation
Specification
Vector operation

STORE COMPRESSED

Mnemonic $VR_1,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VSTK	'A40F'	Binary or logical
VSTKD	'A41F'	Long
VSTKE	'A40F'	Short

Element by element, elements of the first-operand vector corresponding to ones in the active bits of the vector-mask register are placed unchanged in storage at successive element locations of the second operand.

First-operand elements corresponding to zeros in the active bits of the vector-mask register are skipped, and there are no corresponding element locations of the second operand. If the active bits of the vector-mask register are all zeros, no access exceptions are recognized for the storage location specified by the second operand, the change bits for the storage operand remain unchanged, and no PER event for storage alteration is indicated.

A specification exception is recognized when the VR_1 field designates an invalid register number, when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

STORE COMPRESSED is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

Access (store, operand 2)
Operation
Specification
Vector operation

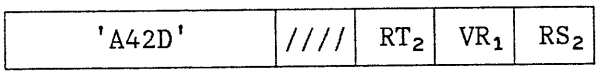
Programming Notes

1. The number of vector elements which are stored and the amount by which the address in the general register designated by RS_2 is updated correspond to the number of ones among the active bits of the vector-mask register.

2. The operation performed by STORE COMPRESSED is the opposite of LOAD EXPANDED.

STORE HALFWORD

VSTH $VR_1,RS_2(RT_2)$ [VST]



Element by element, the rightmost 16 bits of each first-operand vector element are placed unchanged in storage at the second-operand location.

A specification exception is recognized when the second operand is not designated on a halfword boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

STORE HALFWORD is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

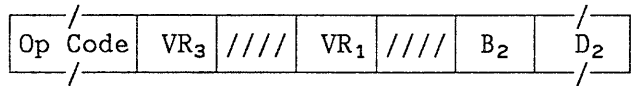
Condition Code: The code remains unchanged.

Program Exceptions:

Access (store, operand 2)
Operation
Specification
Vector operation

STORE INDIRECT

Mnemonic $VR_1,VR_3,D_2(B_2)$ [RSE]



Mnemonic	Op Code	Operands
VSTI	'E401'	Binary or logical
VSTID	'E411'	Long
VSTIE	'E401'	Short

Element by element, the third operand is used to select element locations of the second operand in storage, at which elements of the first-operand vector are placed. The element positions of the first operand correspond to those of the third operand.

The method of selecting elements of the first, second, and third operands is the same as for LOAD INDIRECT, the amount of left shift of the third-operand elements being two bits for VSTI or VSTIE and three bits for VSTID. The selected first-operand elements are stored at the specified second-operand locations.

A specification exception is recognized when the VR_1 field designates an invalid register number, or when the second operand is not designated on an integral boundary.

STORE INDIRECT is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

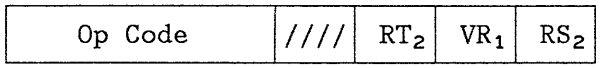
Access (store, operand 2)
Operation
Specification
Vector operation

Programming Note

STORE INDIRECT, which is the opposite of LOAD INDIRECT, is used to store a vector by indirect element selection. See also the programming note under LOAD INDIRECT.

STORE MATCHED

Mnemonic $VR_1,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VSTM	'A40E'	Binary or logical
VSTMD	'A41E'	Long
VSTME	'A40E'	Short

Element by element, elements of the first-operand vector corresponding to ones in the active bits of the vector-mask register are placed unchanged in storage at the corresponding element locations of the second operand. Elements of the first operand corresponding to zeros in the active bits of the vector-mask register are not stored, and the corresponding second-operand locations in storage remain unchanged.

A specification exception is recognized when the VR_1 field designates an invalid register number, when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field.

No access exceptions and PER storage-alteration events are recognized for

elements of the second operand which correspond to zeros in the active bits of the vector-mask register, and the corresponding change bits remain unchanged; however, the general register designated by the RS_2 field is updated for each of those elements.

STORE MATCHED is a class-IC instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

Access (store, operand 2)
Operation
Specification
Vector operation

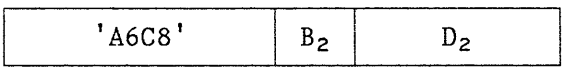
Programming Notes

1. STORE MATCHED functions the same as STORE for those elements which correspond to ones in the active bits of the vector-mask register: each such element is moved from the same vector-register position into the same storage location. It differs in that storage locations corresponding to zero bits remain unchanged.

2. STORE, STORE COMPRESSED, and STORE MATCHED function the same, for corresponding formats, when all active bit positions of the vector-mask register contain ones.

STORE VECTOR PARAMETERS

VSTVP $D_2(B_2)$ [S]



The 16-bit section size and the 16-bit partial-sum number are placed in storage in the left and right half, respectively, of the word at the location designated by the second-operand address.

A specification exception is recognized when the second operand is not designated on a word boundary.

STORE VECTOR PARAMETERS is a class-NO instruction: it is not interruptible, no elements are processed, and its execution is not affected by the vector-mask mode.

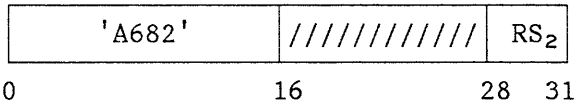
Condition Code: The code remains unchanged.

Program Exceptions:

Access (store, operand 2)
Operation
Specification
Vector operation

STORE VMR

VSTVM RS_2 [VS]



The contents of the active-bit positions of the vector-mask register are stored as a bit vector at the second-operand location.

When the vector count is not a multiple of 8, zeros are stored for any bits in the last byte which are to the right of the last bit specified by the vector count.

When the vector count is zero, no bits are stored. No access exceptions are recognized for the second operand, the change bits for the operand remain unchanged, and PER storage-alteration events are not indicated.

STORE VMR is a class-NC instruction: it is not interruptible, the vector count determines the number of elements processed, and its execution is not affected by the vector-mask mode.

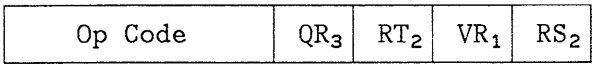
Condition Code: The code remains unchanged.

Program Exceptions:

Access (store, operand 2)
Operation
Vector operation

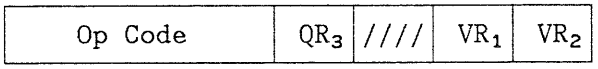
SUBTRACT

Mnemonic $VR_1,QR_3,RS_2(RT_2)$ [QST]



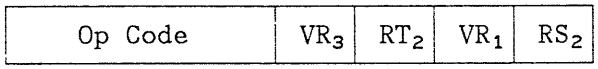
Mnemonic	Op Code	Operands
VSS	'A4A1'	Binary
VSDS	'A491'	Long
VSES	'A481'	Short

Mnemonic VR_1,QR_3,VR_2 [QV]



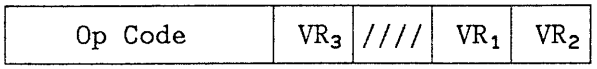
Mnemonic	Op Code	Operands
VSQ	'A5A1'	Binary
VSDQ	'A591'	Long
VSEQ	'A581'	Short

Mnemonic $VR_1,VR_3,RS_2(RT_2)$ [VST]



Mnemonic	Op Code	Operands
VS	'A421'	Binary
VSD	'A411'	Long
VSE	'A401'	Short

Mnemonic VR_1,VR_3,VR_2 [VV]



Mnemonic	Op Code	Operands
VSR	'A521'	Binary
VSDR	'A511'	Long
VSER	'A501'	Short

Element by element, the second-operand vector is subtracted from the third operand, and the result is placed in the first-operand location.

The operation is performed on each pair of elements in the same manner as the corresponding scalar operation, except that the condition code is not set. For floating-point operands, the scalar equivalent is SUBTRACT NORMALIZED.

A specification exception is recognized when a VR or QR field designates an invalid register number. In the QST and VST formats, a specification exception is recognized when the second operand is not designated on an integral boundary, or when the RT_2 field is nonzero and designates the same general register as the RS_2 field. For the VSS instruction, a specification exception is also recognized when the QR_3 field designates the same general register as the RS_2 field.

SUBTRACT is a class-IM instruction: it is interruptible, the vector count and vector interruption index determine the number of elements processed, and its execution is under the control of the vector-mask mode.

Condition Code: The code remains unchanged.

Program Exceptions:

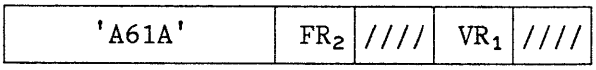
Access (fetch, operand 2 in QST and VST formats)
Exponent overflow (with exception-extension code; floating-point operands only)
Exponent underflow (with exception-extension code; floating-point operands only)
Fixed-point overflow (with exception-extension code; binary operands only)
Operation
Significance (with exception-extension code; floating-point operands only)
Specification
Vector operation

Programming Note

The QST and QV formats provide for subtracting a vector from a scalar operand. The operation of subtracting a scalar from a vector can be replaced by adding the negative of the scalar to the vector operand.

SUM PARTIAL SUMS

VSPSD VR_1,FR_2 [VR, Long Operands]



Partial-sum elements of the first-operand vector are added to the scalar second operand, the result replacing the second operand.

The operand elements are floating-point numbers in the long format, and every addition is performed in the same manner as for the scalar ADD NORMALIZED (ADR) instruction, except that the condition code is not set. The operation begins with adding element *X* of the first operand to the second operand, where *X* is the initial vector interruption index (normally zero). It proceeds in an ascending sequence of element numbers by successively adding *p-X* first-operand elements, where *p* is the model-dependent partial-sum number. The last one to be added is element *p*-1. The vector interruption index is then set to zero.

If the initial vector interruption index *X* is equal to or greater than *p*, no elements are processed, and the scalar second operand remains unchanged. The vector interruption index is set to zero, and instruction execution is completed.

A specification exception is recognized when the VR_1 or FR_2 field designates an invalid register number.

SUM PARTIAL SUMS is a class-IP instruction: it is interruptible, the partial-sum number and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode. The vector count is not used and remains unchanged.

Condition Code: The code remains unchanged.

Program Exceptions:

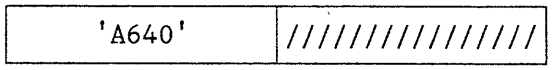
Exponent overflow (with exception-extension code)
Exponent underflow (with exception-extension code)
Operation
Significance (with exception-extension code)
Specification
Vector operation

Programming Note

An example of the use of SUM PARTIAL SUMS is given in Appendix A (see "Sum of Products" on page A-3).

TEST VMR

VTVM [RRE]



The active bits of the vector-mask register are tested, and condition code 0, 1, or 3 is set according to whether those bits are all zeros, mixed zeros and ones, or all ones.

When the vector count is zero, condition code 0 is set.

TEST VMR is a class-NC instruction: it is not interruptible, the vector count determines the number of elements processed, and its execution is not affected by the vector-mask mode.

Resulting Condition Code:

0 Active bits all zeros
1 Active bits mixed zeros and ones
2 --
3 Active bits all ones

Program Exceptions:

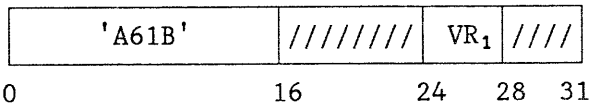
Operation
Vector operation

Programming Note

The instruction TEST VMR performs the testing portion of the instructions COUNT LEFT ZEROS IN VMR and COUNT ONES IN VMR. It may be used to distinguish the all-zeros and all-ones conditions when the exact count is not required.

