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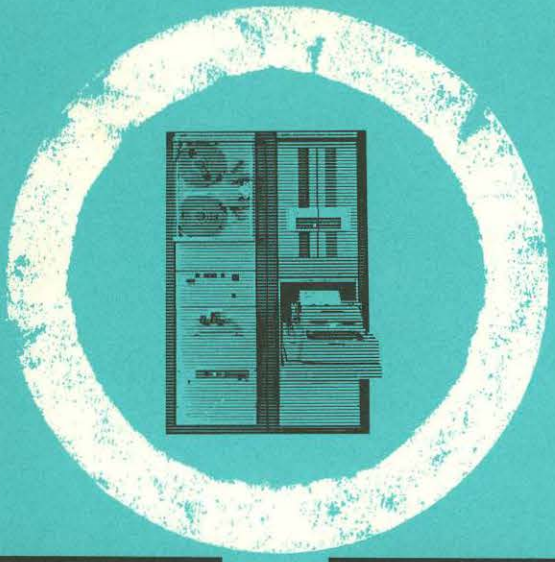
PB250 PROGRAMMING AND REFERENCE MANUAL

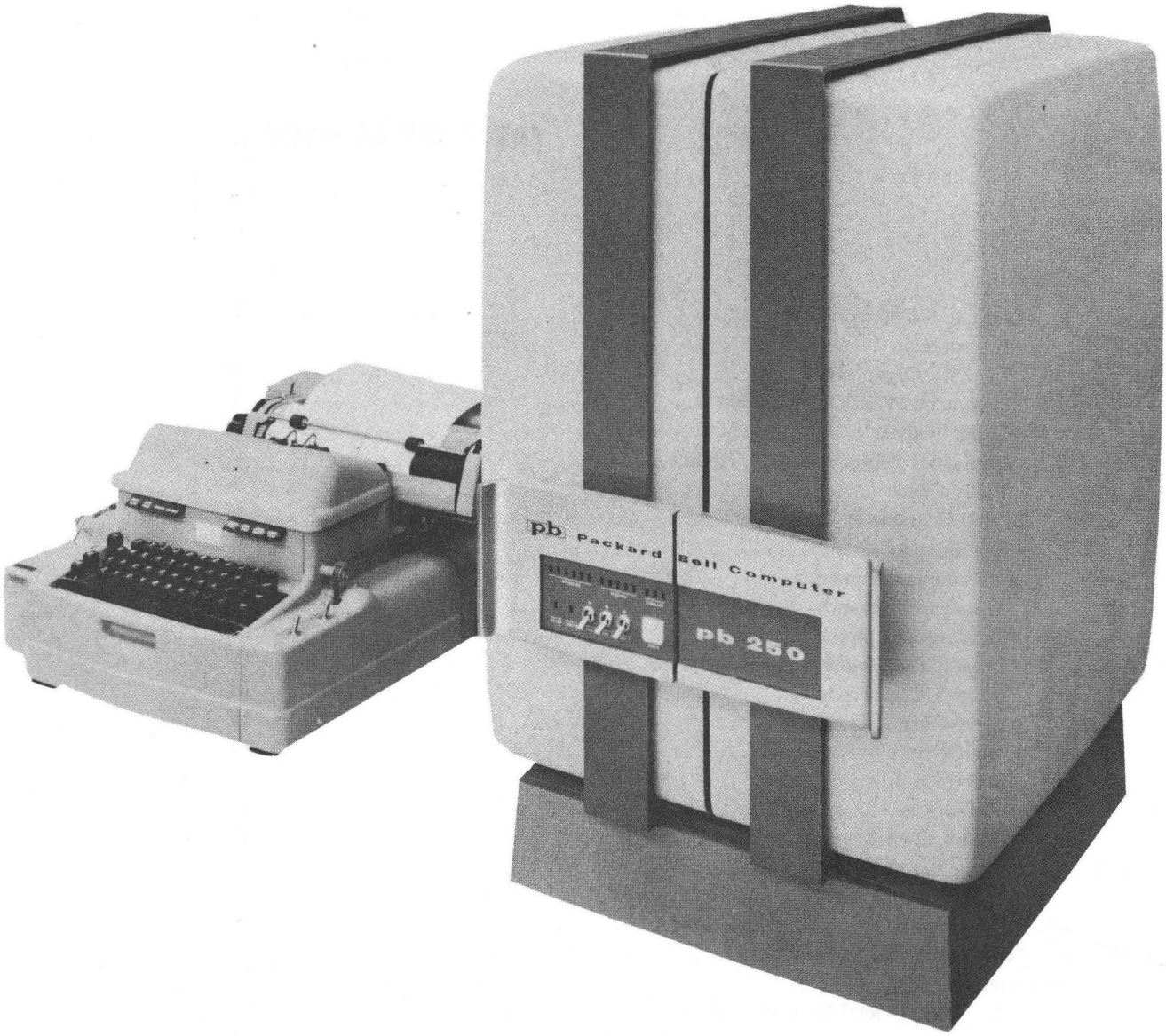


Packard Bell Computer

Reference Manual

PB 250
General Purpose Digital Computer

TABLE OF CONTENTS



PB 250 General Purpose Digital Computer.

1. GENERAL CHARACTERISTICS

Introduction

The Packard Bell PB 250 is a high-speed, completely solid-state general purpose digital computer in which both the data and the commands required for computation are stored in a homogeneous memory. The storage medium is a group of nickel steel magnetostrictive lines along which acoustical pulses are propagated. At one end of each of these lines is a writing device for translating electrical energy into acoustical energy. At the other end of each line is a reading device for translating acoustical energy back into electrical signals. By rewriting the stored information as it is read, information continuously circulates without alteration except for alterations which result from the execution of the computer program.

The PB 250 provides a repertoire of more than 50 commands flexible enough to permit coding of a very broad range of scientific and engineering problems. Double precision commands are provided for operating upon large numbers. Commands to normalize and scale numbers facilitate floating point operation. Square root, and variable length multiplication and division operations are available in the command list. Other features include input-output buffering, and a large number of optional peripheral units such as punched card equipment, tape handlers, shaft encoders, photo readers, and analog-to-digital and digital-to-analog converters. A magnetic core memory of 16,384 words can be linked with the computer, providing an input-output rate of up to 85,000 words per second.

Memory Organization

The memory of the basic PB 250 contains ten lines, numbered octally from 00 through 11, which hold both data and instructions. Each long line, 01 through 11, contains 256 (decimal), or 400 (octal), locations, also called sectors, that are numbered 000 through 377. *Note: All sector and line numbers are given in octal notation throughout this manual.* Since the information in any location can be either data or a command, the generic term "word" is used to cover both. The location of any word is specified by a line and sector number, and these together are called an address. Line 00 is a 16-word Fast Access Line. Since line 00 is 1/16 the length of a long word line, any unit of information contained in it is available 16 times during each complete circulation of the 256-word lines. Thus, any word in the Fast Access Line can be identified by one of 16 sector addresses. For example, sector 000 of the line 00 can be identified by the following addresses: 00000, 02000, 04000, 06000, ... 36000.

Fifty-three additional lines, each of which may have from one to 256 words, can be added. These lines are numbered 10 through 36 and 40 through 77. Line number 37 is used for the Index Register. If all of the additional lines are used, and if all hold 256 words, the memory capacity of the PB 250 is extended to 15,888 words.

Commands can be executed only from lines 00 through 07; these lines are therefore designated "Command Lines."

Data Word Configuration

Every number stored in the PB 250 is represented by a series of pulses which correspond to a series of zeros and ones that are the digits of the binary number system. The term "binary digit" is usually contracted to the word "bit." (A discussion of binary numbers may be found in appendix A.)

A number stored in a location in the PB 250 consists of twenty-one bits that represent magnitude and a twenty-second bit to indicate sign. A negative number has a one in position zero, whereas a positive number has a zero in position zero. Negative numbers are expressed in their 2's complement form. (A discussion of complementary arithmetic may be found in appendix A.)

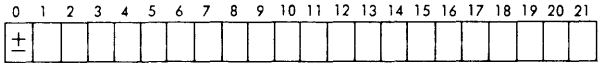


Figure 1.—Data Word Configuration

These 22 positions are sufficient to represent a 6-digit decimal number. Larger numbers may easily be represented by using the double precision features of the computer.

Arithmetic Registers

Three arithmetic registers, A, B, and C, are provided for arithmetic operations and information manipulation. Each register has exactly the same format as a memory location, including the sign, and all are available to the programmer. Double precision commands treat A and B as a double-length register; information may be interchanged between A, B, and C. The contents of a register may be tested for non-positive values or compared against the contents of any memory location. A record may be kept in one register of operations performed on the others. The specific functions of these registers are described in the discussion of the commands in Chapter 2.

Stored Program Concept

The computer is capable of performing certain operations, or "obeying commands," and more than 50 such commands are available to the programmer for problem solving. A set of commands, or instructions, is known as a program and is stored in memory, one command per word; thus the term "stored program." Commands may specify or "address" memory locations, manipulate data, call or read in information from external sources, or even operate on other commands.

Each command has a specific numeric code, but for greater convenience a three-letter mnemonic code has been devised. For example, the command DIVIDE has the numeric code 31, and the mnemonic DIV. A program to accept mnemonic OP codes can be devised which will cause the computer to substitute internally the proper binary representation for an alphabetic code. The code, whether numeric or mnemonic, is referred to as the operation code or, for brevity, the OP code. Numeric OP codes are always specified in octal notation.

Command Word Configuration

As previously mentioned, information in any memory location may be either data or a command. When the information is a command, it has a definite configuration, or format, as illustrated below.

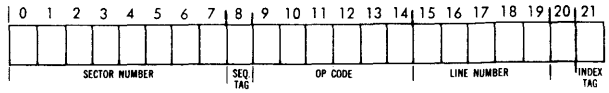


Figure 2.—Command Word Configuration.

Each subdivision, or field, of the command word is uniquely identified. The subdivisions are the sector number, Sequence Tag, OP code, line number, and Index Tag fields. There will be frequent references in subsequent discussions to the address field of a command. Although the address is made up of a sector and a line number, these numbers are not contiguous in the command format. The address field, however, will be considered as a single entity. The address 03204 refers to sector 032, line 04. The contents of the address field in a command do not always designate a memory location. For example, the shifting commands use the address field to indicate the number of places to shift.

The Sequence Tag field may contain either a one or a zero, and its use is detailed in the section entitled "Command Sequence and Timing" in this chapter.

The OP code field contains a numeric code which specifies one of the PB 250 commands.

The Index Tag field may contain either a one or a zero. When a one is placed in this field, the contents of the Index Register are used; a zero in the field indicates no use of that register.

Bit position 20 contains a one only when referring to a line number of 40 or greater.

Index Register

The Index Register stores a line number for use with commands which have an Index Tag of one. When used, the contents of the Index Register replace the line number of the address in the command. This replacement is made during the reading of the command, *but does not change the command as it stands in memory.* For example, if the contents of the Index Register are 01, then in the execution of the following program step:

OP CODE	ADDRESS	INDEX TAG
ADD	03204	1

the computer will add the contents of location 03201, instead of 03204.

Line number 37 is reserved to designate the Index Register. Addresses 00037 through 37737 all apply to this register, and bit positions 16 through 20 are the useful positions for the line number. Thus, a STA into line 37, any sector, places bits 16 through 20 of A into the Index Register, bits 16 through 20.

Command Sequencing and Timing

The PB 250 reads and executes commands from the circulating command lines. The words of the long lines are read serially in sector number sequence (000, 001, 002 - - - 376, 377, 000, 001 - - -). The time for each word to pass through a reading device is 12 microseconds; therefore, the time for all 256 words of a long line is 3072 microseconds. The commands are read and executed in numerical order from a given line starting in sector 000 of line 01 (00001, 00101, 00201, - - -). The performance of each command involves four phases:

Phase I	Wait to read next command.
Phase II	Read next command.
Phase III	Wait to execute command.
Phase IV	Execute command.

For example, a command in 00001 to store A in 03004 will be read (Phase II) in sector 000, held for execution (Phase III) in sectors 001 through 027, executed (Phase IV) in sector 030, and held while waiting to read the next command (Phase I) in sectors 031 through 000. Phase II will follow in sector 001 to read the next command in 00101.

There are four classes of commands in which the nature of Phase IV differs. A tabulation showing into which class each command falls is provided in Table 1.

CLASS 1.
In this class of commands, execution always follows the reading of the command by skipping Phase III. The sector number in the command is used to designate the first sector number in which Phase IV is discontinued. This class of commands consists of all those which require an extended interval of execution such as block transfer, shifting, and multiplication. The execution time for this class of command varies with the required duration. For example, block transfers require 12 microseconds per word, shifting requires 12 microseconds per bit, and multiplication requires 12 microseconds per multiplier bit.

CLASS 2.
In this class of commands, execution is always completed in the sector specified by the sector number of the command. This class consists of all one-sector operations such as load, store, add,

TABLE 1.—COMMAND CLASSIFICATION.

CLASS 1.—Executed between command location and address sector number

HALT	HLT	(00)
MERGE A INTO C	MAC	(00)
NORMALIZE AND DECREMENT	NAD	(20)
LEFT SHIFT AND DECREMENT	LSD	(21)
RIGHT SHIFT AND INCREMENT	RSI	(22)
SCALE RIGHT AND INCREMENT	SAI	(23)
NO OPERATION	NOP	(24)
INTERCHANGE A AND M	IAM	(25)
MOVE LINE X TO LINE 7	MLX	(26)
SQUARE ROOT	SQR	(30)
DIVIDE	DIV	(31)
DIVIDE REMAINDER	DVR	(31)
MULTIPLY	MUP	(32)
SHIFT B RIGHT	SBR	(33)
WRITE OUTPUT CHARACTER	WOC	(6X)
PULSE TO SPECIFIED UNIT	PTU	(70)
MOVE COMMAND LINE BLOCK	MCL	(71)
BLOCK SERIAL OUTPUT	BSO	(72)
BLOCK SERIAL INPUT	BSI	(73)

CLASS 2.—Executed in address sector number.

INTERCHANGE A AND C	IAC	(01)
INTERCHANGE B AND C	IBC	(02)
LOAD A	LDA	(05)
LOAD B	LDB	(06)
LOAD C	LDC	(04)
STORE A	STA	(11)
STORE B	STB	(12)
STORE C	STC	(10)
ADD	ADD	(14)
SUBTRACT	SUB	(15)
EXTEND BIT PATTERN	EBP	(40)
GRAY TO BINARY	GTB	(41)
AND M & C	AMC	(42)
CLEAR A	CLA	(45)
CLEAR B	CLB	(43)
CLEAR C	CLC	(44)
AND OR COMBINED	AOC	(46)
EXTRACT FIELD	EXF	(47)
DISCONNECT INPUT UNIT	DIU	(50)
READ TYPEWRITER KEYBOARD	RTK	(51)
READ PAPER TAPE	RPT	(52)
READ FAST UNIT	RFU	(53)
LOAD A FROM INPUT BUFFER	LAI	(55)
COMPARE A AND M	CAM	(56)
CLEAR INPUT BUFFER	CIB	(57)

CLASS 3.—Executed in address sector number and following sector.

ROTATE	ROT	(03)
LOAD DOUBLE PRECISION	LDP	(07)
STORE DOUBLE PRECISION	STD	(13)
DOUBLE PRECISION ADD	DPA	(16)
DOUBLE PRECISION SUBTRACT	DPS	(17)

CLASS 4.—Executed between command location and address sector number.

TRANSFER UNCONDITIONALLY	TRU	(37)
TRANSFER IF A NEGATIVE	TAN	(35)
TRANSFER IF B NEGATIVE	TBN	(36)
TRANSFER IF C NEGATIVE	TCN	(34)
TRANSFER ON OVERFLOW	TOF	(75)
TRANSFER ON EXTERNAL SIGNAL	TES	(77)

and clear. All commands of this class require 12 microseconds to execute.

CLASS 3.
Class 3 is an extension of Class 2 to handle double precision operations. As in Class 2, execution always starts in the sector specified by the sector number of the command but the execution phase is always extended into the following sector. All commands of this class require 24 microseconds to execute.