ZERO PARTIAL SUMS

VZPSD VR_1 [VR]



Partial-sum element locations of the vector-register pair designated by VR_1 are set to zero.

The operation begins with setting to zero element *X* of the first operand, where *X* is the initial vector interruption index (normally zero). It proceeds in an ascending sequence of element numbers by successively setting to zero *p-X* first-operand elements, where *p* is the model-dependent partial-sum number. The last one is element *p*-1. The vector interruption index is then set to zero.

If the initial vector interruption index *X* is equal to or greater than *p*, the vector-register contents and the associated vector in-use bit and vector change bit remain unchanged. The vector interruption index is set to zero, and instruction execution is completed.

A specification exception is recognized if the VR_1 field designates an invalid register number.

ZERO PARTIAL SUMS is a class-IP instruction: it is interruptible, the partial-sum number and vector interruption index determine the number of elements processed, and its execution is not affected by the vector-mask mode. The vector count is not used by the instruction and remains unchanged.

Condition Code: The code remains unchanged.

Program Exceptions:

Operation
Specification
Vector operation

Programming Note

An example of the use of ZERO PARTIAL SUMS is given in Appendix A (see "Sum of Products" on page A-3).

APPENDIX A. INSTRUCTION-USE EXAMPLES

This appendix contains a number of simple examples of the use of vector instructions.

Every example has a sectioning loop, so that vectors of any length can be handled, independent of the section size. The first example illustrates sectioning in some detail; the others use the same or a similar technique.

The examples are written in assembler language. Register operands are indicated symbolically with a prefix G, F, or V to identify more clearly whether an operand refers to a general register, floating-point register, or vector register, respectively.

Comments are written to the right of the instruction or on separate lines that begin with an asterisk (*).

OPERATIONS ON FULL VECTORS

The following examples illustrate operations on full vectors, where both zero and nonzero elements are represented in storage. Vectors in storage are accessed by sequential addressing.

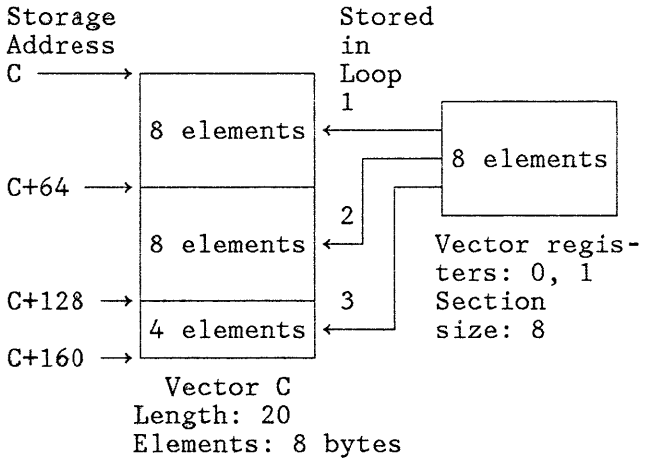
The first three examples use three different methods of controlling the sectioning loop.

Contiguous Vectors

Two contiguous vectors *A* and *B* in storage are added, and the result is stored in contiguous vector *C*. The number of elements in each is specified by *N*. All vectors are in the long floating-point format.

```
*          C = A + B
*
     L     G0,N       Vector length to GR0
     LA    G1,A       Address of A to GR1
     LA    G2,B       Address of B to GR2
     LA    G3,C       Address of C to GR3
LP   VLVCU G0         Load VCT, update GR0
     VLD   V0,G1      Load section of A
     VAD   V0,V0,G2   Add section of B
     VSTD  V0,G3      Store section in C
     BC    2,LP       Test condition code
*                     set by VLVCU, branch
*                     if not last section
```

Assuming, for purposes of illustration, a vector-section size of 8 and a vector length of 20, the above program would process three sections in turn (two full sections of eight elements and one partial section of four elements) before ending the loop. One section of *A* and one section of *B* are added in vector-register pair 0 and 1. The result is stored in a section of *C*, as illustrated below:



Since all vectors are stored contiguously, the stride for the three vector instructions VLD, VAD, and VSTD is set to one by specifying a value of zero in the RT_2 subfield. This may be done in

the assembler language either by placing a zero inside the parentheses of the stride subfield, as in:

Mnemonic $VR_1,VR_3,RS_2(0)$

or by omitting the subfield, including the parentheses, altogether:

Mnemonic VR_1,VR_3,RS_2

Each of these instructions automatically updates the storage address in the designated general register to the value that will be needed for the next time, if any, around the loop.

The BRANCH ON CONDITION (BC) instruction tests the condition code set by VLVCU, because none of the intervening instructions change the condition code. If an instruction setting the condition code had intervened, the instruction "LTR G0,G0" inserted before the BC instruction would test the contents of GR0; BC would test for condition code 2 in either case.

The following figure shows the condition-code setting (CC), the vector count (VCT), and the contents of the general registers at the start, before executing the first VLVCU instruction, and at the end of each loop thereafter.

Loop	CC	VCT	GR0	GR1	GR2	GR3
Start	-	-	20	A	B	C
End 1	2	8	12	A+64	B+64	C+64
End 2	2	8	4	A+128	B+128	C+128
End 3	3	4	0	A+160	B+160	C+160

Vectors with Stride

This example modifies the previous example in four ways. All vector elements are in the short floating-point format. The result of the addition is returned to the storage location of vector *B*. Vector *B* is assumed to be stored with a stride *T*. Finally, a BC instruction which tests for the end of the loop is placed immediately after the VLVCU instruction, and the loop is closed with an unconditional branch. This method, which could be used if additional instructions were to change the condition code later in the loop, allows the loop to be bypassed when the initial vector count is zero. (Note, however, that the previous loop control also works with a vector count of zero, because no elements would be processed if vector instructions were executed with a zero vector count.)

```
*          B = A + B
*
    L      G0,N       Vector length to GR0
    LA     G1,A       Address of A to GR1
    LA     G2,B       Address of B to GR2
    LR     G3,G2      Copy address in GR3
    L      G4,T       Stride for B to GR4
LP  VLVCU  G0         Load VCT, update GR0
    BC     12,NXT     Exit loop if VCT=0
    VLE    V0,G1      Load section of A
    VAE    V0,V0,G2(G4)
*                     Add section of B
    VSTE   V0,G3(G4)  Return section to B
    BC     15,LP      Branch to loop start
NXT Next instruction
```

Two registers, GR2 and GR3, are used to specify the current address of *B*, so that the two instructions VAE and VSTE in the sectioning loop will refer to the same section. Each of the two instructions updates its separate copy of the address. (If a vector in storage is referred to more than twice within a sectioning loop, the address could be copied inside the loop for each use except the last, so as to reduce the number of general registers needed.)

Vector and Scalar Operands

This example illustrates the use of both vector and scalar operands. It also shows how the three-operand arithmetic vector instructions can sometimes be used to avoid a separate vector-load instruction. A third loop-control method is used here.

A and *B* are vectors of length *N*, and *S* is a scalar. All are in the long floating-point format.

```
*          B = A * (S-A)
*
     L     G0,N       Vector length to GR0
     LA    G1,A       Address of A to GR1
     LR    G2,G1      Copy address in GR2
     LA    G3,B       Address of B to GR3
     LD    F0,S       Load S into FR0
     VLVCU G0         Load VCT, update GR0
LP   VSDS  V0,F0,G1   Compute S-A
     VMD   V0,V0,G2   Compute A*(S-A)
     VSTD  V0,G3      Store result in B
     VLVCU G0         Load VCT, update GR0
     BC    3,LP       Branch back if VCT>0
```

The VSDS instruction subtracts vector *A* in storage from the scalar *S*. VMD multiplies the result by vector *A*, again from its storage location. VSTD stores the product as *B*. There are two VLVCU loop-control instructions, one before entry into the loop and one at the end.

Note that the QST-format arithmetic instruction (VSDS) saves a separate load instruction at the expense of having to access storage twice for the same vector section *A*. Depending on the model, a separate load instruction followed by QV-format arithmetic instructions may be more efficient in some circumstances, particularly when the stride is greater than one.

Note further that the QST-format instructions are defined such that VSDS subtracts a vector from a scalar (*S-V*). Subtracting a scalar from a vector (*V-S*) can be done conveniently by first changing the sign of the scalar and then adding, using VADS. Similarly, the VDDS instruction divides a scalar by a vector (*S/V*). Division of a vector by a scalar (*V/S*) can be performed by first taking the reciprocal of the scalar and then multiplying, using VMDS. (The same comment applies to the corresponding QV-format instructions.)

Sum of Products

The use of MULTIPLY AND ACCUMULATE and related instructions is illustrated by computing the inner product of a row vector *A*, taken from a matrix of dimensions *I* by *J*, and a column vector *B*, taken from another matrix of dimensions *J* by *K*. Each matrix is assumed to be stored in column order. Therefore, row vector *A* has a stride *I* and a length *J*, and column vector *B* is contiguous and has the same length *J*. The inner product of the two vectors is a scalar value that is the sum of the element-by-element products of vectors *A* and *B*; it is stored at address *C*.

```
*          C = SUM (A * B)
*
     L     G0,J       Vector length to GR0
     LA    G1,A       Address of A to GR1
     L     G2,I       Stride for A to GR2
     LA    G3,B       Address of B to GR3
     VZPSD V0         Zero partial sums
LP   VLVCU G0         Load VCT, update GR0
     VLD   V2,G1(G2)  Row A section to VR2
     VMCD  V0,V2,G3   Multiply by column B
*                     partial sums to VR0
     BC    2,LP       Branch back if GR0>0
     SDR   F0,F0      Clear FR0 to zero
     VSPSD V0,F0      Scalar sum to FR0
     STD   F0,C       Store scalar sum
```

First the VZPSD instruction clears the partial-sum locations in VR0 to zero. Then the sectioning loop accumulates partial sums: The VLD instruction loads a section of row *A* (with stride) into VR2. The VMCD instruction multiplies the elements of row *A* in VR2 by elements of column *B* in storage (without stride) and accumulates *p* partial sums in VR0; the number *p* depends on the model.

After the sectioning loop is ended and all partial sums have been accumulated in VR0, FR0 is cleared by means of SDR, and the *p* partial sums are then added to FR0 by use of the VSPSD instruction. The scalar sum is stored in *C* by STD.

Note that the program is independent of the vector-section size and the number of partial sums, both of which depend on the model, because the instructions VZPSD, VLVCU, VMCD, and VSPSD take care of these dependencies automatically.