CLASS 4.
Class 4 consists of commands for conditional and unconditional transfer of control. The condition for a conditional transfer is tested in Phase II and, if the condition is met, the next command is read from the line and sector number specified by the command. If the condition is not met, the command directly following the transfer of control command is read. A conditional transfer where the condition is not met, thus requires no execution time. The unconditional transfer selects the next command with no restrictions. The execution time when control is transferred is 12 microseconds per sector for the interval between the transfer of control command and the next command.

With commands stored in sequential sectors, the indicated command sequence will proceed at the rate of one instruction per (3072 + 12) microseconds. To provide for a higher computation rate, a Sequence Tag of one may be used in bit position 8 of commands in Classes 1, 2, and 3. The use of this option will dictate that the next command will be read in the sector directly following the end of the execution phase. For example, a command in 00001 to store A in 03004 will be followed by the command in 03101 if the Sequence Tag is a one. The use of the Sequence Tag will increase the computation rate from 300 commands per second to a rate approaching 40,000 commands per second.

When the 16-word line, line 00, is used as the command line, the command sequence will be improved. For example, a command read from location 00100 to store A in 03004 will be executed in sector 030 and the next normal command in location 00200 will be read in sector 042. If the Sequence Tag is one in the command, the next command will be read in sector 031 and will be, therefore, the command in location 01100.

Parity Check

The arithmetic registers and each memory word carry an additional position for an even parity check. This position is not under program control and need not concern the programmer in the design and coding of his problem. The parity check is generated during the execution of the STORE and MOVE commands and is tested when loading the arithmetic registers, during adding and subtracting operations, and when reading commands.

Computation will stop on a parity error, and may be restarted by clearing the parity flip-flop with the BREAKPOINT SWITCH and the ENABLE SWITCH of the typewriter.

2. PB 250 COMMANDS

Introduction

The commands described in this chapter have been grouped according to function. Mnemonics are derived from or are abbreviations of the command names. For example, DIV is derived from DIVIDE, STA from STORE A, and LSD from LEFT SHIFT AND DECREMENT.

Certain conventions are employed in this and subsequent chapters to facilitate the illustration of the various computer functions. A program step is shown as follows:

LOCATION	OP CODE	ADDRESS

The Location is the memory location in which the command is stored. The OP Code refers to the operation, such as LOAD A or STORE C, and in this field the mnemonic code is used for convenience. The Address contains the operand. The command SUBTRACT 23204, which is located at 22101, is designated by:

LOCATION	OP CODE	ADDRESS
22101	SUB	23204

The letters A, B, and C refer to the arithmetic registers; the letter M symbolizes a memory location. Parentheses around A, B, C, or M indicate the contents of that register or word. For example, (A) indicates the contents of A, (M) the contents of M, and (AB) the contents of A and B as one register.

In cases where there might be confusion as to whether a number is binary, decimal, or octal, a subscript will be used to indicate which number base applies. For instance, $10110)_2$ indicates a binary number, $496210)_{10}$ a decimal number, and $37110)_8$ an octal number. The numeric code for commands is expressed in octal.

Arithmetic Commands

Add	**ADD**	**(14)**
Subtract	**SUB**	**(15)**
Double Precision Add	**DPA**	**(16)**
Double Precision Subtract	**DPS**	**(17)**
Square Root	**SQR**	**(30)**
Divide	**DIV**	**(31)**
Divide Remainder	**DVR**	**(31)**
Multiply	**MUP**	**(32)**
Clear A	**CLA**	**(45)**
Clear B	**CLB**	**(43)**
Clear C	**CLC**	**(44)**
Gray To Binary	**GTB**	**(41)**
Compare A and M	**CAM**	**(56)**

In the use of the commands ADD, SUBTRACT, DOUBLE PRECISION ADD, and DOUBLE PRECISION SUBTRACT, the resulting value may exceed the capacity of the arithmetic registers. In this event, the Overflow Switch is turned on. The command TRANSFER ON OVERFLOW is used to test for this condition.

ADD Add (14)

The contents of M, the specified address, are added to the contents of the A register. This sum replaces the contents of A; the contents of M are unaffected. Overflow is possible.

SUB Subtract (15)

The contents of M, the specified address, are subtracted from the contents of the A register. The result re-

places the contents of A; the contents of M are unaffected. Overflow is possible.

Double Precision Operations

Double precision numbers must be stored in consecutive words and the specified address is the lower ordered address. For example, if the specified memory location is 03404, the double precision number is stored in memory locations 03404 and 03504. The location 03404 contains the Least Significant Word (LSW) and 03504 contains the Most Significant Word (MSW). In double precision operations, the A and B registers are combined and treated as one register.

DPA Double Precision Add (16)

The contents of the word pair starting at M, the specified address, are added to the contents of the combined A and B registers. The result replaces the contents of A and B. The word pair at M is not affected. Position 0 of the B register does not act as a sign but is a part of the number and any carry from position 0 propagates into position 21 of the A register. Overflow is possible.

DPS Double Precision Subtract (17)

The contents of the word pair starting at M, the specified address, are subtracted from the contents of the combined A and B registers. The result replaces the contents of A and B. The word pair at M is not affected. Position 0 of the B register does not act as a sign but is a part of the number and any carry from position 0 propagates into position 21 of the A register. Overflow is possible.

SQR Square Root (30)

The argument is (AB), the square root appears in B and the remainder in A. The C register takes part in the operation and its contents are replaced by the square root. This result in C will always be scaled as the full root but it will differ from (B) in the least significant bit computed. If only A is loaded with the argument, B should be cleared or it may influence the least significant bit of the computed root.

The address field of the SQUARE ROOT command is not used to specify the location of an operand, but contains an address number, N, which specifies the first sector number following the completion of the operation. The SQUARE ROOT command is a variable length operation and, as such, the programmer may specify a quantity, S, which is the number of bits of the root that are to be developed, starting with the half unit bit. The programmer should determine if the argument is positive before performing a SQUARE ROOT operation. If the binary point is always considered as being to the right of the sign bit, and S is $25)_8$, then the full root is formed in B with the binary point to the right of the sign bit. N is determined from S in the following manner:

$N)_8 = \text{The sector number of the command})_8 + S)_8 + 1)_8.$

For example: It is desired to generate a full root of 21 bits plus sign in B and the SQUARE ROOT command is in 00104.

LOCATION	OP CODE	ADDRESS
00104	SQR	02700

If a Sequence Tag of one is used, the next command is read from 02704. With a Sequence Tag of zero the next command is read from 00204.

When S is $12)_8$, the half unit bit is formed in bit 12 of B, the one-fourth unit bit is formed in bit 13 of B, etc. Bit 11 of B will be a zero, and bits originally in bits 10 through 20 of B are moved to bits 0 through 10 of B as part of the remainder in A. The result in C will be: a plus sign in bit 0, the first nine bits of the root in bits 1 through 9, and non-useful data in bits 10 through 21. The line number of the address field *must* be 00.

DIV Divide (31)

The dividend is (AB) and the divisor is (C). The quotient appears in B, the remainder in A, and (C) are unaffected. If only A is loaded with a dividend, B should be cleared or it may influence the least significant bit of the quotient.

The address field of the DIVIDE command is not used to specify the location of an operand, but contains an address number, N, which specifies the first sector number following the completion of division. The line number of the address field *must* be 00.

The DIVIDE command is a variable length operation and, as such, the programmer may specify a quantity, S, which is the number of bits of the quotient, including a units bit, that are to be developed. The sign bit is always developed in addition to the S bits. If the binary point is always considered as being to the right of the sign bit, and S is $26)_8$, then the full quotient is formed in B with the binary point to the right of the sign bit (the sign bit is discarded, and

replaced by the units bit). If S is $25)_8$, one-half of the quotient is formed in B with the binary point to the right of the sign bit. N is determined from S in the following manner:

$N)_8 =$ The sector number of the command$)_8 +$ $S)_8 + 1)_8$.

For example: It is desired to obtain the full quotient in B and the DIVIDE command is located in 05605.

LOCATION	OP CODE	ADDRESS
05605	DIV	10500

If a Sequence Tag of one is used, the next command is read from 10505. With a Sequence Tag of zero the next command is read from 05705.

When S is $12)_8$, the sign of the quotient in B is formed in bit 11, the units bit of the quotient is formed in bit 12, the half unit bit of the quotient is formed in bit 13, etc. The original contents of B in bits 10 through 20 are moved to bits 0 through 10 of B as part of the remainder in A.

DVR Divide Remainder (31)

To obtain the least significant half of a double length quotient, store the first quotient obtained in B and perform the DIVIDE REMAINDER command again with S equal to $26)_8$ to divide the remainder in A by (C). The second result in B may then be joined directly to the first quotient to form a normal double length number. The line number of the address field should be 01.

MUP Multiply (32)

The multiplier must be loaded into the B register and the multiplicand into the C register. The computer clears the A register and puts the product in the combined A and B registers; C is unaffected. The most significant portion of the product will appear in A. The address field of the MULTIPLY command is not used to specify the location of an operand but contains an address number, N, which specifies the first sector number following the completion of multiplication. The MULTIPLY command is a variable length operation and, as such, the programmer may specify a quantity, S, which is the number of bits, starting from the least significant end, of the multiplier to operate on the multiplicand. If the binary point is always considered to be to the right of the sign, and S is $26)_8$, then the full product is formed in A and B with the binary point to the right of the sign bit in A. Note that the sign of B is counted as a multiplier bit. If S is $27)_8$, one-half of the product is formed in A and B with the binary point to the right of the sign bit in A. N is determined from S in the following manner:

$N)_8 =$ The sector number of the command$)_8 +$ $S)_8 + 1)_8$.

For example: It is desired to obtain the full product and the MULTIPLY command is located in 01103.

LOCATION	OP CODE	ADDRESS
01103	MUP	04000

If a Sequence Tag of one is used, the next command is read from 04003. With a Sequence Tag of zero the next command is read from 01203.

The last bit used of the multiplier is treated as the sign of the multiplier. When S is $26)_8$ or $27)_8$, the normal sign is used from bit 0 of B. When S is $12)_8$, bits 13 through 21 of B are used for the multiplier, with bit 12 used for the sign. Bits 0 through 11 of B are moved to 10 through 21, with the bit in 10 repeated in 9. The product is formed in A and in bits 0 through 8 of B. The line number of the address *must* be 00.

CLA Clear A (45)

Each bit in the A register is set to zero, including the sign position.

CLB Clear B (43)

Each bit in the B register is set to zero, including the sign position.

CLC Clear C (44)

Each bit in the C register is set to zero, including the sign position.

GTB Gray To Binary (41)

The GRAY TO BINARY command sends the binary representation of a Gray-coded number in A to A. The result in A is correct if its sign is positive. If its sign is negative, the inverse of the result in A should be used.

For example: It is desired to convert the Gray-coded number in the A register to binary.

Before execution of GTB, (A) are Gray 5, + 0000006. After execution of GTB, (A) are + 0000005.

It should be noted that if the contents of the A register are negative, after executing GTB, the one's complement of the correct result is obtained.

This command will also aid in parity tests on input data. If, after this command is given, the sign of A is negative, A had an odd number of ones in bits 1 through 21.

CAM Compare A and M (56)

The contents of A are compared with the contents of M and, if the two are identical, the Overflow Switch is turned on. If not, the Overflow Switch will be turned off. In either case, (A) and (M) are unaltered and command execution continues in the regular manner. All 22 positions of A and M are compared.

Transfer Commands

Transfer Unconditionally	**TRU**	**(37)**
Transfer If A Negative	**TAN**	**(35)**
Transfer If B Negative	**TBN**	**(36)**
Transfer If C Negative	**TCN**	**(34)**
Transfer On Overflow	**TOF**	**(75)**
Transfer On External Signal	**TES**	**(77)**

TAN Transfer If A Negative (35)

If the contents of the A register are negative, the computer will take its next command from the specified address, which may be in any command line. If (A) are not negative, the next sequential command is executed. A Sequence Tag of zero is required.

TBN Transfer If B Negative (36)

If the contents of the B register are negative, the computer will take its next command from the specified address, which may be in any command line. If (B) are not negative, the next sequential command is executed. A Sequence Tag of zero is required.

TCN Transfer If C Negative (34)

If the contents of the C register are negative, the computer will take its next command from the specified address, which may be in any command line. If (C) are not negative, the next sequential command is executed. A Sequence Tag of zero is required.

TRU Transfer Unconditionally (37)

The computer will take its next command from the specified address, which may be in any command line. A Sequence Tag of one is required.

TOF Transfer On Overflow (75)

An overflow results from generating a number too large for the capacity of the arithmetic registers, specifically from the ADD, SUBTRACT, DOUBLE PRECISION ADD, and DOUBLE PRECISION SUBTRACT commands. When an overflow occurs, the Overflow Switch is turned on. The command COMPARE A AND M will also turn the Overflow Switch on if (A) are equal to (M). After execution of the command SQUARE ROOT, the Overflow Switch is turned off.

The TRANSFER ON OVERFLOW command will cause the computer to take its next command from the specified address if the Overflow Switch is on, and *then turn the switch off*. If the Overflow Switch is not on, the next sequential command is executed. Transfer may be to any command line. A Sequence Tag of zero is required for conditional transfer. A Sequence Tag of one provides an unconditional transfer and turns the Overflow Switch off, if on.

TES Transfer On External Signal (77)

This command will cause the computer to take its next command from the specified address upon sensing a signal from a source external to the computer. The nature of this signal is specified by the line number portion of the address. In the standard PB 250, line numbers 25 through 37 are used to specify the following input signals:

Lines 25 – 32: Arbitrary input signals.

Line 33: Magnetic tape reader clock input signal.

Line 34: Photo tape reader sprocket input signal.

Line 35: BREAKPOINT SWITCH input signal.

Line 36: Typewriter or paper tape reader character input complete signal.

Line 37: Typewriter not ready for an output character signal.

Line numbers 00 through 24 will provide additional input selectors which may be obtained as an option for additional arbitrary input signals. Since the line number of the address is reserved for signal specification, the effected transfer can be only to some sector in the same line as the TRANSFER ON EXTERNAL SIGNAL command.

For example:

LOCATION	OP CODE	ADDRESS
02206	TES	02736

If a transfer is effected, the computer will take the next command from location 02736. If no transfer is effected, the next command will be executed from 02306. The Sequence Tag should always be zero for this command.

Loading and Storing Commands

Load A	**LDA**	**(05)**
Load B	**LDB**	**(06)**
Load C	**LDC**	**(04)**
Load Double Precision	**LDP**	**(07)**
Interchange A and C	**IAC**	**(01)**
Interchange B and C	**IBC**	**(02)**
Interchange A and M	**IAM**	**(25)**
Rotate	**ROT**	**(03)**
Store A	**STA**	**(11)**
Store B	**STB**	**(12)**
Store C	**STC**	**(10)**
Store Double Precision	**SDP**	**(13)**
Move Command Line Block	**MCL**	**(71)**
Move Line X To Line 7	**MLX**	**(26)**

LDA Load A (05)

The A register is cleared and the contents of M, the specified address, are read into the A register. The contents of M are not affected.

For example: It is desired to load the A register with the contents of memory location M.

	(A)	(M)
Before execution of command	0423361	-0644551
After execution of command	-0644551	-0644551

LDB Load B (06)

The B register is cleared and the contents of M, the specified address, are read into the B register. The contents of M are not affected.

LDC Load C (04)

The C register is cleared and the contents of M, the specified address, are read into the C register. The contents of M are not affected.

LDP Load Double Precision (07)

Both the A and B registers are cleared. The contents of M, the specified address, are read into the B register and the contents of the next memory location are read into the A register. The contents of the two memory locations are not affected.

IAC Interchange A and C (01)

The contents of the A register are loaded into the C register and the contents of the C register are loaded into the A register.

For example:

	(A)	(C)
Before execution of INTERCHANGE A AND C	1012556	-3543255
After execution of INTERCHANGE A AND C	-3543255	1012556

IBC Interchange B and C (02)

The contents of the B register are loaded into the C register and the contents of the C register are loaded into the B register.

IAM Interchange A and M (25)

This command interchanges the information in the line designated by the line field of the address with the information in the A register. The interchange starts in the sector following the IAM command and continues up to, but not including, the address sector number. This command results in a one-word precession of the information in the designated line. The information originally in the A register is entered into the first sector and is replaced by the information in the last sector.

ROT **Rotate** **(03)**

The contents of the A register are loaded into the C register, the contents of the C register are loaded into the B register, and the contents of the B register are loaded into the A register.

For example:

	(A)	(B)	(C)
Before execution of ROTATE	0213405	1333624	-2453201
After execution of ROTATE	1333624	-2453201	0213405

This command requires two sectors of execution, thus an optimized ROT command would appear as follows:

LOCATION	OP CODE	ADDRESS
00203	ROT	00300

with a one in bit position 8. The next command to be executed would be located in 00503.

STA **Store A** **(11)**

The contents of the A register are stored in M, the specified address. The previous contents of M are lost and the contents of the A register are not affected.

For example: Store the contents of the A register in memory location M.

	(A)	(M)
Before execution of STORE A	0021213	-6000457
After execution of STORE A	0021213	0021213

STB **Store B** **(12)**

The contents of the B register are stored in M, the specified address. The previous contents of M are lost and the contents of the B register are not affected.

STC **Store C** **(10)**

The contents of the C register are stored in M, the specified address. The previous contents of M are lost and the contents of the C register are not affected.

STD **Store Double Precision** **(13)**

This command operates on both the A and B registers. The contents of the B register are stored in M, the specified address, and the contents of the A register are stored in the memory location following M. For example, if the specified address is 00004, the contents of B are stored in 00004 and the contents of the A register are stored in 00104. The contents of A and B are not affected and the previous contents of 00004 and 00104 are lost.

Some discussion on double precision is in order. A double precision number consists of two words, or 44 bits. The commands functioning in the double precision mode will operate on two words and treat A and B as one register, where A is the Most Significant Word (MSW) and B is the Least Significant Word (LSW). These commands are STORE DOUBLE PRECISION, LOAD DOUBLE PRECISION, DOUBLE PRECISION ADD, and DOUBLE PRECISION SUBTRACT.

MCL **Move Command Line Block** **(71)**

The contents of the first word following the MCL command and all subsequent words on that line, up to but not including the address sector number, are copied into the corresponding sector positions of the address line number.

MLX **Move Line X To Line 7** **(26)**

This command transfers information from the line designated by the line field of the address (X) to line 07. The transfer starts in the sector following the MLX command and continues up to, but not including, the address sector number.

Logical and Shifting Commands

Extend Bit Pattern	**EBP**	**(40)**
And M & C	**AMC**	**(42)**
Merge A Into C	**MAC**	**(00)**
And Or Combined	**AOC**	**(46)**
Extract Field	**EXF**	**(47)**
Normalize And Decrement	**NAD**	**(20)**
Left Shift And Decrement	**LSD**	**(21)**
Right Shift And Increment	**RSI**	**(22)**
Scale Right And Increment	**SAI**	**(23)**
Shift B Right	**SBR**	**(33)**

EBP **Extend Bit Pattern** **(40)**

Starting from the right, each position of M is checked; if the position contains a zero, the corresponding position in A is unaffected. If the position contains a one, the corresponding position of A is changed so that it

is the same as the bit written to its immediate right. The (M) are unaffected. All 22 positions of A and M take part in this operation.

For example:

(M)	1 1 1 0 0 0 1 1 1 0 0 0
(A)	0 1 0 1 0 1 0 1 0 0 0 1
Result (in A register)	1 1 1 1 0 1 0 0 0 0 0 1

AMC And M & C (42)

A one is placed in each of those bit positions of B where there are ones in the corresponding positions of both C and M. Zeros are placed in all other positions of B. Neither (C) nor (M) are altered.

For example:

(M)	1 1 0 0
(C)	1 0 1 0
Result (in B register)	1 0 0 0

All 22 positions of M, B, and C take part in this operation.

MAC Merge A Into C (00)

A one is placed in each of those bit positions of C where there is a one in the corresponding positions of A or C, or in both; thus, a logical OR is accomplished. Zeroes are placed in all other positions of C.

For example:

(A)	0 1 0 0 1 1 1 0 0 1 1 1
(C)	1 0 0 0 0 1 1 0 0 0 1 1
Result (in C register)	1 1 0 0 1 1 1 0 0 1 1 1

All 22 positions of A and C take part in this operation. The address field of this command is not used to specify the location of an operand but *must* contain an address number which is the sector number of the command +1.

AOC And Or Combined (46)

Symbolically, this command is MC or $\overline{M}$B with the result appearing in B. (The notation $\overline{M}$ refers to the logical operation of negation.) For each one in M, the bit in the corresponding position of C is copied into B. For each zero in M, the bit in the corresponding position of B is preserved. All 22 positions of M, B, and C take part in this operation.

For example:

(M)	1 1 1 1 0 0 0 0
(C)	1 1 0 0 1 0 1 0
(B)	0 1 0 1 1 1 0 0
Result (in B register)	1 1 0 0 1 1 0 0

EXF Extract Field (47)

Symbolically, this command is $\overline{M}$B with the result appearing in B. For each one in M, a zero is put in the corresponding position in B. For each zero in M, the bit in the corresponding position of B is preserved.

For example:

(M)	1 1 1 0 0 0
(B)	1 1 0 1 0 1
Result (in B register)	0 0 0 1 0 1

All 22 positions of M and B take part in this operation.

NAD Normalize And Decrement (20)

The address field of the NORMALIZE AND DECREMENT command is not used to specify the location of an operand, but contains an address number, N, which specifies the first sector number following the completion of execution. In executing this command, the (AB) are shifted left until one of two conditions is met:

1. (AB) $\geqq$ ½ or (AB) $<$ $-$½ (considering the binary point between the sign and position 1).
2. (AB) have been shifted S positions (where S is selected by the programmer).

The (C) are decremented by one for each position shifted. The sign (position 0) of A does not move, but position 0 of B takes part in the shifting. The vacated positions of B are filled with zeros. The programmer should select S large enough so as not to inhibit proper normalization. S is used in determining N in the following manner:

$N)_8 = \text{The sector number of the command})_8 + S)_8 + 1)_8$.

For example: It is desired to normalize a number occupying the combined A and B registers. Choosing S equal to $53)_8$ allows for normalizing every possible number in AB but still terminates the operation if the (AB) equal zero.

LOCATION	OP CODE	ADDRESS
02206	NAD	07600

If a Sequence Tag of one is used, the next command is read from 07606. With a Sequence Tag of zero the next command is read from 02306.

LSD **Left Shift And Decrement** **(21)**

The (AB) are shifted left for S positions, S being determined by the programmer. The (C) are decremented by one for each position shifted. Bits shifted past position 1 of A are lost and zeros fill the vacated right end of B. Position 0 (the sign) of A is not moved, but position 0 of B takes part in the shifting. The address field of this command is not used to specify the location of an operand, but contains an address number, N, which is determined by:

$N)_8 = \text{The sector number of the command})_8 + S)_8 + 1)_8$.

RSI **Right Shift And Increment** **(22)**

The (AB) are shifted right for S positions, S being determined by the programmer. The (C) are incremented by one for each position shifted. The bit in the sign position of A is copied into the vacated positions of A. The bits shifted past position 21 of B are lost. Position 0 (the sign) of A is not moved but position 0 of B takes part in the shifting. The address field of this command is not used to specify the location of an operand but contains an address number, N, which is determined by:

$N)_8 = \text{The sector number of the command})_8 + S)_8 + 1)_8$.

SAI **Scale Right And Increment** **(23)**

The (AB) are shifted right and the (C) are incremented by one for each position shifted. The operation continues until one of the two conditions is met:

1. $(C) \geqq 0$.
2. (AB) are shifted S positions (where S is selected by the programmer).

The bit in the sign position of A is copied into the vacated positions of A. Position 0 (the sign) of A is not moved, but position 0 of B takes part in the shifting. S should be selected so as not to inhibit the scaling. The address field of this command is not used to specify the location of an operand but contains an address number, N, which is determined by:

$N)_8 = \text{The sector number of the command})_8 + S)_8 + 1)_8$.

SBR **Shift B Right** **(33)**

This command functions in the same way as RSI with the following exceptions:

1. The C register is not affected by this command.
2. The A register is cleared after shifting right one position.

Bits shifted past position 21 of the B register are lost. The address field of this command is not used to specify the location of an operand but contains an address number, N, which is determined by:

$N)_8 = \text{The sector number of the command})_8 + S)_8 + 1)_8$.

Control Commands

Halt	**HLT**	**(00)**
No Operation	**NOP**	**(24)**

HLT **Halt** **(00)**

This command stops computation and turns on the parity error indicator light on the console. To continue execution of the program, the ENABLE SWITCH and the BREAKPOINT SWITCH on the Flexowriter must be depressed. This will turn off the parity error indicator and, upon release of the ENABLE SWITCH, the program will continue.

The address field of this command is not used to specify the location of an operand, but *must* contain an address number other than the sector number of the command + 1.

NOP **No Operation** **(24)**

This command causes the computer to continue in regular command sequence. Memory and registers are not affected.

Input-Output Commands

Disconnect Input Unit	**DIU**	**(50)**
Read Typewriter Keyboard	**RTK**	**(51)**
Read Paper Tape	**RPT**	**(52)**
Read Fast Unit	**RFU**	**(53)**
Load A From Input Buffer	**LAI**	**(55)**
Clear Input Buffer	**CIB**	**(57)**
Write Output Character	**WOC**	**(6X)**
Pulse to Specified Unit	**PTU**	**(70)**
Block Serial Input	**BSI**	**(73)**
Block Serial Output	**BSO**	**(72)**

DIU **Disconnect Input Unit** **(50)**

The Input Buffer, which is the register for accepting input characters, is disabled. The INDICATING LIGHT of the Flexowriter, if on, is turned off.

RTK **Read Typewriter Keyboard** **(51)**

The INDICATING LIGHT on the Flexowriter is turned on, the typewriter keyboard is energized, and the Input Buffer is enabled to accept a character input. After a typewriter key has been depressed and the loading of the Input Buffer has been completed, the Flexowriter sends a signal to the computer. Upon receiving this signal, the computer de-energizes the keyboard and turns the INDICATING LIGHT off. The command TRANSFER ON EXTERNAL SIGNAL with an address line number of 36 is used to determine if the computer has received the Flexowriter signal. It is necessary to execute this command for each input character.

RPT **Read Paper Tape** **(52)**

This command causes the Flexowriter paper tape reader to read a character and enables the Input Buffer to accept this character. After the Input Buffer has been loaded, the Flexowriter sends a signal to the computer. The command TRANSFER ON EXTERNAL SIGNAL with an address line number of 36 is used to determine if the computer has received the Flexowriter signal. It is necessary to execute this command for each character input.

RFU **Read Fast Unit** **(53)**

This command will enable the Input Buffer to accept input from a fast unit such as a photo reader or a magnetic tape handler. The PULSE TO SPECIFIED UNIT command is used to select, start, and stop the selected input medium. This command differs from the other READ commands in that it is not self-disabling. The DISCONNECT INPUT UNIT command must be used to terminate the operation.

LAI **Load A From Input Buffer** **(55)**

The capacity of the Input Buffer is any character up to eight bits. This command will load the contents of the Input Buffer into positions 14 through 21 of the A register under control of a Format Word, or "mask." The Format Word must be in the same line as the LOAD A FROM INPUT BUFFER instruction, and its location is specified by the sector number of the address. Positions 0 through 13 of A are affected if the Format Word is not properly constructed. The Format Word functions as follows: In those positions of the words where there are ones, the corresponding positions bits of the Input Buffer Register are transferred to the corresponding positions of A. No other positions of A are altered. After the transfer of information to A, the Input Buffer is cleared.

CIB **Clear Input Buffer** **(57)**

Zero bits are placed in all positions of the Input Buffer. Execution will occur during the sector number of the address.

WOC **Write Output Character** **(6X)**

A single character up to eight bits may be sent to an output unit. The character is incorporated into the command and occupies positions 12 through 19 (the line number field and the right-most three positions of the OP code field). The X in the numerical code (6X) is thus determined by the output character. The output medium is determined by the command line from which the command is executed. The output is to the typewriter when the command is executed from line 05, and to the punch when executed from line 06.

Prior to executing the next command, the computer must be delayed to provide sufficient time for the execute phase of the designated output device. To accomplish this delay a predetermined number, in effect a delay number, must be loaded into C. When output begins, the (C) are decremented until they are negative, after which the next command is read. The (C) are decremented once each sector. A detailed outline of Flexowriter output is available in Chapter 3.

PTU Pulse To Specified Unit (70)

This command produces a specified combination of signals on five output signal lines and an "activate" signal on a sixth line. These signals are used to start and stop equipment external to the computer. The line number of the address field specifies the combination of signals, and the sector number defines the first sector number following the execution. The activate signal is presented in the sectors between the command location and the sector number.

BSI Block Serial Input (73)

This command loads information directly into memory at the rate of 0.5 microseconds per bit. Input information is presented to the computer in the form of a series of bits, normally from some external shift register. The shifting operation in the external register must be under computer clock control. A Format Block determines when a bit will be accepted from the input device. This Format Block is formed by the binary configuration of the information contained in that portion of the command line which begins with the sector following the BLOCK SERIAL INPUT command and continues up to, but not including, the address sector number in the command. The information entering the computer will be loaded into the line specified by the address in the command. It will occupy those positions of this line that correspond with one bits in the Format Block. Positions of this data line that correspond with zero bits in the Format Block will be loaded with zeros.

The following example illustrates the functioning of the BLOCK SERIAL INPUT command. The source from which information enters the computer will be called the External Register (ER). The line containing the BLOCK SERIAL INPUT command and the Format Block will be called the Command And Format Line (C & FL). The line receiving the data from (ER) will be called the Data Line (DL).

For example:

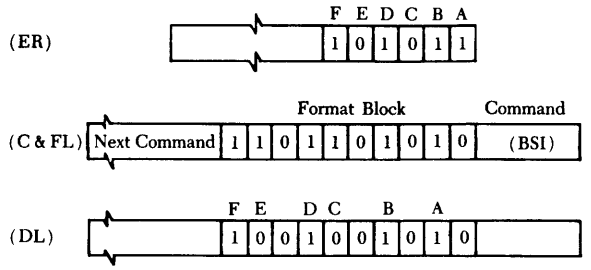


Figure 3.—Functioning of BLOCK SERIAL INPUT Command.

BSO Block Serial Output (72)

The BLOCK SERIAL OUTPUT command operates in a manner which is effectively the reverse of the BLOCK SERIAL INPUT (73) command. That is, the information in the Data Line is shifted into the External Register whenever a one appears in the Format Block. Nothing is done with the information in those positions of the Data Line which correspond to zero bits in the Format Word. For details of this command, reference is made to the description of the BLOCK SERIAL INPUT (73) command. Memory and registers are unaffected by this command.

3. INPUT-OUTPUT SYSTEM

Introduction

The PB 250 has three separate input-output systems. The first processes up to an eight-bit character from the Flexowriter, high-speed paper tape reader, or magnetic tape handlers. High-speed character input is described in the manuals for the various fast equipments. The second system is incorporated in the BLOCK SERIAL commands (72) and (73). The third system is used for control rather than for numerical information and uses the PULSE TO SPECIFIED UNIT and TRANSFER ON EXTERNAL SIGNAL commands (70) and (77).

Flexowriter

A Model FL Flexowriter is used as the control unit for the PB 250. This machine is also used to prepare, duplicate, and read tapes. The Flexowriter can be used on-line (Flexowriter under control of computer), or off-line (Flexowriter under control of operator). The general appearance and operation of the Flexowriter are similar to a standard electric typewriter. (See diagram of Flexowriter Keyboard in Figure 6.) Such features as space lever, paper release lever, platen knobs, margin release lever, ribbon position lever, margin and tab stops, and type guide, are used in exactly the same manner as for a standard typewriter. This section will be primarily concerned with the on-line mode of operation.

The Flexowriter prepares tape by punching coded holes across the width of the tape. The punched tape is prepared manually from the keyboard (off-line) or by output commands from the computer (on-line), and is described as having channels and characters. The channels run lengthwise along the tape while characters are across its width. The PB 250 system uses six channels of an eight-channel tape; the code used in this tape is pictured in Figure 5. The Tape Reader can read and type out the information contained on a coded tape. The Flexowriter type format is illustrated in Figure 4; the upper line shows the upper case characters and the lower line the lower case characters.