Compare and Swap Vector Elements

Two vectors *A* and *B*, both of length *N*, are to be compared and their elements swapped so that vector *A* will have the smaller element of each pair and vector *B* the larger. The elements are 32-bit signed binary integers and stored contiguously.

```
     L      G0,N       Vector length to GR0
     LA     G1,A       Address of A to GR1
     LR     G2,G1      Copy address in GR2
     LA     G3,B       Address of B to GR3
     LR     G4,G3      Copy address in GR4
LP   VLVCU  G0         Load VCT, update GR0
     VL     V0,G1      Section of A to VR0
     VL     V1,G3      Section of B to VR1
     VCR    2,V0,V1    Check where A>B
     VSTM   V0,G4      Store greater in B
     VSTM   V1,G2      Store lesser in A
     BC     2,LP       Branch back if GR0>0
```

```
*          C = A / B
*
     L      G0,N       Vector length to GR0
     LA     G1,A       Address of A to GR1
     LA     G2,B       Address of B to GR2
     LR     G3,G2      Copy address in GR3
     LA     G4,C       Address of C to GR4
     SDR    F0,F0      Clear FR0 to zero
     LD     F2,MP      Load max. positive
*                      number MP in FR2
     VSVMM  1          Vector-mask mode on
LP   VLVCU  G0         Load VCT, update GR0
     VCDS   6,F0,G2     Compare section of B
*                      not equal to zero
     VLDQ   V0,F2       Load MP in all elem.
*                      positions of VR0
     VLD    V2,G1       Load section of A
     VDD    V0,V2,G3    Conditionally divide
*                      A by section of B
     VSTD   V0,G4       Store section in C
     BC     2,LP        Branch back if GR0>0
     VSVMM  0           Set mask mode off
```

CONDITIONAL ARITHMETIC

Exception Avoidance

One use of conditional arithmetic in the vector-mask mode is to bypass vector elements which would cause an exception during the arithmetic operation and to provide a predetermined alternate result for those elements. The example divides two vectors *A* and *B*. The divisor *B* is tested for zeros. By using the vector-mask mode, no division is performed for zero divisor elements, thus avoiding a disruptive floating-point-divide exception; the corresponding elements in result vector *C* are set to the maximum positive value *MP*. All floating-point numbers are in the long format.

In this example, performing the arithmetic conditionally requires two extra vector instructions inside the sectioning loop.

Add to Magnitude

Another use of conditional arithmetic is to perform addition to the magnitude of a vector regardless of signs. This may be illustrated by rounding a vector *V* of length *N*, consisting of floating-point numbers in the short format, to integer values. First, 0.5 is added to the magnitude of each element. Then, the digits to the right of the implied radix point are truncated. The rounded vector *R* remains in the short floating-point format.

Let *H* and *Z* be constants with the following hexadecimal formats and values:

H = 40 80 00 00 = 0.5
Z = 47 00 00 00 = 0 (unnormalized)

H is the value which is to be added to or subtracted from each vector element, depending on its sign.

The constant *Z* is an unnormalized zero with such a characteristic that its addition to a short floating-point number having a smaller characteristic forces that number to be shifted to the right, placing the units digit in the guard-digit position. This causes any digits to the right of the implied radix point to be truncated and the result to

be normalized. Any number with an equal or larger characteristic has no significant digits to the right of the implied radix point and remains unchanged.

```
*            R = ROUND(V)
*
     L      G0,N        Vector length to GR0
     LA     G1,V        Address of V to GR1
     LA     G2,R        Address of R to GR2
     SDR    F0,F0       Clear FR0 to zero
     LE     F2,H        Load H into FR2
     LNER   F4,F2       Load -H into FR4
     LE     F6,Z        Load Z into FR6
LP   VLVCU  G0          Load VCT, update GR0
     VLE    V0,G1       Load section of V
     VSVMM  1           Vector-mask mode on
     VCEQ   12,F0,V0    Compare; set mask to
*                       one where 0≤V
     VAEQ   V0,F2,V0    Add 0.5 under mask
     VCVM               Complement mask bits
     VAEQ   V0,F4,V0    Add -0.5 under mask
     VSVMM  0           Vector-mask mode off
     VAEQ   V0,F6,V0    Add Z
     VSTE   V0,G2       Store section of R
     BC     2,LP        Branch back if GR0>0
```

A variation of this rounding technique is incorporated in a later example of floating-point to fixed-point conversion.

OPERATIONS ON SPARSE VECTORS

This section gives some examples of operating on sparse vectors, where only nonzero elements are directly represented in storage.

When many vector elements are zero, considerable storage may be saved by using a dense representation containing only those elements which are nonzero. The resulting nonzero elements can be stored in contiguous locations along with a bit vector indicating the nonzero values in the corresponding full vector. A full vector can be converted to such a dense vector by performing a not-equal comparison of the vector to a scalar zero and using the resulting bit vector as a mask in a STORE COMPRESSED instruction.

For use in the following examples, assume two vectors *A* and *B*. The full vectors are 10 elements in length; elements 0, 2, 5, 6, 7, and 9 of vector *A* are nonzero; and elements 2, 4, 5, and 7 of vector *B* are nonzero. The figures show the full vectors, the result of a not-equal comparison to zero, and the dense vectors for *A* and *B*.

Full Vector *A* (*AF*):

A0	A1	A2	A3	A4	A5	A6	A7	A8	A9

Result of comparing *A* ≠ 0 (mask *AM*):

1 0 1 0 0 1 1 1 0 1

Dense Vector *A* (*AD*):

A0	A2	A5	A6	A7	A9

Full Vector *B* (*BF*):

B0	B1	B2	B3	B4	B5	B6	B7	B8	B9

Result of comparing *B* ≠ 0 (mask *BM*):

0 0 1 0 1 1 0 1 0 0

Dense Vector *B* (*BD*):

B2	B4	B5	B7

Full Added to Sparse to Give Full

This example shows the addition of elements of full vector *BF*, which correspond to nonzero elements of vector *A*, to dense vector *AD*. The result elements are replaced in *BF*. The length of the full vectors is *N*, which is also the number of bits in the mask.

```
     LA     G0,AD       Address of AD to GR0
     SR     G2,G2       Clear bit index, GR2
     L      G3,N        Set bit count N, GR3
LP   VLBIX  V0,G2,AM    Convert mask AM to
*                       element numbers, VR0
     VLID   V2,V0,BF     Load BF indirectly
     VAD    V2,V2,G0     Add AD contiguously
     VSTID  V2,V0,BF     Store indirectly
     BC     2,LP         Branch back if GR3>0
```

The VLBIX instruction converts the bit mask *AM* to a vector of element numbers, using the general-register pair GR2 and GR3 as the bit index and bit count. This instruction creates up to a full section of element numbers in VR0 and places the corresponding vector count in VCT for use by subsequent vector instructions. GR2 and GR3 are updated for the next pass through the loop. VLID uses the generated element numbers to select elements of full *BF* to correspond to all the elements of dense *AD*, which are added together by the instruction VAD. VSTID then stores the results back into the same elements of *BF*. The BC instruction tests the condition code set by VLBIX and branches back if there are more bits to be processed.

Sparse Added to Sparse to Give Sparse

The following example adds dense vectors *AD* and *BD* to obtain dense vector *CD*. The mask for *CD* is obtained by ORing the mask for *AD* with the mask for *BD*, using the instruction OR TO VMR.

```
    LA     G0,AD       Address of AD to GR0
    LA     G1,BD       Address of BD to GR1
    LA     G2,CD       Address of CD to GR2
    LA     G3,AM       Address of AM to GR3
    LR     G4,G3       Copy address in GR4
    LA     G5,BM       Address of BM to GR5
    LA     G6,CM       Address of CM to GR6
    L      G7,N        Length of full
*                      vectors to GR7
LP  VLVCU  G7          Load VCT, update GR7
    VLVM   G3          Load mask AM in VMR
    VLZDR  V0          Zeros into VR0, VR1
    VLYD   V0,G0       Load AD expanded: AF
    VLVM   G5          Load mask BM in VMR
    VLZDR  V2          Zeros into VR2, VR3
    VLYD   V2,G1       Load BD expanded: BF
    VADR   V0,V0,V2    Add BF to AF
    VOVM   G4          or mask AM into VMR
    VSTKD  V0,G2       Store compressed: CD
    VSTVM  G6          Store VMR as mask CM
    BC     2,LP        Branch back if GR7>0
```

FLOATING-POINT-VECTOR CONVERSIONS

The conversion techniques illustrated here are similar to the scalar examples in *IBM 370-XA Principles of Operation* and *IBM System/370 Principles of Operation* which may be consulted for more details. The methods differ, however, because of different characteristics of the vector-instruction set.

Fixed Point to Floating Point

Assume a vector *K* of length *N* in storage, the elements of which are 32-bit signed binary integers. The elements are to be converted to floating-point numbers in the long format, and the result is to be stored as vector *W*.

Assume a floating-point constant *C* in storage with the following hexadecimal format and value:

$$C = \text{CE 00 00 00 80 00 00 00} = -2^{31}$$

This is an unnormalized floating-point number in the long format with the characteristic 4E, which is the proper characteristic for a right-aligned, unnormalized integer.

```
    LA     G0,K        Address of K to GR0
    LA     G1,W        Address of W to GR1
    L      G2,N        Vector length to GR2
    LD     F0,C        Load C into FR0
LP  VLVCU  G2          Load VCT, update GR2
    VL     V1,G0       Load K into VR1
    VLCER  V1,V1       K + 2**31
    VLEQ   V0,F0       V = -(K + 2**31)
    VSDQ   V0,F0,V0    W = -2**31 - V
    VSTD   V0,G1       Store W
    BC     2,LP        Branch back if GR2>0
```

Inside the sectioning loop, the VLCER instruction (LOAD COMPLEMENT in short floating-point format) inverts the sign bit, bit 0, of each element in VR1, without altering bits 1-31. Considering these elements still as signed binary integers, the operation is equivalent to adding 2^{31} to each, ignoring overflow, which changes all elements into positive numbers in the range 0 to $2^{32}-1$. The VLEQ instruction places the left half of

the constant *C* into each element position of VR0, which has the effect of converting the contents of VR1 to a vector *V* of negative unnormalized floating-point numbers in the long format, occupying VR0 and VR1.

The next instruction, VSDQ, subtracts *V* from the entire constant *C*, which is equivalent to subtracting 2^{31} from the original elements, thus restoring them to the range -2^{31} to $2^{31}-1$. The elements are normalized during this operation.

The next example presents an alternate program, the loop of which is shorter by one vector instruction.

```
    LA     G0,K       Address of K to GR0
    LA     G1,W       Address of W to GR1
    L      G2,N       Vector length to GR2
    LD     F0,C       Load C into FR0
LP  VLVCU  G2         Load VCT, update GR2
    VLDQ   V0,F0      Load C into VR0, VR1
    VX     V1,V1,G0   V = -(K+2**31)
    VSDQ   V0,F0,V0   W = -2**31 - V
    VSTD   V0,G1      Store W
    BC     2,LP       Branch back if GR2>0
```

The VLDQ instruction loads the entire constant *C* into VR0 and VR1. Then, the VX instruction fetches the elements of *K* from storage and EXCLUSIVE ORs them into VR1, which contained a leftmost one followed by 31 zeros. This inverts the sign bit, as did VLCER in the previous example. The rest of the program is the same.