When the Flexowriter is under the control of the computer, its Paper Tape Reader, Typewriter Keyboard, and Paper Tape Punch are used as input-output devices by the computer. Each typewriter character has a specific code, which is sent to the computer as a pattern of six bits.

The command READ PAPER TAPE will cause the Tape Reader to read a single character and load it into the Input Buffer of the computer. The command READ TYPEWRITER KEYBOARD will turn on the INDICATING LIGHT of the Flexowriter, after which a typewriter key must be depressed in order to load the Input Buffer. The INDICATING LIGHT is turned off by the loading operation.

The command WRITE OUTPUT CHARACTER provides information to either the typewriter or the punch. It is possible to prepare a tape with as many as eight channels by this command and read such a tape back into the computer with the READ PAPER TAPE command.

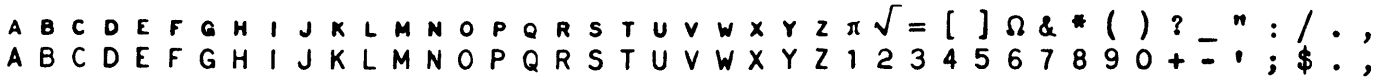


Figure 4.–Flexowriter Characters.

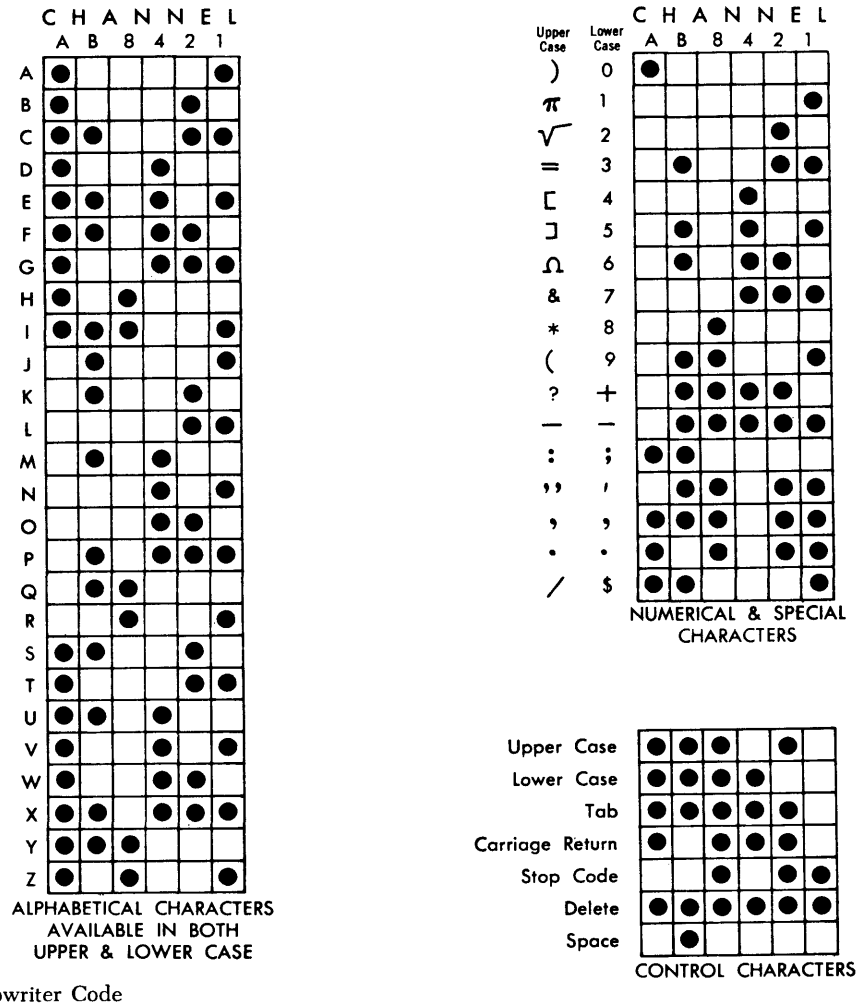


Figure 5.–Flexowriter Code

Multiple Operations

With commands READ PAPER TAPE, READ TYPEWRITER KEYBOARD, and WRITE OUTPUT CHARACTER the five kinds of multiple simultaneous operations shown below are possible with the Flexowriter.

Keyboard

The keyboard of the Flexowriter is similar to a standard typewriter keyboard and may serve many of the same purposes. The numeric, alphabetic, and symbolic keys require no explanation other than the alpha-

TABLE 2.–SIMULTANEOUS OPERATING MODES.

Number	Type In Data	Read Input Tape	Punch Output Tape	Type Output Data	Read Output Data Into Computer for Verification	Use Type in Operation to Verify each Output Character	Compute
1		X	X				X
2		X		X			X
3	X		X				X
4			X		X		X
5				X		X	X

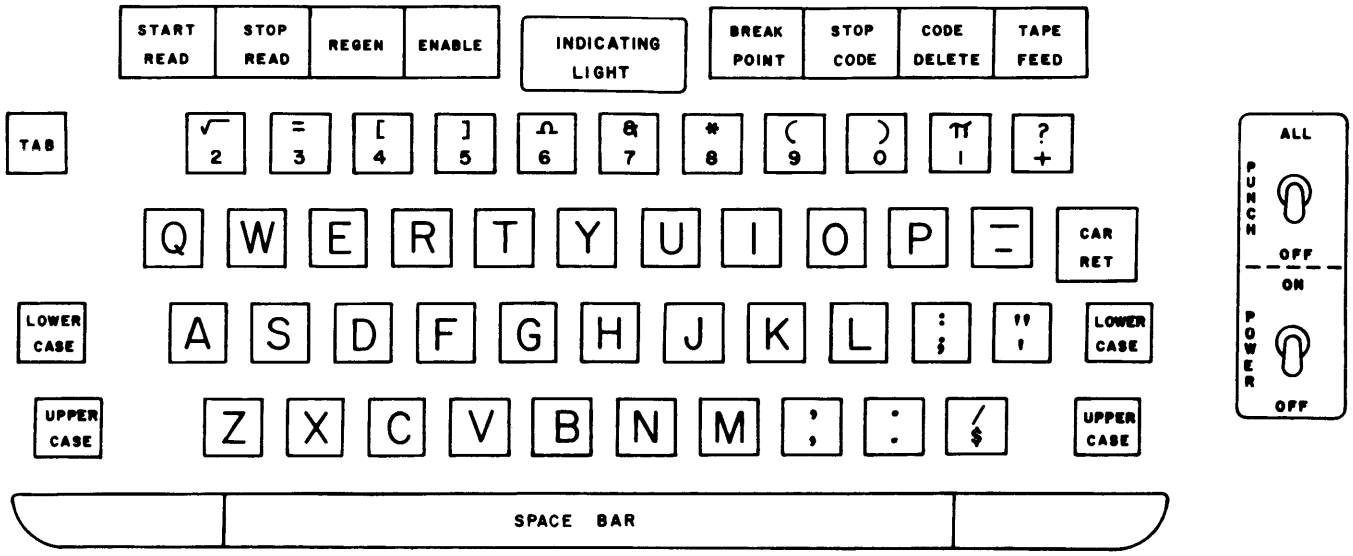


Figure 6.—Flexowriter Keyboard

numeric code for the computer as given in Figure 5. The TAB KEY, CAR RET (carriage return), LOWER CASE, UPPER CASE, and SPACE BAR are self-explanatory and are analogous to controls on a standard typewriter. The REGEN SWITCH, when depressed, permits exact duplication of the tape which is in the Flexowriter Tape Reader.

Control Switches

Certain switches and keys on the Flexowriter are used to control the computer.

ENABLE SWITCH:

1. Interrupts computation.
2. Conditions the use of other switches and keys of the Flexowriter.

BREAKPOINT SWITCH:

1. Sends signal to computer which may be tested by the command TRANSFER ON EXTERNAL SIGNAL.
2. With ENABLE SWITCH will clear parity flip-flop (indicated by PARITY light on).

I Key: With ENABLE SWITCH will cause the computer to execute the command in memory location 00001.

C Key: With ENABLE SWITCH will cause the computer to cycle by one command.

The Computer Console

The console of the PB 250, shown in Figure 7, is composed of lights and switches arranged in two rows. The top row has three sets of lights: six for OPERATION, five for OPERAND, and three for COMMAND. OPERATION specifies which OP code is being executed, i.e., ADD, LOAD A, etc. Using 1 to indicate a light on, and 0 for a light off, the pattern 001100 represents the command ADD (Command 14 in octal). OPERAND specifies the line number portion of the address, and COMMAND indicates from which command line the command is being executed.

On the second row are the O'FLOW light, PARITY light, FILL switch, TEST switches, and POWER button. The O'FLOW light is on if an overflow has occurred. The PARITY light indicates a parity check error. Computation may be started by depressing the ENABLE and BREAKPOINT SWITCHES on the Flexowriter to clear the parity flip-flop. The FILL switch is used for loading a "bootstrap loading program" and the method is outlined below. The TEST switches are utilized by the Field Service Representative for maintenance of the system. The POWER button is an alternating type, turning the power to the computer on or off.

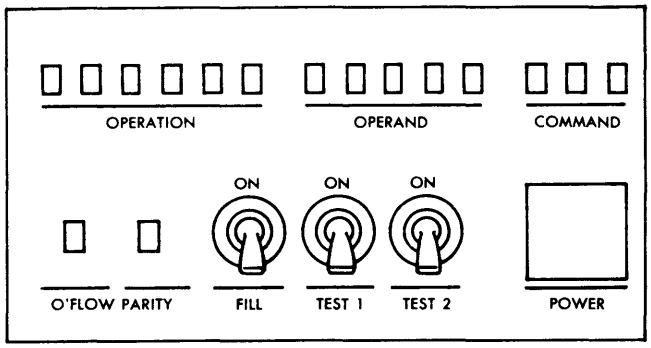


Figure 7.—PB 250 Computer Console

Loading The Computer

To start the computer after power is applied, a special one-channel service routine tape is inserted in the Tape Reader. To load the one-channel tape, the FILL switch on the front of the computer must be set on until the Tape Reader stops (about 30 seconds). When the Tape Reader stops, the service routine will be loaded with its first command in location 00001, and the parity flip-flop will be set to block computation. The ENABLE SWITCH on the Flexowriter must be depressed while the BREAKPOINT SWITCH and then the "I" key are operated to clear the parity flip-flop and set the computer to obey the first command. When the Flexowriter ENABLE SWITCH is released, the computer uses the service routine to continue loading the memory.

Flexowriter Input

The following description assumes a familiarity with the commands READ TYPEWRITER KEYBOARD, READ PAPER TAPE, LOAD A FROM INPUT BUFFER, and TRANSFER ON EXTERNAL SIGNAL, which were discussed in the preceding chapter.

The Input Buffer of the computer receives the input from the Flexowriter and can accept up to an eight-bit character. This entry is logically accumulative for each bit of the character, requiring that the buffer be cleared before each input. The Input Buffer is enabled to accept an input by either READ TYPEWRITER KEYBOARD or READ PAPER TAPE. The single character sent by the reader, or provided by the depressed typewriter key, is loaded into the buffer and upon completion of buffer loading the computer is signaled by the Flexowriter. This action requires a period of time, during which it is possible to execute a large number of commands.

The command TRANSFER ON EXTERNAL SIGNAL is used to determine if the computer has received the Flexowriter signal and, upon a positive indication, the contents of the buffer may be loaded into the A register by the LOAD A FROM INPUT BUFFER command. After approximately 60 milliseconds, it is possible to execute another READ TYPEWRITER KEYBOARD or READ PAPER TAPE command to read in the next character.

Program steps to accomplish this character input are as follows (Dotted lines indicate intervening program steps):

OP CODE	ADDRESS
RPT	
. . .	. . . . .
. . .	. . . . .
TES	Address of LAI instruction
. . .	. . . . .
LAI	Address of Format Word

It is possible, after executing READ TYPEWRITER KEYBOARD, that a typewriter key is not depressed. In anticipation of such an event, the programmer may provide commands to "wait" a period of time and then go on with computation. In this case, the commands DISCONNECT INPUT UNIT and CLEAR INPUT BUFFER should be used to turn off the Flexowriter INDICATING LIGHT and clear the buffer.

Flexowriter Output

As with the input system, the output system is capable of transmitting characters with any number of bits up to a maximum of eight. In the case of outputs, however, the character sent to the output unit is part of the WRITE OUTPUT CHARACTER command. This is illustrated in the following figure of the command word structure.

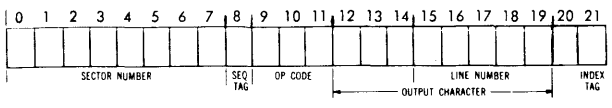


Figure 8.—Position of output character in command word.

The three right-hand bits of the OP code and the five left-hand bits of the line address contain the code for the output character. For outputs to the typewriter, the output command must be located in line 05, whereas for outputs to the punch, the output command must be located in line 06.

Just prior to the execution of the command WRITE OUTPUT CHARACTER, a "delay" number must be loaded into the C register. This delay number is used to provide the output unit with a sufficiently long signal. The value of the delay number is related to the amount of time required by a particular output device. For the Flexowriter the delay numbers are:

Paper Tape Punch	$0002424)_8$
Typewriter	$0003232)_8$

During execution of the output command, the delay number is decremented, and execution is completed after the (C) become negative. The next command to be executed will be located in the next sequential location of the command line if there is no sequence bit, and from the addressed sector of the command line if there is a sequence bit. The time necessary to execute the output command is (12 x delay number) microseconds. The output cycle, then, consists of two commands. The first loads the delay number into C; the second, the WRITE OUTPUT CHARACTER command (with the character incorporated in the command), activates the output unit.

In order to keep the Flexowriter operating at maximum speed, an output command must be available every 105 milliseconds. For the punch an execute phase of 15 milliseconds is required, leaving 90 milliseconds for computation before the next output command is required; for the typewriter an execute phase of 20 milliseconds is required, leaving 85 milliseconds for computation. In either case, a maximum of between 3,000 and 4,000 commands can be executed between consecutive output operations while operating the Flexowriter or punch at maximum speed of approximately 10 characters per second. To prevent typing an output character before the Flexowriter has completed the previous character, the TRANSFER ON EXTERNAL SIGNAL command with an address line number of 37 should be used to test the readiness of the typewriter. In the case of the punch, however, no signal is available, and an adequate delay must be built into the program itself.

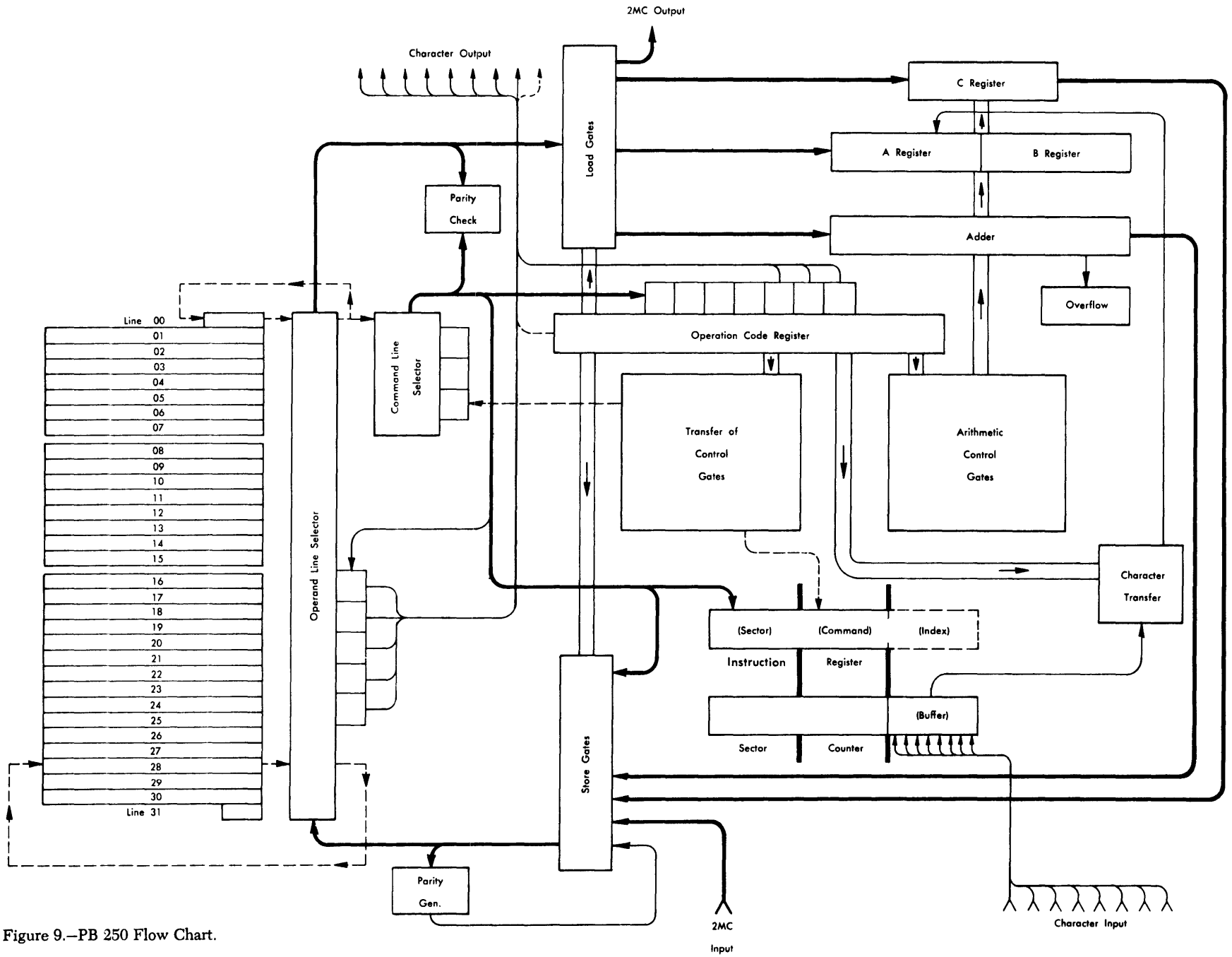


Figure 9.–PB 250 Flow Chart.

4. FUNCTIONAL COMPUTER LOGIC

The flow of information is built around the operation of the circulating memory lines and registers as indicated in the Flow Chart, Figure 9. The program commands are obtained through the Command Line Selector which is set to one of the seven long lines or to the Fast Access Line. As each command is read from a command line, its component fields are set into the proper storage elements to control the execution of the command. Depending upon the Index Tag of the command, either the line number of the address or the line number in the Index Register is entered into the Operand Line Selector. The OP code and Sequence Tag are entered into the Operation Code Register, while the sector number of the address is entered into the Instruction Register. As the command is read, the next command sector number in the Instruction Register is advanced by one count.

Depending on the command read, the computer goes through a wait to execute phase, an execute phase, and a wait to read next command phase. The timing for the execute phase is provided by comparing the address sector number in the Instruction Register with the sector numbers in the Sector Counter. The timing for the read command phase is provided by comparing the next command sector number in the Instruction Register with the sector numbers in the Sector Counter.

For load commands, the OP code routes the data from the Operand Line Selector into one of the circulating registers, A, B, or C. The flow for a 2 mc serial output follows a similar path. For store commands, the OP code selects one of the registers as a source of data to be stored through the Operand Line Selector. A 2 mc serial input also follows this type of path. A Parity Code is generated with each store command and checked with each load command.

Addition and subtraction into the A register or the A and B register pair is accomplished by routing the data through the Adder. These operations are checked for Overflow. For other arithmetic operations, such as multiplication, the OP code conditions the Arithmetic Control Gates to execute the prescribed operations on the contents of A, B, and C.

For several OP codes, a transfer of control may be conditional, depending upon the signs of A, B, or C or an Overflow or upon external inputs. If the conditions of the transfer are met, the address in the command is used to change the Command Line Selector as well as the next command sector number in the Instruction Register.

An eight-bit Buffer is provided in the Sector Counter for input characters. These may be transferred upon command to the A register. An eight-bit character output is provided by the Operand Line Selector and three stages of the Operation Code Register. An activate signal is obtained from the Operation Code Register to indicate the transmission of each output character.

A load or store command with an address indicating line $37)_8$ operates on the Index Register portion of the Instruction Register. The data in this portion of the Instruction Register is called into the Operand Selector by an Index Tag of one in the command.

APPENDIX A

Binary-Octal Number Systems

Numerical Systems

Any number can be represented as the sum of a group of terms, having the form $a_n\ b^n \ldots + a_3\ b^3 + a_2\ b^2 + a_1\ b^1 + a_0\ b^0$, where $b > 1$ and $0 \leq a \leq (b\text{-}1)$. The integer b is called the base, or radix of the particular numerical system, while *a* represents the range of numerical values in that system.

Decimal System

The numerical system of radix 10 is called the decimal system. In this case, numerical values are specified by combining powers of ten in the form of $a_n\ (10^n) \ldots + a_3\ (10^3) + a_2\ (10^2) + a_1\ (10^1) + a_0\ (10^0)$. The usual practice, when writing decimal numbers, is to omit the powers of ten and write out only the values of *a*. For example, consider the decimal number 1875. This number actually represents $1\ (10^3) + 8\ (10^2) + 7\ (10^1) + 5\ (10^0)$ but for the sake of convenience is merely written as 1875, with the position of the particular decimal digit indicating with which power of ten the digit is associated.

Binary System

The PB 250 operates in the binary or radix 2 mode; hence, to understand the operation of the computer, an understanding of binary arithmetic is essential.

Here, numerical values are specified by combining powers of two in the form $a_n\ (2^n) \ldots + a_3\ (2^3) + a_2\ (2^2) + a_1\ (2^1) + a_0\ (2^0)$. As before, the usual practice when writing binary numbers is to omit the powers of two and write out only the values of the *a* terms. For example, consider the binary number 1011. This number actually represents $1\ (2^3) + 0\ (2^2) + 1\ (2^1) + 1\ (2^0)$ but for the sake of convenience is merely written as 1011, with the position of the particular binary digit (or bit) indicating with which power of two the digit is associated.

Binary-to-Decimal Conversion

The relationship between binary and decimal notation becomes obvious if, in the above binary example, the powers of two are actually added up, giving a result of $8 + 0 + 2 + 1 = 11)_{10}$; therefore, $1011)_2 = 11)_{10}$.

NOTE

The notation $)_{10}$ indicates that the particular number is in the radix 10, or decimal system. The notation $)_2$ indicates radix 2, or binary system, and $)_8$ indicates radix 8, or octal system.

Any decimal number can be represented in binary by the summation of appropriate powers of two. Table 3 shows how any decimal number up to 12 can be written in binary form. The relation between the number of bits, n, and the highest decimal digit, N, that these bits can represent is $N = (2^n - 1)$. Thus, in the 4-bit Table 3, the highest decimal value possible is $(2^4 - 1)$ or $15)_{10}$ which would appear in Table 3 as $1111)_2$.

TABLE 3.–DECIMAL NUMBER EQUIVALENTS

Decimal	Binary			
	2^3	2^2	2^1	2^0
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0

Decimal-to-Binary Conversion

One method of converting decimal numbers to binary is to divide the decimal number repeatedly by two, ignoring the remainder each time, until the decimal number is reduced to one or zero. Then, reading from the end, the successive remainders will be the binary representation of the original decimal number.

Octal Notation

As the decimal number increases in magnitude, its

binary representation becomes rather long and inconvenient to handle; hence, the octal system (radix 8) is used as a convenient shorthand notation for binary numbers.

Binary-to-Octal Conversion

Since $2^3 = 8$, it can be seen that three binary digits are represented by one octal digit. The binary-to-octal conversion is performed by merely grouping the binary number into 3-bit units, starting from the binary point, and interpreting each unit individually. For instance, the number $101011010)_2$ becomes

101	011	010
5	3	2

or $532)_8$. Conversely, it can be seen that any octal number can be translated to binary by simply writing the binary equivalent of each digit. For instance, the number $612)_8$ becomes

6	1	2
110	001	010

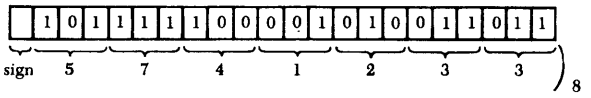
or $110001010)_2$.

PB 250 Data Word

A data word in the PB 250 consists of 21 bits plus sign; therefore, the highest number that can be stored in one memory word is $(2^{21} - 1)$ or

a) $111\ 111\ 111\ 111\ 111\ 111\ 111)_2$
b) $7,\ 777,\ 777)_8$
c) $2,\ 097,\ 151)_{10}$

A typical data word might appear as shown below. (Note the convenience of the octal notation.)



Binary Complementary Arithmetic

Certain computer operations, such as subtraction or the manipulation of negative numbers, are performed in the computer by using the complement of the particular number. An understanding of complementary arithmetic is therefore important as an aid in understanding computer operation.

The 1's complement of a binary number is defined as the number that must be added to the original number to give a result consisting of all 1's. The 1's complement is obtained by simply inverting, i.e., by changing all 1's to 0's and changing all 0's to 1's in the given binary number. For example, the 1's complement of 1010110 would be 0101001.

The 2's (or "true") complement of a binary number is formed by first finding the 1's complement of the number and then adding 1 to the least significant bit position.

For example, the 2's complement of 1010110 would be the 1's complement (0101001) plus 1, or 0101010.

Note how negative numbers are manipulated using complementary arithmetic. For example, add $111)_2$ to $-010)_2$. Replacing the negative number by its 2's complement makes the problem 111 + 110. Adding (neglecting overflow), gives $101)_2$, which is the correct answer.

Similar examples are indicated below in decimal, binary, and complemented binary forms. The complemented binary form has a leading zero, to indicate positive numbers, which becomes a leading one when complemented for negative numbers. A negative answer appears in complemented form with a leading one.

	Decimal	Binary	Complemented Binary
a)	+12	+1100	0 1100
	−04	−0100	1 1100
	+08	+1000	0 1000
b)	+10	+1010	0 1010
	−10	−1010	1 0110
	+00	+0000	0 0000
c)	+12	+1100	0 1100
	−14	−1110	1 0010
	−02	−0010	1 1110

APPENDIX B

Table of Powers of 2

2^n	n	2^{-n}
1	0	1.0
2	1	0.5
4	2	0.25
8	3	0.125
16	4	0.062 5
32	5	0.031 25
64	6	0.015 625
128	7	0.007 812 5
256	8	0.003 906 25
512	9	0.001 953 125
1 024	10	0.000 976 562 5
2 048	11	0.000 488 281 25
4 096	12	0.000 244 140 625
8 192	13	0.000 122 070 312 5
16 384	14	0.000 061 035 156 25
32 768	15	0.000 030 517 578 125
65 536	16	0.000 015 258 789 062 5
131 072	17	0.000 007 629 394 531 25
262 144	18	0.000 003 814 697 265 625
524 288	19	0.000 001 907 348 632 812 5
1 048 576	20	0.000 000 953 674 316 406 25
2 097 152	21	0.000 000 476 837 158 203 125
4 194 304	22	0.000 000 238 418 579 101 562 5
8 388 608	23	0.000 000 119 209 289 550 781 25
16 777 216	24	0.000 000 059 604 644 775 390 625
33 554 432	25	0.000 000 029 802 322 387 695 312 5
67 108 864	26	0.000 000 014 901 161 193 847 656 25
134 217 728	27	0.000 000 007 450 580 596 923 828 125
268 435 456	28	0.000 000 003 725 290 298 461 914 062 5
536 870 912	29	0.000 000 001 862 645 149 230 957 031 25
1 073 741 824	30	0.000 000 000 931 322 574 615 478 515 625
2 147 483 648	31	0.000 000 000 465 661 287 307 739 257 812 5
4 294 967 296	32	0.000 000 000 232 830 643 653 869 628 906 25
8 589 934 592	33	0.000 000 000 116 415 321 826 934 814 453 125
17 179 869 184	34	0.000 000 000 058 207 660 913 467 407 226 562 5
34 359 738 368	35	0.000 000 000 029 103 830 456 733 703 613 281 25
68 719 476 736	36	0.000 000 000 014 551 915 228 366 851 806 640 625
137 438 953 472	37	0.000 000 000 007 275 957 614 183 425 903 320 312 5
274 877 906 944	38	0.000 000 000 003 637 978 807 091 712 951 660 156 25
549 755 813 888	39	0.000 000 000 001 818 989 403 545 856 475 830 078 125

APPENDIX C

Octal-Decimal Integer Conversion Table

0000 (Octal)	0000 (Decimal)
to	to
0777 (Octal)	0511 (Decimal)

Octal	Decimal
10000 -	4096
20000 -	8192
30000 -	12288
40000 -	16384
50000 -	20480
60000 -	24576
70000 -	28672

	0	1	2	3	4	5	6	7
0000	0000	0001	0002	0003	0004	0005	0006	0007
0010	0008	0009	0010	0011	0012	0013	0014	0015
0020	0016	0017	0018	0019	0020	0021	0022	0023
0030	0024	0025	0026	0027	0028	0029	0030	0031
0040	0032	0033	0034	0035	0036	0037	0038	0039
0050	0040	0041	0042	0043	0044	0045	0046	0047
0060	0048	0049	0050	0051	0052	0053	0054	0055
0070	0056	0057	0058	0059	0060	0061	0062	0063
0100	0064	0065	0066	0067	0068	0069	0070	0071
0110	0072	0073	0074	0075	0076	0077	0078	0079
0120	0080	0081	0082	0083	0084	0085	0086	0087
0130	0088	0089	0090	0091	0092	0093	0094	0095
0140	0096	0097	0098	0099	0100	0101	0102	0103
0150	0104	0105	0106	0107	0108	0109	0110	0111
0160	0112	0113	0114	0115	0116	0117	0118	0119
0170	0120	0121	0122	0123	0124	0125	0126	0127
0200	0128	0129	0130	0131	0132	0133	0134	0135
0210	0136	0137	0138	0139	0140	0141	0142	0143
0220	0144	0145	0146	0147	0148	0149	0150	0151
0230	0152	0153	0154	0155	0156	0157	0158	0159
0240	0160	0161	0162	0163	0164	0165	0166	0167
0250	0168	0169	0170	0171	0172	0173	0174	0175
0260	0176	0177	0178	0179	0180	0181	0182	0183
0270	0184	0185	0186	0187	0188	0189	0190	0191
0300	0192	0193	0194	0195	0196	0197	0198	0199
0310	0200	0201	0202	0203	0204	0205	0206	0207
0320	0208	0209	0210	0211	0212	0213	0214	0215
0330	0216	0217	0218	0219	0220	0221	0222	0223
0340	0224	0225	0226	0227	0228	0229	0230	0231
0350	0232	0233	0234	0235	0236	0237	0238	0239
0360	0240	0241	0242	0243	0244	0245	0246	0247
0370	0248	0249	0250	0251	0252	0253	0254	0255