Floating Point to Fixed Point

This example combines conversion from floating to fixed point with a variation of the rounding technique shown in a previous example.

```
* Start of range test
    LA     G0,W       Address of W to GR0
    LR     G1,G0      Copy address to GR1
    L      G2,N       Vector length to GR2
    LD     F0,L       FR0: upper limit L
    LNDR   F2,F0      FR2: lower limit -L
LP1 VLVCU  G2         Load VCT, update GR2
    VCDS   12,F0,G0   Compare L and W; set
*                     mask bit to one when
*                     L is equal or low
    VTVM              Test mask bits
    BC     5,OVFLO    Exit if any ones
    VCDS   2,F2,G1    Compare -L and W;
*                     set mask bit to one
*                     when -L is high
    VTVM              Test mask bits
    BC     5,OVFLO    Exit if any ones
    LTR    G2,G2      Test residual count
    BC     2,LP1      Branch back if GR2>0
* Start of conversion with rounding
    LA     G0,W       Address of W to GR0
    LA     G1,K       Address of K to GR1
    L      G2,N       Vector length to GR2
    LD     F0,G       Load G into FR0
    LD     F2,H       Load H into FR2
    LD     F4,M       Load M into FR4
LP2 VLVCU  G2         Load VCT, update GR2
    VADS   V0,F2,G0   Add 0.5 to W section
    VSVMM  1          Vector-mask mode on
    VCDQ   2,F2,V0    Compare; set mask to
*                     one where 0.5>W
    VADQ   V0,F4,V0   Add -1.0 under mask
    VSVMM  0          Set mask mode off
    VADQ   V0,F0,V0   Add 2**53
    VST    V1,G1      Store K from VR1
    BC     2,LP2      Branch back if GR2>0
```

Assume a vector *W* of length *N* in storage, the elements of which are floating-point numbers in the long format. Assume this vector is to be converted to a vector of signed binary integers, and the result is to be stored as vector *K*. Assume floating-point constants in storage with the following names, hexadecimal formats, and values:

L = 48 80 00 00 00 00 00 00 = 2^{31}
G = 4F 02 00 00 00 00 00 00 = 2^{53}
H = 40 80 00 00 00 00 00 00 = 0.5
M = C1 10 00 00 00 00 00 00 = -1.0

L is the upper limit of the range of numbers which, after truncation of the fractional part, are representable as signed binary integers. Vector *W* is compared with this limit in a separate

sectioning loop before conversion is started, so that nothing is stored if any element of *W* is out of range. This comparison loop can be omitted if all elements are known to be within range.

H and *M* are the constants 0.5 and -1.0, respectively. Rounding is accomplished by first adding 0.5 unconditionally to vector *W*, and then adding -1.0 conditionally where the elements are now less than 0.5, which is equivalent to subtracting 0.5 from all initially negative elements.

The constant *G* is chosen such that its addition to a number within the representable range forces that number to be shifted to the right, with the units digit in the guard-digit position, and the result to be normalized to the left by one digit position. This causes any fraction part to be truncated, leaving the rounded integer part in the right half of the vector-register pair.

APPENDIX B. LISTS OF INSTRUCTIONS

The following figures list the vector instructions by name, mnemonic, and op code.

Explanation of Symbols in "Characteristics" Column

- A Access exceptions
- C Condition code is set
- EO Exponent-overflow exception
- EU Exponent-underflow exception
- FK Floating-point-divide exception
- IC Class-IC instruction; interruptible; vector count and vector interruption index determine number of elements processed; does not depend on vector-mask mode
- IF Fixed-point-overflow exception
- IG Class-IG instruction; interruptible; general register, vector interruption index, and section size determine number of elements processed; sets vector count; does not depend on vector-mask mode
- IM Class-IM instruction; interruptible; vector count and vector interruption index determine number of elements processed; depends on vector-mask mode
- IP Class-IP instruction; interruptible; partial-sum number and vector interruption index determine number of elements processed; does not depend on vector-mask mode
- IZ Class-IZ instruction; interruptible; vector-section size determines number of elements processed; does not depend on vector-mask mode
- J Arithmetic exception; exception-extension code is stored
- LS Significance exception
- NC Class-NC instruction; not interruptible; vector count determines number of elements processed; does not depend on vector-mask mode
- NZ Class-NZ instruction; not interruptible; vector-section size determines number of elements processed; does not depend on vector-mask mode
- N0 Class-N0 instruction; not interruptible; no vector elements processed; does not depend on vector-mask mode
- N1 Class-N1 instruction; not interruptible; one vector element processed; does not depend on vector-mask mode
- P Privileged-operation exception
- QST QST instruction format
- QV QV instruction format
- R* PER general-register-alteration event may or may not be recognized
- RRE RRE instruction format
- RSE RSE instruction format
- S S instruction format
- SP Specification exception
- ST PER storage-alteration event
- U Unnormalized-operand exception
- VB Sets vector in-use bit and vector change bit
- VE Vector facility and vector-operation exception
- VH Sets vector change bit
- VR VR instruction format
- VS VS instruction format
- VST VST instruction format
- VU Leaves vector change bit unaltered
- VV VV instruction format

Notes

1. Same op code as for short; separate mnemonic for programming convenience
2. Execution differs in problem state and supervisor state

Name	Mnemonic	Characteristics					Op Code
ACCUMULATE (long)	VACD	VST VE	A SP	J EU EO LS IM VB	R*		A417
ACCUMULATE (long)	VACDR	VV VE	SP	J EU EO LS IM VB			A517
ACCUMULATE (short to long)	VACE	VST VE	A SP	J EU EO LS IM VB	R*		A407
ACCUMULATE (short to long)	VACER	VV VE	SP	J EU EO LS IM VB			A507
ADD (binary)	VA	VST VE	A SP	J IF IM VB	R*		A420
ADD (binary)	VAQ	QV VE		J IF IM VB			A5A0
ADD (binary)	VAR	VV VE		J IF IM VB			A520
ADD (binary)	VAS	QST VE	A SP	J IF IM VB	R*		A4A0
ADD (long)	VAD	VST VE	A SP	J EU EO LS IM VB	R*		A410
ADD (long)	VADQ	QV VE	SP	J EU EO LS IM VB			A590
ADD (long)	VADR	VV VE	SP	J EU EO LS IM VB			A510
ADD (long)	VADS	QST VE	A SP	J EU EO LS IM VB	R*		A490
ADD (short)	VAE	VST VE	A SP	J EU EO LS IM VB	R*		A400
ADD (short)	VAEQ	QV VE	SP	J EU EO LS IM VB			A580
ADD (short)	VAER	VV VE		J EU EO LS IM VB			A500
ADD (short)	VAES	QST VE	A SP	J EU EO LS IM VB	R*		A480
AND	VN	VST VE	A SP	IM VB	R*		A424
AND	VNQ	QV VE		IM VB			A5A4
AND	VNR	VV VE		IM VB			A524
AND	VNS	QST VE	A SP	IM VB	R*		A4A4
AND TO VMR	VNVM	VS VE	A	NC	R*		A684
CLEAR VR	VRCL	S VE		IZ VB			A6C5
COMPARE (binary)	VC	VST VE	A SP	IC	R*		A428
COMPARE (binary)	VCQ	QV VE		IC			A5A8
COMPARE (binary)	VCR	VV VE		IC			A528
COMPARE (binary)	VCS	QST VE	A SP	IC	R*		A4A8
COMPARE (long)	VCD	VST VE	A SP	IC	R*		A418
COMPARE (long)	VCDQ	QV VE	SP	IC			A598
COMPARE (long)	VCDR	VV VE	SP	IC			A518
COMPARE (long)	VCDS	QST VE	A SP	IC	R*		A498
COMPARE (short)	VCE	VST VE	A SP	IC	R*		A408
COMPARE (short)	VCEQ	QV VE	SP	IC			A588
COMPARE (short)	VCER	VV VE		IC			A508
COMPARE (short)	VCES	QST VE	A SP	IC	R*		A488
COMPLEMENT VMR	VCVM	RRE VE		NC			A641
COUNT LEFT ZEROS IN VMR	VCZVM	RRE C VE		NC	R*		A642
COUNT ONES IN VMR	VCOVM	RRE C VE		NC	R*		A643
DIVIDE (long)	VDD	VST VE	A SP	J U EU EO FK IM VB	R*		A413
DIVIDE (long)	VDDQ	QV VE	SP	J U EU EO FK IM VB			A593
DIVIDE (long)	VDDR	VV VE	SP	J U EU EO FK IM VB			A513
DIVIDE (long)	VDDS	QST VE	A SP	J U EU EO FK IM VB	R*		A493
DIVIDE (short)	VDE	VST VE	A SP	J U EU EO FK IM VB	R*		A403
DIVIDE (short)	VDEQ	QV VE	SP	J U EU EO FK IM VB			A583
DIVIDE (short)	VDER	VV VE		J U EU EO FK IM VB			A503
DIVIDE (short)	VDES	QST VE	A SP	J U EU EO FK IM VB	R*		A483

Figure B-1 (Part 1 of 4). Instructions Arranged by Name

Name	Mne-monic	Characteristics					Op Code
EXCLUSIVE OR	VX	VST VE	A SP		IM VB	R*	A426
EXCLUSIVE OR	VXQ	QV VE			IM VB		A5A6
EXCLUSIVE OR	VXR	VV VE			IM VB		A526
EXCLUSIVE OR	VXS	QST VE	A SP		IM VB	R*	A4A6
EXCLUSIVE OR TO VMR	VXVM	VS VE	A		NC	R*	A686
EXTRACT ELEMENT (binary)	VXEL	VR VE	SP		N1	R*	A629
EXTRACT ELEMENT (long)	VXELD	VR VE	SP		N1		A619
EXTRACT ELEMENT (short)	VXELE	VR VE	SP		N1		A609
EXTRACT VCT	VXVC	RRE VE			N0	R*	A644
EXTRACT VECTOR MASK MODE	VXVMM	RRE VE			N0	R*	A646
LOAD (binary)[1]	VL	VST VE	A SP		IC VB	R*	A409
LOAD (binary)	VLQ	QV VE			IC VB		A5A9
LOAD (binary)[1]	VLR	VV VE			IC VB		A509
LOAD (long)	VLD	VST VE	A SP		IC VB	R*	A419
LOAD (long)	VLDQ	QV VE	SP		IC VB		A599
LOAD (long)	VLDR	VV VE	SP		IC VB		A519
LOAD (short)	VLE	VST VE	A SP		IC VB	R*	A409
LOAD (short)	VLEQ	QV VE	SP		IC VB		A589
LOAD (short)	VLER	VV VE			IC VB		A509
LOAD BIT INDEX	VLBIX	RSE C VE	A SP		IG VB	R*	E428
LOAD COMPLEMENT (binary)	VLCR	VV VE		J IF	IM VB		A562
LOAD COMPLEMENT (long)	VLCDR	VV VE	SP		IM VB		A552
LOAD COMPLEMENT (short)	VLCER	VV VE			IM VB		A542
LOAD ELEMENT (binary)	VLEL	VR VE	SP		N1 VB		A628
LOAD ELEMENT (long)	VLELD	VR VE	SP		N1 VB		A618
LOAD ELEMENT (short)	VLELE	VR VE	SP		N1 VB		A608
LOAD EXPANDED (binary)[1]	VLY	VST VE	A SP		IC VB	R*	A40B
LOAD EXPANDED (long)	VLYD	VST VE	A SP		IC VB	R*	A41B
LOAD EXPANDED (short)	VLYE	VST VE	A SP		IC VB	R*	A40B
LOAD HALFWORD	VLH	VST VE	A SP		IC VB	R*	A429
LOAD INDIRECT (binary)[1]	VLI	RSE VE	A SP		IC VB		E400
LOAD INDIRECT (long)	VLID	RSE VE	A SP		IC VB		E410
LOAD INDIRECT (short)	VLIE	RSE VE	A SP		IC VB		E400
LOAD INTEGER VECTOR	VLINT	VST VE	SP		IC VB	R*	A42A
LOAD MATCHED (binary)[1]	VLM	VST VE	A SP		IC VB	R*	A40A
LOAD MATCHED (binary)	VLMQ	QV VE			IC VB		A5AA
LOAD MATCHED (binary)[1]	VLMR	VV VE			IC VB		A50A
LOAD MATCHED (long)	VLMD	VST VE	A SP		IC VB	R*	A41A
LOAD MATCHED (long)	VLMDQ	QV VE	SP		IC VB		A59A
LOAD MATCHED (long)	VLMDR	VV VE	SP		IC VB		A51A
LOAD MATCHED (short)	VLME	VST VE	A SP		IC VB	R*	A40A
LOAD MATCHED (short)	VLMEQ	QV VE	SP		IC VB		A58A
LOAD MATCHED (short)	VLMER	VV VE			IC VB		A50A
LOAD NEGATIVE (binary)	VLNR	VV VE			IM VB		A561
LOAD NEGATIVE (long)	VLNDR	VV VE	SP		IM VB		A551