	0	1	2	3	4	5	6	7
0400	0256	0257	0258	0259	0260	0261	0262	0263
0410	0264	0265	0266	0267	0268	0269	0270	0271
0420	0272	0273	0274	0275	0276	0277	0278	0279
0430	0280	0281	0282	0283	0284	0285	0286	0287
0440	0288	0289	0290	0291	0292	0293	0294	0295
0450	0296	0297	0298	0299	0300	0301	0302	0303
0460	0304	0305	0306	0307	0308	0309	0310	0311
0470	0312	0313	0314	0315	0316	0317	0318	0319
0500	0320	0321	0322	0323	0324	0325	0326	0327
0510	0328	0329	0330	0331	0332	0333	0334	0335
0520	0336	0337	0338	0339	0340	0341	0342	0343
0530	0344	0345	0346	0347	0348	0349	0350	0351
0540	0352	0353	0354	0355	0356	0357	0358	0359
0550	0360	0361	0362	0363	0364	0365	0366	0367
0560	0368	0369	0370	0371	0372	0373	0374	0375
0570	0376	0377	0378	0379	0380	0381	0382	0383
0600	0384	0385	0386	0387	0388	0389	0390	0391
0610	0392	0393	0394	0395	0396	0397	0398	0399
0620	0400	0401	0402	0403	0404	0405	0406	0407
0630	0408	0409	0410	0411	0412	0413	0414	0415
0640	0416	0417	0418	0419	0420	0421	0422	0423
0650	0424	0425	0426	0427	0428	0429	0430	0431
0660	0432	0433	0434	0435	0436	0437	0438	0439
0670	0440	0441	0442	0443	0444	0445	0446	0447
0700	0448	0449	0450	0451	0452	0453	0454	0455
0710	0456	0457	0458	0459	0460	0461	0462	0463
0720	0464	0465	0466	0467	0468	0469	0470	0471
0730	0472	0473	0474	0475	0476	0477	0478	0479
0740	0480	0481	0482	0483	0484	0485	0486	0487
0750	0488	0489	0490	0491	0492	0493	0494	0495
0760	0496	0497	0498	0499	0500	0501	0502	0503
0770	0504	0505	0506	0507	0508	0509	0510	0511

1000 (Octal)	0512 (Decimal)
to	to
1777 (Octal)	1023 (Decimal)

	0	1	2	3	4	5	6	7
1000	0512	0513	0514	0515	0516	0517	0518	0519
1010	0520	0521	0522	0523	0524	0525	0526	0527
1020	0528	0529	0530	0531	0532	0533	0534	0535
1030	0536	0537	0538	0539	0540	0541	0542	0543
1040	0544	0545	0546	0547	0548	0549	0550	0551
1050	0552	0553	0554	0555	0556	0557	0558	0559
1060	0560	0561	0562	0563	0564	0565	0566	0567
1070	0568	0569	0570	0571	0572	0573	0574	0575
1100	0576	0577	0578	0579	0580	0581	0582	0583
1110	0584	0585	0586	0587	0588	0589	0590	0591
1120	0592	0593	0594	0595	0596	0597	0598	0599
1130	0600	0601	0602	0603	0604	0605	0606	0607
1140	0608	0609	0610	0611	0612	0613	0614	0615
1150	0616	0617	0618	0619	0620	0621	0622	0623
1160	0624	0625	0626	0627	0628	0629	0630	0631
1170	0632	0633	0634	0635	0636	0637	0638	0639
1200	0640	0641	0642	0643	0644	0645	0646	0647
1210	0648	0649	0650	0651	0652	0653	0654	0655
1220	0656	0657	0658	0659	0660	0661	0662	0663
1230	0664	0665	0666	0667	0668	0669	0670	0671
1240	0672	0673	0674	0675	0676	0677	0678	0679
1250	0680	0681	0682	0683	0684	0685	0686	0687
1260	0688	0689	0690	0691	0692	0693	0694	0695
1270	0696	0697	0698	0699	0700	0701	0702	0703
1300	0704	0705	0706	0707	0708	0709	0710	0711
1310	0712	0713	0714	0715	0716	0717	0718	0719
1320	0720	0721	0722	0723	0724	0725	0726	0727
1330	0728	0729	0730	0731	0732	0733	0734	0735
1340	0736	0737	0738	0739	0740	0741	0742	0743
1350	0744	0745	0746	0747	0748	0749	0750	0751
1360	0752	0753	0754	0755	0756	0757	0758	0759
1370	0760	0761	0762	0763	0764	0765	0766	0767

	0	1	2	3	4	5	6	7
1400	0768	0769	0770	0771	0772	0773	0774	0775
1410	0776	0777	0778	0779	0780	0781	0782	0783
1420	0784	0785	0786	0787	0788	0789	0790	0791
1430	0792	0793	0794	0795	0796	0797	0798	0799
1440	0800	0801	0802	0803	0804	0805	0806	0807
1450	0808	0809	0810	0811	0812	0813	0814	0815
1460	0816	0817	0818	0819	0820	0821	0822	0823
1470	0824	0825	0826	0827	0828	0829	0830	0831
1500	0832	0833	0834	0835	0836	0837	0838	0839
1510	0840	0841	0842	0843	0844	0845	0846	0847
1520	0848	0849	0850	0851	0852	0853	0854	0855
1530	0856	0857	0858	0859	0860	0861	0862	0863
1540	0864	0865	0866	0867	0868	0869	0870	0871
1550	0872	0873	0874	0875	0876	0877	0878	0879
1560	0880	0881	0882	0883	0884	0885	0886	0887
1570	0888	0889	0890	0891	0892	0893	0894	0895
1600	0896	0897	0898	0899	0900	0901	0902	0903
1610	0904	0905	0906	0907	0908	0909	0910	0911
1620	0912	0913	0914	0915	0916	0917	0918	0919
1630	0920	0921	0922	0923	0924	0925	0926	0927
1640	0928	0929	0930	0931	0932	0933	0934	0935
1650	0936	0937	0938	0939	0940	0941	0942	0943
1660	0944	0945	0946	0947	0948	0949	0950	0951
1670	0952	0953	0954	0955	0956	0957	0958	0959
1700	0960	0961	0962	0963	0964	0965	0966	0967
1710	0968	0969	0970	0971	0972	0973	0974	0975
1720	0976	0977	0978	0979	0980	0981	0982	0983
1730	0984	0985	0986	0987	0988	0989	0990	0991
1740	0992	0993	0994	0995	0996	0997	0998	0999
1750	1000	1001	1002	1003	1004	1005	1006	1007
1760	1008	1009	1010	1011	1012	1013	1014	1015
1770	1016	1017	1018	1019	1020	1021	1022	1023

Octal-Decimal Integer Conversion Table

	0	1	2	3	4	5	6	7
2000	1024	1025	1026	1027	1028	1029	1030	1031
2010	1032	1033	1034	1035	1036	1037	1038	1039
2020	1040	1041	1042	1043	1044	1045	1046	1047
2030	1048	1049	1050	1051	1052	1053	1054	1055
2040	1056	1057	1058	1059	1060	1061	1062	1063
2050	1064	1065	1066	1067	1068	1069	1070	1071
2060	1072	1073	1074	1075	1076	1077	1078	1079
2070	1080	1081	1082	1083	1084	1085	1086	1087
2100	1088	1089	1090	1091	1092	1093	1094	1095
2110	1096	1097	1098	1099	1100	1101	1102	1103
2120	1104	1105	1106	1107	1108	1109	1110	1111
2130	1112	1113	1114	1115	1116	1117	1118	1119
2140	1120	1121	1122	1123	1124	1125	1126	1127
2150	1128	1129	1130	1131	1132	1133	1134	1135
2160	1136	1137	1138	1139	1140	1141	1142	1143
2170	1144	1145	1146	1147	1148	1149	1150	1151
2200	1152	1153	1154	1155	1156	1157	1158	1159
2210	1160	1161	1162	1163	1164	1165	1166	1167
2220	1168	1169	1170	1171	1172	1173	1174	1175
2230	1176	1177	1178	1179	1180	1181	1182	1183
2240	1184	1185	1186	1187	1188	1189	1190	1191
2250	1192	1193	1194	1195	1196	1197	1198	1199
2260	1200	1201	1202	1203	1204	1205	1206	1207
2270	1208	1209	1210	1211	1212	1213	1214	1215
2300	1216	1217	1218	1219	1220	1221	1222	1223
2310	1224	1225	1226	1227	1228	1229	1230	1231
2320	1232	1233	1234	1235	1236	1237	1238	1239
2330	1240	1241	1242	1243	1244	1245	1246	1247
2340	1248	1249	1250	1251	1252	1253	1254	1255
2350	1256	1257	1258	1259	1260	1261	1262	1263
2360	1264	1265	1266	1267	1268	1269	1270	1271
2370	1272	1273	1274	1275	1276	1277	1278	1279

	0	1	2	3	4	5	6	7
2400	1280	1281	1282	1283	1284	1285	1286	1287
2410	1288	1289	1290	1291	1292	1293	1294	1295
2420	1296	1297	1298	1299	1300	1301	1302	1303
2430	1304	1305	1306	1307	1308	1309	1310	1311
2440	1312	1313	1314	1315	1316	1317	1318	1319
2450	1320	1321	1322	1323	1324	1325	1326	1327
2460	1328	1329	1330	1331	1332	1333	1334	1335
2470	1336	1337	1338	1339	1340	1341	1342	1343
2500	1344	1345	1346	1347	1348	1349	1350	1351
2510	1352	1353	1354	1355	1356	1357	1358	1359
2520	1360	1361	1362	1363	1364	1365	1366	1367
2530	1368	1369	1370	1371	1372	1373	1374	1375
2540	1376	1377	1378	1379	1380	1381	1382	1383
2550	1384	1385	1386	1387	1388	1389	1390	1391
2560	1392	1393	1394	1395	1396	1397	1398	1399
2570	1400	1401	1402	1403	1404	1405	1406	1407
2600	1408	1409	1410	1411	1412	1413	1414	1415
2610	1416	1417	1418	1419	1420	1421	1422	1423
2620	1424	1425	1426	1427	1428	1429	1430	1431
2630	1432	1433	1434	1435	1436	1437	1438	1439
2640	1440	1441	1442	1443	1444	1445	1446	1447
2650	1448	1449	1450	1451	1452	1453	1454	1455
2660	1456	1457	1458	1459	1460	1461	1462	1463
2670	1464	1465	1466	1467	1468	1469	1470	1471
2700	1472	1473	1474	1475	1476	1477	1478	1479
2710	1480	1481	1482	1483	1484	1485	1486	1487
2720	1488	1489	1490	1491	1492	1493	1494	1495
2730	1496	1497	1498	1499	1500	1501	1502	1503
2740	1504	1505	1506	1507	1508	1509	1510	1511
2750	1512	1513	1514	1515	1516	1517	1518	1519
2760	1520	1521	1522	1523	1524	1525	1526	1527
2770	1528	1529	1530	1531	1532	1533	1534	1535

2000	1024
to	to
2777	1535
(Octal)	(Decimal)

Octal	Decimal
10000 -	4096
20000 -	8192
30000 -	12288
40000 -	16384
50000 -	20480
60000 -	24576
70000 -	28672

	0	1	2	3	4	5	6	7
3000	1536	1537	1538	1539	1540	1541	1542	1543
3010	1544	1545	1546	1547	1548	1549	1550	1551
3020	1552	1553	1554	1555	1556	1557	1558	1559
3030	1560	1561	1562	1563	1564	1565	1566	1567
3040	1568	1569	1570	1571	1572	1573	1574	1575
3050	1576	1577	1578	1579	1580	1581	1582	1583
3060	1584	1585	1586	1587	1588	1589	1590	1591
3070	1592	1593	1594	1595	1596	1597	1598	1599
3100	1600	1601	1602	1603	1604	1605	1606	1607
3110	1608	1609	1610	1611	1612	1613	1614	1615
3120	1616	1617	1618	1619	1620	1621	1622	1623
3130	1624	1625	1626	1627	1628	1629	1630	1631
3140	1632	1633	1634	1635	1636	1637	1638	1639
3150	1640	1641	1642	1643	1644	1645	1646	1647
3160	1648	1649	1650	1651	1652	1653	1654	1655
3170	1656	1657	1658	1659	1660	1661	1662	1663
3200	1664	1665	1666	1667	1668	1669	1670	1671
3210	1672	1673	1674	1675	1676	1677	1678	1679
3220	1680	1681	1682	1683	1684	1685	1686	1687
3230	1688	1689	1690	1691	1692	1693	1694	1695
3240	1696	1697	1698	1699	1700	1701	1702	1703
3250	1704	1705	1706	1707	1708	1709	1710	1711
3260	1712	1713	1714	1715	1716	1717	1718	1719
3270	1720	1721	1722	1723	1724	1725	1726	1727
3300	1728	1729	1730	1731	1732	1733	1734	1735
3310	1736	1737	1738	1739	1740	1741	1742	1743
3320	1744	1745	1746	1747	1748	1749	1750	1751
3330	1752	1753	1754	1755	1756	1757	1758	1759
3340	1760	1761	1762	1763	1764	1765	1766	1767
3350	1768	1769	1770	1771	1772	1773	1774	1775
3360	1776	1777	1778	1779	1780	1781	1782	1783
3370	1784	1785	1786	1787	1788	1789	1790	1791

	0	1	2	3	4	5	6	7
3400	1792	1793	1794	1795	1796	1797	1798	1799
3410	1800	1801	1802	1803	1804	1805	1806	1807
3420	1808	1809	1810	1811	1812	1813	1814	1815
3430	1816	1817	1818	1819	1820	1821	1822	1823
3440	1824	1825	1826	1827	1828	1829	1830	1831
3450	1832	1833	1834	1835	1836	1837	1838	1839
3460	1840	1841	1842	1843	1844	1845	1846	1847
3470	1848	1849	1850	1851	1852	1853	1854	1855
3500	1856	1857	1858	1859	1860	1861	1862	1863
3510	1864	1865	1866	1867	1868	1869	1870	1871
3520	1872	1873	1874	1875	1876	1877	1878	1879
3530	1880	1881	1882	1883	1884	1885	1886	1887
3540	1888	1889	1890	1891	1892	1893	1894	1895
3550	1896	1897	1898	1899	1900	1901	1902	1903
3560	1904	1905	1906	1907	1908	1909	1910	1911
3570	1912	1913	1914	1915	1916	1917	1918	1919
3600	1920	1921	1922	1923	1924	1925	1926	1927
3610	1928	1929	1930	1931	1932	1933	1934	1935
3620	1936	1937	1938	1939	1940	1941	1942	1943
3630	1944	1945	1946	1947	1948	1949	1950	1951
3640	1952	1953	1954	1955	1956	1957	1958	1959
3650	1960	1961	1962	1963	1964	1965	1966	1967
3660	1968	1969	1970	1971	1972	1973	1974	1975
3670	1976	1977	1978	1979	1980	1981	1982	1983
3700	1984	1985	1986	1987	1988	1989	1990	1991
3710	1992	1993	1994	1995	1996	1997	1998	1999
3720	2000	2001	2002	2003	2004	2005	2006	2007
3730	2008	2009	2010	2011	2012	2013	2014	2015
3740	2016	2017	2018	2019	2020	2021	2022	2023
3750	2024	2025	2026	2027	2028	2029	2030	2031
3760	2032	2033	2034	2035	2036	2037	2038	2039
3770	2040	2041	2042	2043	2044	2045	2046	2047

3000	1536
to	to
3777	2047
(Octal)	(Decimal)

Octal-Decimal Integer Conversion Table

4000 (Octal)	2048 (Decimal)
to	to
4777 (Octal)	2559 (Decimal)

Octal	Decimal
10000 -	4096
20000 -	8192
30000 -	12288
40000 -	16384
50000 -	20480
60000 -	24576
70000 -	28672

	0	1	2	3	4	5	6	7
4000	2048	2049	2050	2051	2052	2053	2054	2055
4010	2056	2057	2058	2059	2060	2061	2062	2063
4020	2064	2065	2066	2067	2068	2069	2070	2071
4030	2072	2073	2074	2075	2076	2077	2078	2079
4040	2080	2081	2082	2083	2084	2085	2086	2087
4050	2088	2089	2090	2091	2092	2093	2094	2095
4060	2096	2097	2098	2099	2100	2101	2102	2103
4070	2104	2105	2106	2107	2108	2109	2110	2111
4100	2112	2113	2114	2115	2116	2117	2118	2119
4110	2120	2121	2122	2123	2124	2125	2126	2127
4120	2128	2129	2130	2131	2132	2133	2134	2135
4130	2136	2137	2138	2139	2140	2141	2142	2143
4140	2144	2145	2146	2147	2148	2149	2150	2151
4150	2152	2153	2154	2155	2156	2157	2158	2159
4160	2160	2161	2162	2163	2164	2165	2166	2167
4170	2168	2169	2170	2171	2172	2173	2174	2175
4200	2176	2177	2178	2179	2180	2181	2182	2183
4210	2184	2185	2186	2187	2188	2189	2190	2191
4220	2192	2193	2194	2195	2196	2197	2198	2199
4230	2200	2201	2202	2203	2204	2205	2206	2207
4240	2208	2209	2210	2211	2212	2213	2214	2215
4250	2216	2217	2218	2219	2220	2221	2222	2223
4260	2224	2225	2226	2227	2228	2229	2230	2231
4270	2232	2233	2234	2235	2236	2237	2238	2239
4300	2240	2241	2242	2243	2244	2245	2246	2247
4310	2248	2249	2250	2251	2252	2253	2254	2255
4320	2256	2257	2258	2259	2260	2261	2262	2263
4330	2264	2265	2266	2267	2268	2269	2270	2271
4340	2272	2273	2274	2275	2276	2277	2278	2279
4350	2280	2281	2282	2283	2284	2285	2286	2287
4360	2288	2289	2290	2291	2292	2293	2294	2295
4370	2296	2297	2298	2299	2300	2301	2302	2303

	0	1	2	3	4	5	6	7
4400	2304	2305	2306	2307	2308	2309	2310	2311
4410	2312	2313	2314	2315	2316	2317	2318	2319
4420	2320	2321	2322	2323	2324	2325	2326	2327
4430	2328	2329	2330	2331	2332	2333	2334	2335
4440	2336	2337	2338	2339	2340	2341	2342	2343
4450	2344	2345	2346	2347	2348	2349	2350	2351
4460	2352	2353	2354	2355	2356	2357	2358	2359
4470	2360	2361	2362	2363	2364	2365	2366	2367
4500	2368	2369	2370	2371	2372	2373	2374	2375
4510	2376	2377	2378	2379	2380	2381	2382	2383
4520	2384	2385	2386	2387	2388	2389	2390	2391
4530	2392	2393	2394	2395	2396	2397	2398	2399
4540	2400	2401	2402	2403	2404	2405	2406	2407
4550	2408	2409	2410	2411	2412	2413	2414	2415
4560	2416	2417	2418	2419	2420	2421	2422	2423
4570	2424	2425	2426	2427	2428	2429	2430	2431
4600	2432	2433	2434	2435	2436	2437	2438	2439
4610	2440	2441	2442	2443	2444	2445	2446	2447
4620	2448	2449	2450	2451	2452	2453	2454	2455
4630	2456	2457	2458	2459	2460	2461	2462	2463
4640	2464	2465	2466	2467	2468	2469	2470	2471
4650	2472	2473	2474	2475	2476	2477	2478	2479
4660	2480	2481	2482	2483	2484	2485	2486	2487
4670	2488	2489	2490	2491	2492	2493	2494	2495
4700	2496	2497	2498	2499	2500	2501	2502	2503
4710	2504	2505	2506	2507	2508	2509	2510	2511
4720	2512	2513	2514	2515	2516	2517	2518	2519
4730	2520	2521	2522	2523	2524	2525	2526	2527
4740	2528	2529	2530	2531	2532	2533	2534	2535
4750	2536	2537	2538	2539	2540	2541	2542	2543
4760	2544	2545	2546	2547	2548	2549	2550	2551
4770	2552	2553	2554	2555	2556	2557	2558	2559

5000 (Octal)	2560 (Decimal)
to	to
5777 (Octal)	3071 (Decimal)

	0	1	2	3	4	5	6	7
5000	2560	2561	2562	2563	2564	2565	2566	2567
5010	2568	2569	2570	2571	2572	2573	2574	2575
5020	2576	2577	2578	2579	2580	2581	2582	2583
5030	2584	2585	2586	2587	2588	2589	2590	2591
5040	2592	2593	2594	2595	2596	2597	2598	2599
5050	2600	2601	2602	2603	2604	2605	2606	2607
5060	2608	2609	2610	2611	2612	2613	2614	2615
5070	2616	2617	2618	2619	2620	2621	2622	2623
5100	2624	2625	2626	2627	2628	2629	2630	2631
5110	2632	2633	2634	2635	2636	2637	2638	2639
5120	2640	2641	2642	2643	2644	2645	2646	2647
5130	2648	2649	2650	2651	2652	2653	2654	2655
5140	2656	2657	2658	2659	2660	2661	2662	2663
5150	2664	2665	2666	2667	2668	2669	2670	2671
5160	2672	2673	2674	2675	2676	2677	2678	2679
5170	2680	2681	2682	2683	2684	2685	2686	2687
5200	2688	2689	2690	2691	2692	2693	2694	2695
5210	2696	2697	2698	2699	2700	2701	2702	2703
5220	2704	2705	2706	2707	2708	2709	2710	2711
5230	2712	2713	2714	2715	2716	2717	2718	2719
5240	2720	2721	2722	2723	2724	2725	2726	2727
5250	2728	2729	2730	2731	2732	2733	2734	2735
5260	2736	2737	2738	2739	2740	2741	2742	2743
5270	2744	2745	2746	2747	2748	2749	2750	2751
5300	2752	2753	2754	2755	2756	2757	2758	2759
5310	2760	2761	2762	2763	2764	2765	2766	2767
5320	2768	2769	2770	2771	2772	2773	2774	2775
5330	2776	2777	2778	2779	2780	2781	2782	2783
5340	2784	2785	2786	2787	2788	2789	2790	2791
5350	2792	2793	2794	2795	2796	2797	2798	2799
5360	2800	2801	2802	2803	2804	2805	2806	2807
5370	2808	2809	2810	2811	2812	2813	2814	2815

	0	1	2	3	4	5	6	7
5400	2816	2817	2818	2819	2820	2821	2822	2823
5410	2824	2825	2826	2827	2828	2829	2830	2831
5420	2832	2833	2834	2835	2836	2837	2838	2839
5430	2840	2841	2842	2843	2844	2845	2846	2847
5440	2848	2849	2850	2851	2852	2853	2854	2855
5450	2856	2857	2858	2859	2860	2861	2862	2863
5460	2864	2865	2866	2867	2868	2869	2870	2871
5470	2872	2873	2874	2875	2876	2877	2878	2879
5500	2880	2881	2882	2883	2884	2885	2886	2887
5510	2888	2889	2890	2891	2892	2893	2894	2895
5520	2896	2897	2898	2899	2900	2901	2902	2903
5530	2904	2905	2906	2907	2908	2909	2910	2911
5540	2912	2913	2914	2915	2916	2917	2918	2919
5550	2920	2921	2922	2923	2924	2925	2926	2927
5560	2928	2929	2930	2931	2932	2933	2934	2935
5570	2936	2937	2938	2939	2940	2941	2942	2943
5600	2944	2945	2946	2947	2948	2949	2950	2951
5610	2952	2953	2954	2955	2956	2957	2958	2959
5620	2960	2961	2962	2963	2964	2965	2966	2967
5630	2968	2969	2970	2971	2972	2973	2974	2975
5640	2976	2977	2978	2979	2980	2981	2982	2983
5650	2984	2985	2986	2987	2988	2989	2990	2991
5660	2992	2993	2994	2995	2996	2997	2998	2999
5670	3000	3001	3002	3003	3004	3005	3006	3007
5700	3008	3009	3010	3011	3012	3013	3014	3015
5710	3016	3017	3018	3019	3020	3021	3022	3023
5720	3024	3025	3026	3027	3028	3029	3030	3031
5730	3032	3033	3034	3035	3036	3037	3038	3039
5740	3040	3041	3042	3043	3044	3045	3046	3047
5750	3048	3049	3050	3051	3052	3053	3054	3055
5760	3056	3057	3058	3059	3060	3061	3062	3063
5770	3064	3065	3066	3067	3068	3069	3070	3071

Octal-Decimal Integer Conversion Table

	0	1	2	3	4	5	6	7
6000	3072	3073	3074	3075	3076	3077	3078	3079
6010	3080	3081	3082	3083	3084	3085	3086	3087
6020	3088	3089	3090	3091	3092	3093	3094	3095
6030	3096	3097	3098	3099	3100	3101	3102	3103
6040	3104	3105	3106	3107	3108	3109	3110	3111
6050	3112	3113	3114	3115	3116	3117	3118	3119
6060	3120	3121	3122	3123	3124	3125	3126	3127
6070	3128	3129	3130	3131	3132	3133	3134	3135
6100	3136	3137	3138	3139	3140	3141	3142	3143
6110	3144	3145	3146	3147	3148	3149	3150	3151
6120	3152	3153	3154	3155	3156	3157	3158	3159
6130	3160	3161	3162	3163	3164	3165	3166	3167
6140	3168	3169	3170	3171	3172	3173	3174	3175
6150	3176	3177	3178	3179	3180	3181	3182	3183
6160	3184	3185	3186	3187	3188	3189	3190	3191
6170	3192	3193	3194	3195	3196	3197	3198	3199
6200	3200	3201	3202	3203	3204	3205	3206	3207
6210	3208	3209	3210	3211	3212	3213	3214	3215
6220	3216	3217	3218	3219	3220	3221	3222	3223
6230	3224	3225	3226	3227	3228	3229	3230	3231
6240	3232	3233	3234	3235	3236	3237	3238	3239
6250	3240	3241	3242	3243	3244	3245	3246	3247
6260	3248	3249	3250	3251	3252	3253	3254	3255
6270	3256	3257	3258	3259	3260	3261	3262	3263
6300	3264	3265	3266	3267	3268	3269	3270	3271
6310	3272	3273	3274	3275	3276	3277	3278	3279
6320	3280	3281	3282	3283	3284	3285	3286	3287
6330	3288	3289	3290	3291	3292	3293	3294	3295
6340	3296	3297	3298	3299	3300	3301	3302	3303
6350	3304	3305	3306	3307	3308	3309	3310	3311
6360	3312	3313	3314	3315	3316	3317	3318	3319
6370	3320	3321	3322	3323	3324	3325	3326	3327

	0	1	2	3	4	5	6	7
6400	3328	3329	3330	3331	3332	3333	3334	3335
6410	3336	3337	3338	3339	3340	3341	3342	3343
6420	3344	3345	3346	3347	3348	3349	3350	3351
6430	3352	3353	3354	3355	3356	3357	3358	3359
6440	3360	3361	3362	3363	3364	3365	3366	3367
6450	3368	3369	3370	3371	3372	3373	3374	3375
6460	3376	3377	3378	3379	3380	3381	3382	3383
6470	3384	3385	3386	3387	3388	3389	3390	3391
6500	3392	3393	3394	3395	3396	3397	3398	3399
6510	3400	3401	3402	3403	3404	3405	3406	3407
6520	3408	3409	3410	3411	3412	3413	3414	3415
6530	3416	3417	3418	3419	3420	3421	3422	3423
6540	3424	3425	3426	3427	3428	3429	3430	3431
6550	3432	3433	3434	3435	3436	3437	3438	3439
6560	3440	3441	3442	3443	3444	3445	3446	3447
6570	3448	3449	3450	3451	3452	3453	3454	3455
6600	3456	3457	3458	3459	3460	3461	3462	3463
6610	3464	3465	3466	3467	3468	3469	3470	3471
6620	3472	3473	3474	3475	3476	3477	3478	3479
6630	3480	3481	3482	3483	3484	3485	3486	3487
6640	3488	3489	3490	3491	3492	3493	3494	3495
6650	3496	3497	3498	3499	3500	3501	3502	3503
6660	3504	3505	3506	3507	3508	3509	3510	3511
6670	3512	3513	3514	3515	3516	3517	3518	3519
6700	3520	3521	3522	3523	3524	3525	3526	3527
6710	3528	3529	3530	3531	3532	3533	3534	3535
6720	3536	3537	3538	3539	3540	3541	3542	3543
6730	3544	3545	3546	3547	3548	3549	3550	3551
6740	3552	3553	3554	3555	3556	3557	3558	3559
6750	3560	3561	3562	3563	3564	3565	3566	3567
6760	3568	3569	3570	3571	3572	3573	3574	3575
6770	3576	3577	3578	3579	3580	3581	3582	3583

6000 to 6777 (Octal)	3072 to 3583 (Decimal)

Octal	Decimal
10000 -	4096
20000 -	8192
30000 -	12288
40000 -	16384
50000 -	20480
60000 -	24576
70000 -	28672

	0	1	2	3	4	5	6	7
7000	3584	3585	3586	3587	3588	3589	3590	3591
7010	3592	3593	3594	3595	3596	3597	3598	3599
7020	3600	3601	3602	3603	3604	3605	3606	3607
7030	3608	3609	3610	3611	3612	3613	3614	3615
7040	3616	3617	3618	3619	3620	3621	3622	3623
7050	3624	3625	3626	3627	3628	3629	3630	3631
7060	3632	3633	3634	3635	3636	3637	3638	3639
7070	3640	3641	3642	3643	3644	3645	3646	3647
7100	3648	3649	3650	3651	3652	3653	3654	3655
7110	3656	3657	3658	3659	3660	3661	3662	3663
7120	3664	3665	3666	3667	3668	3669	3670	3671
7130	3672	3673	3674	3675	3676	3677	3678	3679
7140	3680	3681	3682	3683	3684	3685	3686	3687
7150	3688	3689	3690	3691	3692	3693	3694	3695
7160	3696	3697	3698	3699	3700	3701	3702	3703
7170	3704	3705	3706	3707	3708	3709	3710	3711
7200	3712	3713	3714	3715	3716	3717	3718	3719
7210	3720	3721	3722	3723	3724	3725	3726	3727
7220	3728	3729	3730	3731	3732	3733	3734	3735
7230	3736	3737	3738	3739	3740	3741	3742	3743
7240	3744	3745	3746	3747	3748	3749	3750	3751
7250	3752	3753	3754	3755	3756	3757	3758	3759
7260	3760	3761	3762	3763	3764	3765	3766	3767
7270	3768	3769	3770	3771	3772	3773	3774	3775
7300	3776	3777	3778	3779	3780	3781	3782	3783
7310	3784	3785	3786	3787	3788	3789	3790	3791
7320	3792	3793	3794	3795	3796	3797	3798	3799
7330	3800	3801	3802	3803	3804	3805	3806	3807
7340	3808	3809	3810	3811	3812	3813	3814	3815
7350	3816	3817	3818	3819	3820	3821	3822	3823
7360	3824	3825	3826	3827	3828	3829	3830	3831
7370	3832	3833	3834	3835	3836	3837	3838	3839

	0	1	2	3	4	5	6	7
7400	3840	3841	3842	3843	3844	3845	3846	3847
7410	3848	3849	3850	3851	3852	3853	3854	3855
7420	3856	3857	3858	3859	3860	3861	3862	3863
7430	3864	3865	3866	3867	3868	3869	3870	3871
7440	3872	3873	3874	3875	3876	3877	3878	3879
7450	3880	3881	3882	3883	3884	3885	3886	3887
7460	3888	3889	3890	3891	3892	3893	3894	3895
7470	3896	3897	3898	3899	3900	3901	3902	3903
7500	3904	3905	3906	3907	3908	3909	3910	3911
7510	3912	3913	3914	3915	3916	3917	3918	3919
7520	3920	3921	3922	3923	3924	3925	3926	3927
7530	3928	3929	3930	3931	3932	3933	3934	3935
7540	3936	3937	3938	3939	3940	3941	3942	3943
7550	3944	3945	3946	3947	3948	3949	3950	3951
7560	3952	3953	3954	3955	3956	3957	3958	3959
7570	3960	3961	3962	3963	3964	3965	3966	3967
7600	3968	3969	3970	3971	3972	3973	3974	3975
7610	3976	3977	3978	3979	3980	3981	3982	3983
7620	3984	3985	3986	3987	3988	3989	3990	3991
7630	3992	3993	3994	3995	3996	3997	3998	3999
7640	4000	4001	4002	4003	4004	4005	4006	4007
7650	4008	4009	4010	4011	4012	4013	4014	4015
7660	4016	4017	4018	4019	4020	4021	4022	4023
7670	4024	4025	4026	4027	4028	4029	4030	4031
7700	4032	4033	4034	4035	4036	4037	4038	4039
7710	4040	4041	4042	4043	4044	4045	4046	4047
7720	4048	4049	4050	4051	4052	4053	4054	4055
7730	4056	4057	4058	4059	4060	4061	4062	4063
7740	4064	4065	4066	4067	4068	4069	4070	4071
7750	4072	4073	4074	4075	4076	4077	4078	4079
7760	4080	4081	4082	4083	4084	4085	4086	4087
7770	4088	4089	4090	4091	4092	4093	4094	4095