Figure B-1 (Part 2 of 4). Instructions Arranged by Name

Name	Mnemonic	Characteristics				Op Code
LOAD NEGATIVE (short)	VLNER	VV VE			IM VB	A541
LOAD POSITIVE (binary)	VLPR	VV VE		J IF	IM VB	A560
LOAD POSITIVE (long)	VLPDR	VV VE	SP		IM VB	A550
LOAD POSITIVE (short)	VLPER	VV VE			IM VB	A540
LOAD VCT AND UPDATE	VLVCU	RRE C VE			NO R*	A645
LOAD VCT FROM ADDRESS	VLVCA	S C VE			NO	A6C4
LOAD VMR	VLVM	VS VE	A		NC R*	A680
LOAD VMR COMPLEMENT	VLCVM	VS VE	A		NC R*	A681
LOAD ZERO (binary)[1]	VLZR	VV VE			IC VB	A50B
LOAD ZERO (long)	VLZDR	VV VE	SP		IC VB	A51B
LOAD ZERO (short)	VLZER	VV VE			IC VB	A50B
MAXIMUM ABSOLUTE (long)	VMXAD	VR VE	SP		IM R*	A612
MAXIMUM ABSOLUTE (short)	VMXAE	VR VE	SP		IM R*	A602
MAXIMUM SIGNED (long)	VMXSD	VR VE	SP		IM R*	A610
MAXIMUM SIGNED (short)	VMXSE	VR VE	SP		IM R*	A600
MINIMUM SIGNED (long)	VMNSD	VR VE	SP		IM R*	A611
MINIMUM SIGNED (short)	VMNSE	VR VE	SP		IM R*	A601
MULTIPLY (binary)	VM	VST VE	A SP		IM VB R*	A422
MULTIPLY (binary)	VMQ	QV VE	SP		IM VB	A5A2
MULTIPLY (binary)	VMR	VV VE	SP		IM VB	A522
MULTIPLY (binary)	VMS	QST VE	A SP		IM VB R*	A4A2
MULTIPLY (long)	VMD	VST VE	A SP	J U EU EO	IM VB R*	A412
MULTIPLY (long)	VMDQ	QV VE	SP	J U EU EO	IM VB	A592
MULTIPLY (long)	VMDR	VV VE	SP	J U EU EO	IM VB	A512
MULTIPLY (long)	VMDS	QST VE	A SP	J U EU EO	IM VB R*	A492
MULTIPLY (short to long)	VME	VST VE	A SP	J U EU EO	IM VB R*	A402
MULTIPLY (short to long)	VMEQ	QV VE	SP	J U EU EO	IM VB	A582
MULTIPLY (short to long)	VMER	VV VE	SP	J U EU EO	IM VB	A502
MULTIPLY (short to long)	VMES	QST VE	A SP	J U EU EO	IM VB R*	A482
MULTIPLY AND ACCUMULATE (long)	VMCD	VST VE	A SP	J U EU EO LS	IM VB R*	A416
MULTIPLY AND ACCUMULATE (long)	VMCDR	VV VE	SP	J U EU EO LS	IM VB	A516
MULTIPLY AND ACCUMULATE(s to l)	VMCE	VST VE	A SP	J U EU EO LS	IM VB R*	A406
MULTIPLY AND ACCUMULATE(s to l)	VMCER	VV VE	SP	J U EU EO LS	IM VB	A506
MULTIPLY AND ADD (long)	VMAD	VST VE	A SP	J U EU EO LS	IM VB R*	A414
MULTIPLY AND ADD (long)	VMADQ	QV VE	SP	J U EU EO LS	IM VB	A594
MULTIPLY AND ADD (long)	VMADS	QST VE	A SP	J U EU EO LS	IM VB R*	A494
MULTIPLY AND ADD(short to long)	VMAE	VST VE	A SP	J U EU EO LS	IM VB R*	A404
MULTIPLY AND ADD(short to long)	VMAEQ	QV VE	SP	J U EU EO LS	IM VB	A584
MULTIPLY AND ADD(short to long)	VMAES	QST VE	A SP	J U EU EO LS	IM VB R*	A484
MULTIPLY AND SUBTRACT (long)	VMSD	VST VE	A SP	J U EU EO LS	IM VB R*	A415
MULTIPLY AND SUBTRACT (long)	VMSDQ	QV VE	SP	J U EU EO LS	IM VB	A595
MULTIPLY AND SUBTRACT (long)	VMSDS	QST VE	A SP	J U EU EO LS	IM VB R*	A495
MULTIPLY AND SUBTRACT (s to l)	VMSE	VST VE	A SP	J U EU EO LS	IM VB R*	A405
MULTIPLY AND SUBTRACT (s to l)	VMSEQ	QV VE	SP	J U EU EO LS	IM VB	A585
MULTIPLY AND SUBTRACT (s to l)	VMSES	QST VE	A SP	J U EU EO LS	IM VB R*	A485

Figure B-1 (Part 3 of 4). Instructions Arranged by Name

Name	Mne-monic	Characteristics					Op Code
OR	VO	VST VE	A SP		IM VB	R*	A425
OR	VOQ	QV VE			IM VB		A5A5
OR	VOR	VV VE			IM VB		A525
OR	VOS	QST VE	A SP		IM VB	R*	A4A5
OR TO VMR	VOVM	VS VE	A		NC	R*	A685
RESTORE VAC	VACRS	S VE	A SP	P	NO		A6CB
RESTORE VMR	VMRRS	S VE	A		NZ		A6C3
RESTORE VR	VRRS	RRE C VE	A SP	[2]	IZ VU	R*	A648
RESTORE VSR	VSRRS	S VE	A SP	[2]	IZ VB		A6C2
SAVE CHANGED VR	VRSVC	RRE C VE	A SP	P	IZ VH	R* ST	A649
SAVE VAC	VACSV	S VE	A SP	P	NO	ST	A6CA
SAVE VMR	VMRSV	S VE	A		NZ	ST	A6C1
SAVE VR	VRSV	RRE C VE	A SP		IZ	R* ST	A64A
SAVE VSR	VSRSV	S VE	A SP	[2]	NO	ST	A6C0
SET VECTOR MASK MODE	VSVMM	S VE			NO		A6C6
SHIFT LEFT SINGLE LOGICAL	VSLL	RSE VE			IM VB		E425
SHIFT RIGHT SINGLE LOGICAL	VSRL	RSE VE			IM VB		E424
STORE (binary)[1]	VST	VST VE	A SP		IC	R* ST	A40D
STORE (long)	VSTD	VST VE	A SP		IC	R* ST	A41D
STORE (short)	VSTE	VST VE	A SP		IC	R* ST	A40D
STORE COMPRESSED (binary)[1]	VSTK	VST VE	A SP		IC	R* ST	A40F
STORE COMPRESSED (long)	VSTKD	VST VE	A SP		IC	R* ST	A41F
STORE COMPRESSED (short)	VSTKE	VST VE	A SP		IC	R* ST	A40F
STORE HALFWORD	VSTH	VST VE	A SP		IC	R* ST	A42D
STORE INDIRECT (binary)[1]	VSTI	RSE VE	A SP		IC	ST	E401
STORE INDIRECT (long)	VSTID	RSE VE	A SP		IC	ST	E411
STORE INDIRECT (short)	VSTIE	RSE VE	A SP		IC	ST	E401
STORE MATCHED (binary)[1]	VSTM	VST VE	A SP		IC	R* ST	A40E
STORE MATCHED (long)	VSTMD	VST VE	A SP		IC	R* ST	A41E
STORE MATCHED (short)	VSTME	VST VE	A SP		IC	R* ST	A40E
STORE VECTOR PARAMETERS	VSTVP	S VE	A SP		NO	ST	A6C8
STORE VMR	VSTVM	VS VE	A		NC	R* ST	A682
SUBTRACT (binary)	VS	VST VE	A SP	J IF	IM VB	R*	A421
SUBTRACT (binary)	VSQ	QV VE		J IF	IM VB		A5A1
SUBTRACT (binary)	VSR	VV VE		J IF	IM VB		A521
SUBTRACT (binary)	VSS	QST VE	A SP	J IF	IM VB	R*	A4A1
SUBTRACT (long)	VSD	VST VE	A SP	J EU EO LS	IM VB	R*	A411
SUBTRACT (long)	VSDQ	QV VE	SP	J EU EO LS	IM VB		A591
SUBTRACT (long)	VSDR	VV VE	SP	J EU EO LS	IM VB		A511
SUBTRACT (long)	VSDS	QST VE	A SP	J EU EO LS	IM VB	R*	A491
SUBTRACT (short)	VSE	VST VE	A SP	J EU EO LS	IM VB	R*	A401
SUBTRACT (short)	VSEQ	QV VE	SP	J EU EO LS	IM VB		A581
SUBTRACT (short)	VSER	VV VE		J EU EO LS	IM VB		A501
SUBTRACT (short)	VSES	QST VE	A SP	J EU EO LS	IM VB	R*	A481
SUM PARTIAL SUMS (long)	VSPSD	VR VE	SP	J EU EO LS	IP		A61A
TEST VMR	VTVM	RRE C VE			NC		A640
ZERO PARTIAL SUMS (long)	VZPSD	VR VE	SP		IP VB		A61B

Figure B-1 (Part 4 of 4). Instructions Arranged by Name

Mnemonic	Name	Characteristics				Op Code
VA	ADD (binary)	VST VE	A SP	J IF IM VB	R*	A420
VACD	ACCUMULATE (long)	VST VE	A SP	J EU EO LS IM VB	R*	A417
VACDR	ACCUMULATE (long)	VV VE	SP	J EU EO LS IM VB		A517
VACE	ACCUMULATE (short to long)	VST VE	A SP	J EU EO LS IM VB	R*	A407
VACER	ACCUMULATE (short to long)	VV VE	SP	J EU EO LS IM VB		A507
VACRS	RESTORE VAC	S VE	A SP	P NO		A6CB
VACSV	SAVE VAC	S VE	A SP	P NO	ST	A6CA
VAD	ADD (long)	VST VE	A SP	J EU EO LS IM VB	R*	A410
VADQ	ADD (long)	QV VE	SP	J EU EO LS IM VB		A590
VADR	ADD (long)	VV VE	SP	J EU EO LS IM VB		A510
VADS	ADD (long)	QST VE	A SP	J EU EO LS IM VB	R*	A490
VAE	ADD (short)	VST VE	A SP	J EU EO LS IM VB	R*	A400
VAEQ	ADD (short)	QV VE	SP	J EU EO LS IM VB		A580
VAER	ADD (short)	VV VE		J EU EO LS IM VB		A500
VAES	ADD (short)	QST VE	A SP	J EU EO LS IM VB	R*	A480
VAQ	ADD (binary)	QV VE		J IF IM VB		A5A0
VAR	ADD (binary)	VV VE		J IF IM VB		A520
VAS	ADD (binary)	QST VE	A SP	J IF IM VB	R*	A4A0
VC	COMPARE (binary)	VST VE	A SP	IC	R*	A428
VCD	COMPARE (long)	VST VE	A SP	IC	R*	A418
VCDQ	COMPARE (long)	QV VE	SP	IC		A598
VCDR	COMPARE (long)	VV VE	SP	IC		A518
VCDS	COMPARE (long)	QST VE	A SP	IC	R*	A498
VCE	COMPARE (short)	VST VE	A SP	IC	R*	A408
VCEQ	COMPARE (short)	QV VE	SP	IC		A588
VCER	COMPARE (short)	VV VE		IC		A508
VCES	COMPARE (short)	QST VE	A SP	IC	R*	A488
VCOVM	COUNT ONES IN VMR	RRE C VE		NC	R*	A643
VCQ	COMPARE (binary)	QV VE		IC		A5A8
VCR	COMPARE (binary)	VV VE		IC		A528
VCS	COMPARE (binary)	QST VE	A SP	IC	R*	A4A8
VCVM	COMPLEMENT VMR	RRE VE		NC		A641
VCZVM	COUNT LEFT ZEROS IN VMR	RRE C VE		NC	R*	A642
VDD	DIVIDE (long)	VST VE	A SP	J U EU EO FK IM VB	R*	A413
VDDQ	DIVIDE (long)	QV VE	SP	J U EU EO FK IM VB		A593
VDDR	DIVIDE (long)	VV VE	SP	J U EU EO FK IM VB		A513
VDDS	DIVIDE (long)	QST VE	A SP	J U EU EO FK IM VB	R*	A493
VDE	DIVIDE (short)	VST VE	A SP	J U EU EO FK IM VB	R*	A403
VDEQ	DIVIDE (short)	QV VE	SP	J U EU EO FK IM VB		A583
VDER	DIVIDE (short)	VV VE		J U EU EO FK IM VB		A503
VDES	DIVIDE (short)	QST VE	A SP	J U EU EO FK IM VB	R*	A483
VL	LOAD (binary)[1]	VST VE	A SP	IC VB	R*	A409
VLBIX	LOAD BIT INDEX	RSE C VE	A SP	IG VB	R*	E428
VLCDR	LOAD COMPLEMENT (long)	VV VE	SP	IM VB		A552
VLCER	LOAD COMPLEMENT (short)	VV VE		IM VB		A542

Figure B-2 (Part 1 of 4). Instructions Arranged by Mnemonic

Mnemonic	Name	Characteristics							Op Code
VLCR	LOAD COMPLEMENT (binary)	VV	VE		J	IF	IM	VB	A562
VLCVM	LOAD VMR COMPLEMENT	VS	VE	A			NC	R*	A681
VLD	LOAD (long)	VST	VE	A	SP		IC	VB R*	A419
VLDQ	LOAD (long)	QV	VE		SP		IC	VB	A599
VLDR	LOAD (long)	VV	VE		SP		IC	VB	A519
VLE	LOAD (short)	VST	VE	A	SP		IC	VB R*	A409
VLEL	LOAD ELEMENT (binary)	VR	VE		SP		N1	VB	A628
VLELD	LOAD ELEMENT (long)	VR	VE		SP		N1	VB	A618
VLELE	LOAD ELEMENT (short)	VR	VE		SP		N1	VB	A608
VLEQ	LOAD (short)	QV	VE		SP		IC	VB	A589
VLER	LOAD (short)	VV	VE				IC	VB	A509
VLH	LOAD HALFWORD	VST	VE	A	SP		IC	VB R*	A429
VLI	LOAD INDIRECT (binary)[1]	RSE	VE	A	SP		IC	VB	E400
VLID	LOAD INDIRECT (long)	RSE	VE	A	SP		IC	VB	E410
VLIE	LOAD INDIRECT (short)	RSE	VE	A	SP		IC	VB	E400
VLINT	LOAD INTEGER VECTOR	VST	VE		SP		IC	VB R*	A42A
VLM	LOAD MATCHED (binary)[1]	VST	VE	A	SP		IC	VB R*	A40A
VLMD	LOAD MATCHED (long)	VST	VE	A	SP		IC	VB R*	A41A
VLMDQ	LOAD MATCHED (long)	QV	VE		SP		IC	VB	A59A
VLMDR	LOAD MATCHED (long)	VV	VE		SP		IC	VB	A51A
VLME	LOAD MATCHED (short)	VST	VE	A	SP		IC	VB R*	A40A
VLMEQ	LOAD MATCHED (short)	QV	VE		SP		IC	VB	A58A
VLMER	LOAD MATCHED (short)	VV	VE				IC	VB	A50A
VLMQ	LOAD MATCHED (binary)	QV	VE				IC	VB	A5AA
VLMR	LOAD MATCHED (binary)[1]	VV	VE				IC	VB	A50A
VLNDR	LOAD NEGATIVE (long)	VV	VE		SP		IM	VB	A551
VLNER	LOAD NEGATIVE (short)	VV	VE				IM	VB	A541
VLNR	LOAD NEGATIVE (binary)	VV	VE				IM	VB	A561
VLPDR	LOAD POSITIVE (long)	VV	VE		SP		IM	VB	A550
VLPER	LOAD POSITIVE (short)	VV	VE				IM	VB	A540
VLPR	LOAD POSITIVE (binary)	VV	VE		J	IF	IM	VB	A560
VLQ	LOAD (binary)	QV	VE				IC	VB	A5A9
VLR	LOAD (binary)[1]	VV	VE				IC	VB	A509
VLVCA	LOAD VCT FROM ADDRESS	S	C VE				NO		A6C4
VLVCU	LOAD VCT AND UPDATE	RRE	C VE				NO	R*	A645
VLVM	LOAD VMR	VS	VE	A			NC	R*	A680
VLY	LOAD EXPANDED (binary)[1]	VST	VE	A	SP		IC	VB R*	A40B
VLYD	LOAD EXPANDED (long)	VST	VE	A	SP		IC	VB R*	A41B
VLYE	LOAD EXPANDED (short)	VST	VE	A	SP		IC	VB R*	A40B
VLZDR	LOAD ZERO (long)	VV	VE		SP		IC	VB	A51B
VLZER	LOAD ZERO (short)	VV	VE				IC	VB	A50B
VLZR	LOAD ZERO (binary)[1]	VV	VE				IC	VB	A50B
VM	MULTIPLY (binary)	VST	VE	A	SP		IM	VB R*	A422
VMAD	MULTIPLY AND ADD (long)	VST	VE	A	SP	J U EU EO LS	IM	VB R*	A414
VMADQ	MULTIPLY AND ADD (long)	QV	VE		SP	J U EU EO LS	IM	VB	A594

Figure B-2 (Part 2 of 4). Instructions Arranged by Mnemonic

Mnemonic	Name	Characteristics	Op Code
VMADS	MULTIPLY AND ADD (long)	QST VE A SP J U EU EO LS IM VB R*	A494
VMAE	MULTIPLY AND ADD(short to long)	VST VE A SP J U EU EO LS IM VB R*	A404
VMAEQ	MULTIPLY AND ADD(short to long)	QV VE SP J U EU EO LS IM VB	A584
VMAES	MULTIPLY AND ADD(short to long)	QST VE A SP J U EU EO LS IM VB R*	A484
VMCD	MULTIPLY AND ACCUMULATE (long)	VST VE A SP J U EU EO LS IM VB R*	A416
VMCDR	MULTIPLY AND ACCUMULATE (long)	VV VE SP J U EU EO LS IM VB	A516
VMCE	MULTIPLY AND ACCUMULATE(s to l)	VST VE A SP J U EU EO LS IM VB R*	A406
VMCER	MULTIPLY AND ACCUMULATE(s to l)	VV VE SP J U EU EO LS IM VB	A506
VMD	MULTIPLY (long)	VST VE A SP J U EU EO IM VB R*	A412
VMDQ	MULTIPLY (long)	QV VE SP J U EU EO IM VB	A592
VMDR	MULTIPLY (long)	VV VE SP J U EU EO IM VB	A512
VMDS	MULTIPLY (long)	QST VE A SP J U EU EO IM VB R*	A492
VME	MULTIPLY (short to long)	VST VE A SP J U EU EO IM VB R*	A402
VMEQ	MULTIPLY (short to long)	QV VE SP J U EU EO IM VB	A582
VMER	MULTIPLY (short to long)	VV VE SP J U EU EO IM VB	A502
VMES	MULTIPLY (short to long)	QST VE A SP J U EU EO IM VB R*	A482
VMNSD	MINIMUM SIGNED (long)	VR VE SP IM R*	A611
VMNSE	MINIMUM SIGNED (short)	VR VE SP IM R*	A601
VMQ	MULTIPLY (binary)	QV VE SP IM VB	A5A2
VMR	MULTIPLY (binary)	VV VE SP IM VB	A522
VMRRS	RESTORE VMR	S VE A NZ	A6C3
VMRSV	SAVE VMR	S VE A NZ ST	A6C1
VMS	MULTIPLY (binary)	QST VE A SP IM VB R*	A4A2
VMSD	MULTIPLY AND SUBTRACT (long)	VST VE A SP J U EU EO LS IM VB R*	A415
VMSDQ	MULTIPLY AND SUBTRACT (long)	QV VE SP J U EU EO LS IM VB	A595
VMSDS	MULTIPLY AND SUBTRACT (long)	QST VE A SP J U EU EO LS IM VB R*	A495
VMSE	MULTIPLY AND SUBTRACT (s to l)	VST VE A SP J U EU EO LS IM VB R*	A405
VMSEQ	MULTIPLY AND SUBTRACT (s to l)	QV VE SP J U EU EO LS IM VB	A585
VMSES	MULTIPLY AND SUBTRACT (s to l)	QST VE A SP J U EU EO LS IM VB R*	A485
VMXAD	MAXIMUM ABSOLUTE (long)	VR VE SP IM R*	A612
VMXAE	MAXIMUM ABSOLUTE (short)	VR VE SP IM R*	A602
VMXSD	MAXIMUM SIGNED (long)	VR VE SP IM R*	A610
VMXSE	MAXIMUM SIGNED (short)	VR VE SP IM R*	A600
VN	AND	VST VE A SP IM VB R*	A424
VNQ	AND	QV VE IM VB	A5A4
VNR	AND	VV VE IM VB	A524
VNS	AND	QST VE A SP IM VB R*	A4A4
VNVM	AND TO VMR	VS VE A NC R*	A684
VO	OR	VST VE A SP IM VB R*	A425
VOQ	OR	QV VE IM VB	A5A5
VOR	OR	VV VE IM VB	A525
VOS	OR	QST VE A SP IM VB R*	A4A5
VOVM	OR TO VMR	VS VE A NC R*	A685
VRCL	CLEAR VR	S VE IZ VB	A6C5
VRRS	RESTORE VR	RRE C VE A SP [2] IZ VU R*	A648

Figure B-2 (Part 3 of 4). Instructions Arranged by Mnemonic

Mnemonic	Name	Characteristics				Op Code
VRSV	SAVE VR	RRE C VE	A SP		IZ	R* ST	A64A
VRSVC	SAVE CHANGED VR	RRE C VE	A SP	P	IZ VH	R* ST	A649
VS	SUBTRACT (binary)	VST VE	A SP	J IF	IM VB	R*	A421
VSD	SUBTRACT (long)	VST VE	A SP	J EU EO LS	IM VB	R*	A411
VSDQ	SUBTRACT (long)	QV VE	SP	J EU EO LS	IM VB		A591
VSDR	SUBTRACT (long)	VV VE	SP	J EU EO LS	IM VB		A511
VSDS	SUBTRACT (long)	QST VE	A SP	J EU EO LS	IM VB	R*	A491
VSE	SUBTRACT (short)	VST VE	A SP	J EU EO LS	IM VB	R*	A401
VSEQ	SUBTRACT (short)	QV VE	SP	J EU EO LS	IM VB		A581
VSER	SUBTRACT (short)	VV VE		J EU EO LS	IM VB		A501
VSES	SUBTRACT (short)	QST VE	A SP	J EU EO LS	IM VB	R*	A481
VSLL	SHIFT LEFT SINGLE LOGICAL	RSE VE			IM VB		E425
VSPSD	SUM PARTIAL SUMS (long)	VR VE	SP	J EU EO LS	IP		A61A
VSQ	SUBTRACT (binary)	QV VE		J IF	IM VB		A5A1
VSR	SUBTRACT (binary)	VV VE		J IF	IM VB		A521
VSRL	SHIFT RIGHT SINGLE LOGICAL	RSE VE			IM VB		E424
VSRRS	RESTORE VSR	S VE	A SP	[2]	IZ VB		A6C2
VSRSV	SAVE VSR	S VE	A SP	[2]	NO	ST	A6C0
VSS	SUBTRACT (binary)	QST VE	A SP	J IF	IM VB	R*	A4A1
VST	STORE (binary)[1]	VST VE	A SP		IC	R* ST	A40D
VSTD	STORE (long)	VST VE	A SP		IC	R* ST	A41D
VSTE	STORE (short)	VST VE	A SP		IC	R* ST	A40D
VSTH	STORE HALFWORD	VST VE	A SP		IC	R* ST	A42D
VSTI	STORE INDIRECT (binary)[1]	RSE VE	A SP		IC	ST	E401
VSTID	STORE INDIRECT (long)	RSE VE	A SP		IC	ST	E411
VSTIE	STORE INDIRECT (short)	RSE VE	A SP		IC	ST	E401
VSTK	STORE COMPRESSED (binary)[1]	VST VE	A SP		IC	R* ST	A40F
VSTKD	STORE COMPRESSED (long)	VST VE	A SP		IC	R* ST	A41F
VSTKE	STORE COMPRESSED (short)	VST VE	A SP		IC	R* ST	A40F
VSTM	STORE MATCHED (binary)[1]	VST VE	A SP		IC	R* ST	A40E
VSTMD	STORE MATCHED (long)	VST VE	A SP		IC	R* ST	A41E
VSTME	STORE MATCHED (short)	VST VE	A SP		IC	R* ST	A40E
VSTVM	STORE VMR	VS VE	A		NC	R* ST	A682
VSTVP	STORE VECTOR PARAMETERS	S VE	A SP		NO	ST	A6C8
VSVMM	SET VECTOR MASK MODE	S VE			NO		A6C6
VTVM	TEST VMR	RRE C VE			NC		A640
VX	EXCLUSIVE OR	VST VE	A SP		IM VB	R*	A426
VXEL	EXTRACT ELEMENT (binary)	VR VE	SP		N1	R*	A629
VXELD	EXTRACT ELEMENT (long)	VR VE	SP		N1		A619
VXELE	EXTRACT ELEMENT (short)	VR VE	SP		N1		A609
VXQ	EXCLUSIVE OR	QV VE			IM VB		A5A6
VXR	EXCLUSIVE OR	VV VE			IM VB		A526
VXS	EXCLUSIVE OR	QST VE	A SP		IM VB	R*	A4A6
VXVC	EXTRACT VCT	RRE VE			NO	R*	A644
VXVM	EXCLUSIVE OR TO VMR	VS VE	A		NC	R*	A686
VXVMM	EXTRACT VECTOR MASK MODE	RRE VE			NO	R*	A646
VZPSD	ZERO PARTIAL SUMS (long)	VR VE	SP		IP VB		A61B

Figure B-2 (Part 4 of 4). Instructions Arranged by Mnemonic

Op Code	Name	Mne-monic	Characteristics																	
A400	ADD (short)	VAE	VST	VE	A	SP	J		EU	EO	LS	IM	VB	R*						
A401	SUBTRACT (short)	VSE	VST	VE	A	SP	J		EU	EO	LS	IM	VB	R*						
A402	MULTIPLY (short to long)	VME	VST	VE	A	SP	J	U	EU	EO		IM	VB	R*						
A403	DIVIDE (short)	VDE	VST	VE	A	SP	J	U	EU	EO	FK	IM	VB	R*						
A404	MULTIPLY AND ADD(short to long)	VMAE	VST	VE	A	SP	J	U	EU	EO	LS	IM	VB	R*						
A405	MULTIPLY AND SUBTRACT (s to l)	VMSE	VST	VE	A	SP	J	U	EU	EO	LS	IM	VB	R*						
A406	MULTIPLY AND ACCUMULATE(s to l)	VMCE	VST	VE	A	SP	J	U	EU	EO	LS	IM	VB	R*						
A407	ACCUMULATE (short to long)	VACE	VST	VE	A	SP	J		EU	EO	LS	IM	VB	R*						
A408	COMPARE (short)	VCE	VST	VE	A	SP						IC		R*						
A409	LOAD (binary)[1]	VL	VST	VE	A	SP						IC	VB	R*						
A409	LOAD (short)	VLE	VST	VE	A	SP						IC	VB	R*						
A40A	LOAD MATCHED (binary)[1]	VLM	VST	VE	A	SP						IC	VB	R*						
A40A	LOAD MATCHED (short)	VLME	VST	VE	A	SP						IC	VB	R*						
A40B	LOAD EXPANDED (binary)[1]	VLY	VST	VE	A	SP						IC	VB	R*						
A40B	LOAD EXPANDED (short)	VLYE	VST	VE	A	SP						IC	VB	R*						
A40D	STORE (binary)[1]	VST	VST	VE	A	SP						IC		R*	ST					
A40D	STORE (short)	VSTE	VST	VE	A	SP						IC		R*	ST					
A40E	STORE MATCHED (binary)[1]	VSTM	VST	VE	A	SP						IC		R*	ST					
A40E	STORE MATCHED (short)	VSTME	VST	VE	A	SP						IC		R*	ST					
A40F	STORE COMPRESSED (binary)[1]	VSTK	VST	VE	A	SP						IC		R*	ST					
A40F	STORE COMPRESSED (short)	VSTKE	VST	VE	A	SP						IC		R*	ST					
A410	ADD (long)	VAD	VST	VE	A	SP	J		EU	EO	LS	IM	VB	R*						
A411	SUBTRACT (long)	VSD	VST	VE	A	SP	J		EU	EO	LS	IM	VB	R*						
A412	MULTIPLY (long)	VMD	VST	VE	A	SP	J	U	EU	EO		IM	VB	R*						
A413	DIVIDE (long)	VDD	VST	VE	A	SP	J	U	EU	EO	FK	IM	VB	R*						
A414	MULTIPLY AND ADD (long)	VMAD	VST	VE	A	SP	J	U	EU	EO	LS	IM	VB	R*						
A415	MULTIPLY AND SUBTRACT (long)	VMSD	VST	VE	A	SP	J	U	EU	EO	LS	IM	VB	R*						
A416	MULTIPLY AND ACCUMULATE (long)	VMCD	VST	VE	A	SP	J	U	EU	EO	LS	IM	VB	R*						
A417	ACCUMULATE (long)	VACD	VST	VE	A	SP	J		EU	EO	LS	IM	VB	R*						
A418	COMPARE (long)	VCD	VST	VE	A	SP						IC		R*						
A419	LOAD (long)	VLD	VST	VE	A	SP						IC	VB	R*						
A41A	LOAD MATCHED (long)	VLMD	VST	VE	A	SP						IC	VB	R*						
A41B	LOAD EXPANDED (long)	VLYD	VST	VE	A	SP						IC	VB	R*						
A41D	STORE (long)	VSTD	VST	VE	A	SP						IC		R*	ST					
A41E	STORE MATCHED (long)	VSTMD	VST	VE	A	SP						IC		R*	ST					
A41F	STORE COMPRESSED (long)	VSTKD	VST	VE	A	SP						IC		R*	ST					
A420	ADD (binary)	VA	VST	VE	A	SP	J			IF		IM	VB	R*						
A421	SUBTRACT (binary)	VS	VST	VE	A	SP	J			IF		IM	VB	R*						
A422	MULTIPLY (binary)	VM	VST	VE	A	SP						IM	VB	R*						
A424	AND	VN	VST	VE	A	SP						IM	VB	R*						
A425	OR	VO	VST	VE	A	SP						IM	VB	R*						
A426	EXCLUSIVE OR	VX	VST	VE	A	SP						IM	VB	R*						
A428	COMPARE (binary)	VC	VST	VE	A	SP						IC		R*						
A429	LOAD HALFWORD	VLH	VST	VE	A	SP						IC	VB	R*						
A42A	LOAD INTEGER VECTOR	VLINT	VST	VE		SP						IC	VB	R*						

Figure B-3 (Part 1 of 4). Instructions Arranged by Op Code

Op Code	Name	Mne-monic	Characteristics												
A42D	STORE HALFWORD	VSTH	VST	VE	A	SP						IC		R*	ST
A480	ADD (short)	VAES	QST	VE	A	SP	J		EU	EO	LS	IM	VB	R*	
A481	SUBTRACT (short)	VSES	QST	VE	A	SP	J		EU	EO	LS	IM	VB	R*	
A482	MULTIPLY (short to long)	VMES	QST	VE	A	SP	J	U	EU	EO		IM	VB	R*	
A483	DIVIDE (short)	VDES	QST	VE	A	SP	J	U	EU	EO	FK	IM	VB	R*	
A484	MULTIPLY AND ADD(short to long)	VMAES	QST	VE	A	SP	J	U	EU	EO	LS	IM	VB	R*	
A485	MULTIPLY AND SUBTRACT (s to l)	VMSES	QST	VE	A	SP	J	U	EU	EO	LS	IM	VB	R*	
A488	COMPARE (short)	VCES	QST	VE	A	SP						IC		R*	
A490	ADD (long)	VADS	QST	VE	A	SP	J		EU	EO	LS	IM	VB	R*	
A491	SUBTRACT (long)	VSDS	QST	VE	A	SP	J		EU	EO	LS	IM	VB	R*	
A492	MULTIPLY (long)	VMDS	QST	VE	A	SP	J	U	EU	EO		IM	VB	R*	
A493	DIVIDE (long)	VDDS	QST	VE	A	SP	J	U	EU	EO	FK	IM	VB	R*	
A494	MULTIPLY AND ADD (long)	VMADS	QST	VE	A	SP	J	U	EU	EO	LS	IM	VB	R*	
A495	MULTIPLY AND SUBTRACT (long)	VMSDS	QST	VE	A	SP	J	U	EU	EO	LS	IM	VB	R*	
A498	COMPARE (long)	VCDS	QST	VE	A	SP						IC		R*	
A4A0	ADD (binary)	VAS	QST	VE	A	SP	J			IF		IM	VB	R*	
A4A1	SUBTRACT (binary)	VSS	QST	VE	A	SP	J			IF		IM	VB	R*	
A4A2	MULTIPLY (binary)	VMS	QST	VE	A	SP						IM	VB	R*	
A4A4	AND	VNS	QST	VE	A	SP						IM	VB	R*	
A4A5	OR	VOS	QST	VE	A	SP						IM	VB	R*	
A4A6	EXCLUSIVE OR	VXS	QST	VE	A	SP						IM	VB	R*	
A4A8	COMPARE (binary)	VCS	QST	VE	A	SP						IC		R*	
A500	ADD (short)	VAER	VV	VE			J		EU	EO	LS	IM	VB		
A501	SUBTRACT (short)	VSER	VV	VE			J		EU	EO	LS	IM	VB		
A502	MULTIPLY (short to long)	VMER	VV	VE		SP	J	U	EU	EO		IM	VB		
A503	DIVIDE (short)	VDER	VV	VE			J	U	EU	EO	FK	IM	VB		
A506	MULTIPLY AND ACCUMULATE(s to l)	VMCER	VV	VE		SP	J	U	EU	EO	LS	IM	VB		
A507	ACCUMULATE (short to long)	VACER	VV	VE		SP	J		EU	EO	LS	IM	VB		
A508	COMPARE (short)	VCER	VV	VE								IC			
A509	LOAD (binary)[1]	VLR	VV	VE								IC	VB		
A509	LOAD (short)	VLER	VV	VE								IC	VB		
A50A	LOAD MATCHED (binary)[1]	VLMR	VV	VE								IC	VB		
A50A	LOAD MATCHED (short)	VLMER	VV	VE								IC	VB		
A50B	LOAD ZERO (binary)[1]	VLZR	VV	VE								IC	VB		
A50B	LOAD ZERO (short)	VLZER	VV	VE								IC	VB		
A510	ADD (long)	VADR	VV	VE		SP	J		EU	EO	LS	IM	VB		
A511	SUBTRACT (long)	VSDR	VV	VE		SP	J		EU	EO	LS	IM	VB		
A512	MULTIPLY (long)	VMDR	VV	VE		SP	J	U	EU	EO		IM	VB		
A513	DIVIDE (long)	VDDR	VV	VE		SP	J	U	EU	EO	FK	IM	VB		
A516	MULTIPLY AND ACCUMULATE (long)	VMCDR	VV	VE		SP	J	U	EU	EO	LS	IM	VB		
A517	ACCUMULATE (long)	VACDR	VV	VE		SP	J		EU	EO	LS	IM	VB		
A518	COMPARE (long)	VCDR	VV	VE		SP						IC			
A519	LOAD (long)	VLDR	VV	VE		SP						IC	VB		
A51A	LOAD MATCHED (long)	VLMDR	VV	VE		SP						IC	VB		
A51B	LOAD ZERO (long)	VLZDR	VV	VE		SP						IC	VB		

Figure B-3 (Part 2 of 4). Instructions Arranged by Op Code

Op Code	Name	Mnemonic	Characteristics					
A520	ADD (binary)	VAR	VV	VE		J IF	IM VB	
A521	SUBTRACT (binary)	VSR	VV	VE		J IF	IM VB	
A522	MULTIPLY (binary)	VMR	VV	VE	SP		IM VB	
A524	AND	VNR	VV	VE			IM VB	
A525	OR	VOR	VV	VE			IM VB	
A526	EXCLUSIVE OR	VXR	VV	VE			IM VB	
A528	COMPARE (binary)	VCR	VV	VE			IC	
A540	LOAD POSITIVE (short)	VLPER	VV	VE			IM VB	
A541	LOAD NEGATIVE (short)	VLNER	VV	VE			IM VB	
A542	LOAD COMPLEMENT (short)	VLCER	VV	VE			IM VB	
A550	LOAD POSITIVE (long)	VLPDR	VV	VE	SP		IM VB	
A551	LOAD NEGATIVE (long)	VLNDR	VV	VE	SP		IM VB	
A552	LOAD COMPLEMENT (long)	VLCDR	VV	VE	SP		IM VB	
A560	LOAD POSITIVE (binary)	VLPR	VV	VE		J IF	IM VB	
A561	LOAD NEGATIVE (binary)	VLNR	VV	VE			IM VB	
A562	LOAD COMPLEMENT (binary)	VLCR	VV	VE		J IF	IM VB	
A580	ADD (short)	VAEQ	QV	VE	SP	J EU EO LS	IM VB	
A581	SUBTRACT (short)	VSEQ	QV	VE	SP	J EU EO LS	IM VB	
A582	MULTIPLY (short to long)	VMEQ	QV	VE	SP	J U EU EO	IM VB	
A583	DIVIDE (short)	VDEQ	QV	VE	SP	J U EU EO FK	IM VB	
A584	MULTIPLY AND ADD(short to long)	VMAEQ	QV	VE	SP	J U EU EO LS	IM VB	
A585	MULTIPLY AND SUBTRACT (s to l)	VMSEQ	QV	VE	SP	J U EU EO LS	IM VB	
A588	COMPARE (short)	VCEQ	QV	VE	SP		IC	
A589	LOAD (short)	VLEQ	QV	VE	SP		IC VB	
A58A	LOAD MATCHED (short)	VLMEQ	QV	VE	SP		IC VB	
A590	ADD (long)	VADQ	QV	VE	SP	J EU EO LS	IM VB	
A591	SUBTRACT (long)	VSDQ	QV	VE	SP	J EU EO LS	IM VB	
A592	MULTIPLY (long)	VMDQ	QV	VE	SP	J U EU EO	IM VB	
A593	DIVIDE (long)	VDDQ	QV	VE	SP	J U EU EO FK	IM VB	
A594	MULTIPLY AND ADD (long)	VMADQ	QV	VE	SP	J U EU EO LS	IM VB	
A595	MULTIPLY AND SUBTRACT (long)	VMSDQ	QV	VE	SP	J U EU EO LS	IM VB	
A598	COMPARE (long)	VCDQ	QV	VE	SP		IC	
A599	LOAD (long)	VLDQ	QV	VE	SP		IC VB	
A59A	LOAD MATCHED (long)	VLMDQ	QV	VE	SP		IC VB	
A5A0	ADD (binary)	VAQ	QV	VE		J IF	IM VB	
A5A1	SUBTRACT (binary)	VSQ	QV	VE		J IF	IM VB	
A5A2	MULTIPLY (binary)	VMQ	QV	VE	SP		IM VB	
A5A4	AND	VNQ	QV	VE			IM VB	
A5A5	OR	VOQ	QV	VE			IM VB	
A5A6	EXCLUSIVE OR	VXQ	QV	VE			IM VB	
A5A8	COMPARE (binary)	VCQ	QV	VE			IC	
A5A9	LOAD (binary)	VLQ	QV	VE			IC VB	
A5AA	LOAD MATCHED (binary)	VLMQ	QV	VE			IC VB	
A600	MAXIMUM SIGNED (short)	VMXSE	VR	VE	SP		IM	R*
A601	MINIMUM SIGNED (short)	VMNSE	VR	VE	SP		IM	R*

Figure B-3 (Part 3 of 4). Instructions Arranged by Op Code

Op Code	Name	Mne-monic	Characteristics				
A602	MAXIMUM ABSOLUTE (short)	VMXAE	VR VE	SP		IM	R*
A608	LOAD ELEMENT (short)	VLELE	VR VE	SP		N1 VB	
A609	EXTRACT ELEMENT (short)	VXELE	VR VE	SP		N1	
A610	MAXIMUM SIGNED (long)	VMXSD	VR VE	SP		IM	R*
A611	MINIMUM SIGNED (long)	VMNSD	VR VE	SP		IM	R*
A612	MAXIMUM ABSOLUTE (long)	VMXAD	VR VE	SP		IM	R*
A618	LOAD ELEMENT (long)	VLELD	VR VE	SP		N1 VB	
A619	EXTRACT ELEMENT (long)	VXELD	VR VE	SP		N1	
A61A	SUM PARTIAL SUMS (long)	VSPSD	VR VE	SP	J EU EO LS	IP	
A61B	ZERO PARTIAL SUMS (long)	VZPSD	VR VE	SP		IP VB	
A628	LOAD ELEMENT (binary)	VLEL	VR VE	SP		N1 VB	
A629	EXTRACT ELEMENT (binary)	VXEL	VR VE	SP		N1	R*
A640	TEST VMR	VTVM	RRE C VE			NC	
A641	COMPLEMENT VMR	VCVM	RRE VE			NC	
A642	COUNT LEFT ZEROS IN VMR	VCZVM	RRE C VE			NC	R*
A643	COUNT ONES IN VMR	VCOVM	RRE C VE			NC	R*
A644	EXTRACT VCT	VXVC	RRE VE			NO	R*
A645	LOAD VCT AND UPDATE	VLVCU	RRE C VE			NO	R*
A646	EXTRACT VECTOR MASK MODE	VXVMM	RRE VE			NO	R*
A648	RESTORE VR	VRRS	RRE C VE	A SP	[2]	IZ VU	R*
A649	SAVE CHANGED VR	VRSVC	RRE C VE	A SP	P	IZ VH	R* ST
A64A	SAVE VR	VRSV	RRE C VE	A SP		IZ	R* ST
A680	LOAD VMR	VLVM	VS VE	A		NC	R*
A681	LOAD VMR COMPLEMENT	VLCVM	VS VE	A		NC	R*
A682	STORE VMR	VSTVM	VS VE	A		NC	R* ST
A684	AND TO VMR	VNVM	VS VE	A		NC	R*
A685	OR TO VMR	VOVM	VS VE	A		NC	R*
A686	EXCLUSIVE OR TO VMR	VXVM	VS VE	A		NC	R*
A6C0	SAVE VSR	VSRSV	S VE	A SP	[2]	NO	ST
A6C1	SAVE VMR	VMRSV	S VE	A		NZ	ST
A6C2	RESTORE VSR	VSRRS	S VE	A SP	[2]	IZ VB	
A6C3	RESTORE VMR	VMRRS	S VE	A		NZ	
A6C4	LOAD VCT FROM ADDRESS	VLVCA	S C VE			NO	
A6C5	CLEAR VR	VRCL	S VE			IZ VB	
A6C6	SET VECTOR MASK MODE	VSVMM	S VE			NO	
A6C8	STORE VECTOR PARAMETERS	VSTVP	S VE	A SP		NO	ST
A6CA	SAVE VAC	VACSV	S VE	A SP	P	NO	ST
A6CB	RESTORE VAC	VACRS	S VE	A SP	P	NO	
E400	LOAD INDIRECT (binary)[1]	VLI	RSE VE	A SP		IC VB	
E400	LOAD INDIRECT (short)	VLIE	RSE VE	A SP		IC VB	
E401	STORE INDIRECT (binary)[1]	VSTI	RSE VE	A SP		IC	ST
E401	STORE INDIRECT (short)	VSTIE	RSE VE	A SP		IC	ST
E410	LOAD INDIRECT (long)	VLID	RSE VE	A SP		IC VB	
E411	STORE INDIRECT (long)	VSTID	RSE VE	A SP		IC	ST
E424	SHIFT RIGHT SINGLE LOGICAL	VSRL	RSE VE			IM VB	
E425	SHIFT LEFT SINGLE LOGICAL	VSLL	RSE VE			IM VB	
E428	LOAD BIT INDEX	VLBIX	RSE C VE	A SP		IG VB	R*

Figure B-3 (Part 4 of 4). Instructions Arranged by Op Code

A

B

C

D

E

T

U

V

Z

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