7000 to 7777 (Octal)	3584 to 4095 (Decimal)

APPENDIX D

Octal-Decimal Fraction Conversion Table

OCTAL	DEC.	OCTAL	DEC.	OCTAL	DEC.	OCTAL	DEC.
.000	.000000	.100	.125000	.200	.250000	.300	.375000
.001	.001953	.101	.126953	.201	.251953	.301	.376953
.002	.003906	.102	.128906	.202	.253906	.302	.378906
.003	.005859	.103	.130859	.203	.255859	.303	.380859
.004	.007812	.104	.132812	.204	.257812	.304	.382812
.005	.009765	.105	.134765	.205	.259765	.305	.384765
.006	.011718	.106	.136718	.206	.261718	.306	.386718
.007	.013671	.107	.138671	.207	.263671	.307	.388671
.010	.015625	.110	.140625	.210	.265625	.310	.390625
.011	.017578	.111	.142578	.211	.267578	.311	.392578
.012	.019531	.112	.144531	.212	.269531	.312	.394531
.013	.021484	.113	.146484	.213	.271484	.313	.396484
.014	.023437	.114	.148437	.214	.273437	.314	.398437
.015	.025390	.115	.150390	.215	.275390	.315	.400390
.016	.027343	.116	.152343	.216	.277343	.316	.402343
.017	.029296	.117	.154296	.217	.279296	.317	.404296
.020	.031250	.120	.156250	.220	.281250	.320	.406250
.021	.033203	.121	.158203	.221	.283203	.321	.408203
.022	.035156	.122	.160156	.222	.285156	.322	.410156
.023	.037109	.123	.162109	.223	.287109	.323	.412109
.024	.039062	.124	.164062	.224	.289062	.324	.414062
.025	.041015	.125	.166015	.225	.291015	.325	.416015
.026	.042968	.126	.167968	.226	.292968	.326	.417968
.027	.044921	.127	.169921	.227	.294921	.327	.419921
.030	.046875	.130	.171875	.230	.296875	.330	.421875
.031	.048828	.131	.173828	.231	.298828	.331	.423828
.032	.050781	.132	.175781	.232	.300781	.332	.425781
.033	.052734	.133	.177734	.233	.302734	.333	.427734
.034	.054687	.134	.179687	.234	.304687	.334	.429687
.035	.056640	.135	.181640	.235	.306640	.335	.431640
.036	.058593	.136	.183593	.236	.308593	.336	.433593
.037	.060546	.137	.185546	.237	.310546	.337	.435546
.040	.062500	.140	.187500	.240	.312500	.340	.437500
.041	.064453	.141	.189453	.241	.314453	.341	.439453
.042	.066406	.142	.191406	.242	.316406	.342	.441406
.043	.068359	.143	.193359	.243	.318359	.343	.443359
.044	.070312	.144	.195312	.244	.320312	.344	.445312
.045	.072265	.145	.197265	.245	.322265	.345	.447265
.046	.074218	.146	.199218	.246	.324218	.346	.449218
.047	.076171	.147	.201171	.247	.326171	.347	.451171
.050	.078125	.150	.203125	.250	.328125	.350	.453125
.051	.080078	.151	.205078	.251	.330078	.351	.455078
.052	.082031	.152	.207031	.252	.332031	.352	.457031
.053	.083984	.153	.208984	.253	.333984	.353	.458984
.054	.085937	.154	.210937	.254	.335937	.354	.460937
.055	.087890	.155	.212890	.255	.337890	.355	.462890
.056	.089843	.156	.214843	.256	.339843	.356	.464843
.057	.091796	.157	.216796	.257	.341796	.357	.466796
.060	.093750	.160	.218750	.260	.343750	.360	.468750
.061	.095703	.161	.220703	.261	.345703	.361	.470703
.062	.097656	.162	.222656	.262	.347656	.362	.472656
.063	.099609	.163	.224609	.263	.349609	.363	.474609
.064	.101562	.164	.226562	.264	.351562	.364	.476562
.065	.103515	.165	.228515	.265	.353515	.365	.478515
.066	.105468	.166	.230468	.266	.355468	.366	.480468
.067	.107421	.167	.232421	.267	.357421	.367	.482421
.070	.109375	.170	.234375	.270	.359375	.370	.484375
.071	.111328	.171	.236328	.271	.361328	.371	.486328
.072	.113281	.172	.238281	.272	.363281	.372	.488281
.073	.115234	.173	.240234	.273	.365234	.373	.490234
.074	.117187	.174	.242187	.274	.367187	.374	.492187
.075	.119140	.175	.244140	.275	.369140	.375	.494140
.076	.121093	.176	.246093	.276	.371093	.376	.496093
.077	.123046	.177	.248046	.277	.373046	.377	.498046

Octal-Decimal Fraction Conversion Table

OCTAL	DEC.	OCTAL	DEC.	OCTAL	DEC.	OCTAL	DEC.
.000000	.000000	.000100	.000244	.000200	.000488	.000300	.000732
.000001	.000003	.000101	.000247	.000201	.000492	.000301	.000736
.000002	.000007	.000102	.000251	.000202	.000495	.000302	.000740
.000003	.000011	.000103	.000255	.000203	.000499	.000303	.000743
.000004	.000015	.000104	.000259	.000204	.000503	.000304	.000747
.000005	.000019	.000105	.000263	.000205	.000507	.000305	.000751
.000006	.000022	.000106	.000267	.000206	.000511	.000306	.000755
.000007	.000026	.000107	.000270	.000207	.000514	.000307	.000759
.000010	.000030	.000110	.000274	.000210	.000518	.000310	.000762
.000011	.000034	.000111	.000278	.000211	.000522	.000311	.000766
.000012	.000038	.000112	.000282	.000212	.000526	.000312	.000770
.000013	.000041	.000113	.000286	.000213	.000530	.000313	.000774
.000014	.000045	.000114	.000289	.000214	.000534	.000314	.000778
.000015	.000049	.000115	.000293	.000215	.000537	.000315	.000782
.000016	.000053	.000116	.000297	.000216	.000541	.000316	.000785
.000017	.000057	.000117	.000301	.000217	.000545	.000317	.000789
.000020	.000061	.000120	.000305	.000220	.000549	.000320	.000793
.000021	.000064	.000121	.000308	.000221	.000553	.000321	.000797
.000022	.000068	.000122	.000312	.000222	.000556	.000322	.000801
.000023	.000072	.000123	.000316	.000223	.000560	.000323	.000805
.000024	.000076	.000124	.000320	.000224	.000564	.000324	.000808
.000025	.000080	.000125	.000324	.000225	.000568	.000325	.000812
.000026	.000083	.000126	.000328	.000226	.000572	.000326	.000816
.000027	.000087	.000127	.000331	.000227	.000576	.000327	.000820
.000030	.000091	.000130	.000335	.000230	.000579	.000330	.000823
.000031	.000095	.000131	.000339	.000231	.000583	.000331	.000827
.000032	.000099	.000132	.000343	.000232	.000587	.000332	.000831
.000033	.000102	.000133	.000347	.000233	.000591	.000333	.000835
.000034	.000106	.000134	.000350	.000234	.000595	.000334	.000839
.000035	.000110	.000135	.000354	.000235	.000598	.000335	.000843
.000036	.000114	.000136	.000358	.000236	.000602	.000336	.000846
.000037	.000118	.000137	.000362	.000237	.000606	.000337	.000850
.000040	.000122	.000140	.000366	.000240	.000610	.000340	.000854
.000041	.000125	.000141	.000370	.000241	.000614	.000341	.000858
.000042	.000129	.000142	.000373	.000242	.000617	.000342	.000862
.000043	.000133	.000143	.000377	.000243	.000621	.000343	.000865
.000044	.000137	.000144	.000381	.000244	.000625	.000344	.000869
.000045	.000141	.000145	.000385	.000245	.000629	.000345	.000873
.000046	.000144	.000146	.000389	.000246	.000633	.000346	.000877
.000047	.000148	.000147	.000392	.000247	.000637	.000347	.000881
.000050	.000152	.000150	.000396	.000250	.000640	.000350	.000885
.000051	.000156	.000151	.000400	.000251	.000644	.000351	.000888
.000052	.000160	.000152	.000404	.000252	.000648	.000352	.000892
.000053	.000164	.000153	.000408	.000253	.000652	.000353	.000896
.000054	.000167	.000154	.000411	.000254	.000656	.000354	.000900
.000055	.000171	.000155	.000415	.000255	.000659	.000355	.000904
.000056	.000175	.000156	.000419	.000256	.000663	.000356	.000907
.000057	.000179	.000157	.000423	.000257	.000667	.000357	.000911
.000060	.000183	.000160	.000427	.000260	.000671	.000360	.000915
.000061	.000186	.000161	.000431	.000261	.000675	.000361	.000919
.000062	.000190	.000162	.000434	.000262	.000679	.000362	.000923
.000063	.000194	.000163	.000438	.000263	.000682	.000363	.000926
.000064	.000198	.000164	.000442	.000264	.000686	.000364	.000930
.000065	.000202	.000165	.000446	.000265	.000690	.000365	.000934
.000066	.000205	.000166	.000450	.000266	.000694	.000366	.000938
.000067	.000209	.000167	.000453	.000267	.000698	.000367	.000942
.000070	.000213	.000170	.000457	.000270	.000701	.000370	.000946
.000071	.000217	.000171	.000461	.000271	.000705	.000371	.000949
.000072	.000221	.000172	.000465	.000272	.000709	.000372	.000953
.000073	.000225	.000173	.000469	.000273	.000713	.000373	.000957
.000074	.000228	.000174	.000473	.000274	.000717	.000374	.000961
.000075	.000232	.000175	.000476	.000275	.000720	.000375	.000965
.000076	.000236	.000176	.000480	.000276	.000724	.000376	.000968
.000077	.000240	.000177	.000484	.000277	.000728	.000377	.000972

Octal-Decimal Fraction Conversion Table

OCTAL	DEC.	OCTAL	DEC.	OCTAL	DEC.	OCTAL	DEC.
.000400	.000976	.000500	.001220	.000600	.001464	.000700	.001708
.000401	.000980	.000501	.001224	.000601	.001468	.000701	.001712
.000402	.000984	.000502	.001228	.000602	.001472	.000702	.001716
.000403	.000988	.000503	.001232	.000603	.001476	.000703	.001720
.000404	.000991	.000504	.001235	.000604	.001480	.000704	.001724
.000405	.000995	.000505	.001239	.000605	.001483	.000705	.001728
.000406	.000999	.000506	.001243	.000606	.001487	.000706	.001731
.000407	.001003	.000507	.001247	.000607	.001491	.000707	.001735
.000410	.001007	.000510	.001251	.000610	.001495	.000710	.001739
.000411	.001010	.000511	.001255	.000611	.001499	.000711	.001743
.000412	.001014	.000512	.001258	.000612	.001502	.000712	.001747
.000413	.001018	.000513	.001262	.000613	.001506	.000713	.001750
.000414	.001022	.000514	.001266	.000614	.001510	.000714	.001754
.000415	.001026	.000515	.001270	.000615	.001514	.000715	.001758
.000416	.001029	.000516	.001274	.000616	.001518	.000716	.001762
.000417	.001033	.000517	.001277	.000617	.001522	.000717	.001766
.000420	.001037	.000520	.001281	.000620	.001525	.000720	.001770
.000421	.001041	.000521	.001285	.000621	.001529	.000721	.001773
.000422	.001045	.000522	.001289	.000622	.001533	.000722	.001777
.000423	.001049	.000523	.001293	.000623	.001537	.000723	.001781
.000424	.001052	.000524	.001296	.000624	.001541	.000724	.001785
.000425	.001056	.000525	.001300	.000625	.001544	.000725	.001789
.000426	.001060	.000526	.001304	.000626	.001548	.000726	.001792
.000427	.001064	.000527	.001308	.000627	.001552	.000727	.001796
.000430	.001068	.000530	.001312	.000630	.001556	.000730	.001800
.000431	.001071	.000531	.001316	.000631	.001560	.000731	.001804
.000432	.001075	.000532	.001319	.000632	.001564	.000732	.001808
.000433	.001079	.000533	.001323	.000633	.001567	.000733	.001811
.000434	.001083	.000534	.001327	.000634	.001571	.000734	.001815
.000435	.001087	.000535	.001331	.000635	.001575	.000735	.001819
.000436	.001091	.000536	.001335	.000636	.001579	.000736	.001823
.000437	.001094	.000537	.001338	.000637	.001583	.000737	.001827
.000440	.001098	.000540	.001342	.000640	.001586	.000740	.001831
.000441	.001102	.000541	.001346	.000641	.001590	.000741	.001834
.000442	.001106	.000542	.001350	.000642	.001594	.000742	.001838
.000443	.001110	.000543	.001354	.000643	.001598	.000743	.001842
.000444	.001113	.000544	.001358	.000644	.001602	.000744	.001846
.000445	.001117	.000545	.001361	.000645	.001605	.000745	.001850
.000446	.001121	.000546	.001365	.000646	.001609	.000746	.001853
.000447	.001125	.000547	.001369	.000647	.001613	.000747	.001857
.000450	.001129	.000550	.001373	.000650	.001617	.000750	.001861
.000451	.001132	.000551	.001377	.000651	.001621	.000751	.001865
.000452	.001136	.000552	.001380	.000652	.001625	.000752	.001869
.000453	.001140	.000553	.001384	.000653	.001628	.000753	.001873
.000454	.001144	.000554	.001388	.000654	.001632	.000754	.001876
.000455	.001148	.000555	.001392	.000655	.001636	.000755	.001880
.000456	.001152	.000556	.001396	.000656	.001640	.000756	.001884
.000457	.001155	.000557	.001399	.000657	.001644	.000757	.001888
.000460	.001159	.000560	.001403	.000660	.001647	.000760	.001892
.000461	.001163	.000561	.001407	.000661	.001651	.000761	.001895
.000462	.001167	.000562	.001411	.000662	.001655	.000762	.001899
.000463	.001171	.000563	.001415	.000663	.001659	.000763	.001903
.000464	.001174	.000564	.001419	.000664	.001663	.000764	.001907
.000465	.001178	.000565	.001422	.000665	.001667	.000765	.001911
.000466	.001182	.000566	.001426	.000666	.001670	.000766	.001914
.000467	.001186	.000567	.001430	.000667	.001674	.000767	.001918
.000470	.001190	.000570	.001434	.000670	.001678	.000770	.001922
.000471	.001194	.000571	.001438	.000671	.001682	.000771	.001926
.000472	.001197	.000572	.001441	.000672	.001686	.000772	.001930
.000473	.001201	.000573	.001445	.000673	.001689	.000773	.001934
.000474	.001205	.000574	.001449	.000674	.001693	.000774	.001937
.000475	.001209	.000575	.001453	.000675	.001697	.000775	.001941
.000476	.001213	.000576	.001457	.000676	.001701	.000776	.001945
.000477	.001216	.000577	.001461	.000677	.001705	.000777	.001949

APPENDIX E

Command List

Operation	Mnemonic Code	Numeric Code	Description
Arithmetic	ADD	14	Add
	SUB	15	Subtract
	DPA	16	Double Precision Add
	DPS	17	Double Precision Subtract
	SQR	30	Square Root
	DIV	31	Divide
	DVR	31	Divide Remainder
	MUP	32	Multiply
	CLA	45	Clear A
	CLB	43	Clear B
	CLC	44	Clear C
	GTB	41	Gray to Binary
	CAM	56	Compare A and M
Transfer	TAN	35	Transfer if A Negative
	TBN	36	Transfer if B Negative
	TCN	34	Transfer if C Negative
	TRU	37	Transfer Unconditionally
	TOF	75	Transfer on Overflow
	TES	77	Transfer on External Signal
Loading & Storing	LDA	05	Load A
	LDB	06	Load B
	LDC	04	Load C
	LDP	07	Load Double Precision
	IAC	01	Interchange A & C
	IBC	02	Interchange B & C
	ROT	03	Rotate
	IAM	25	Interchange A & M
	STA	11	Store A
	STB	12	Store B
	STC	10	Store C
	STD	13	Store Double Precision
	MCL	71	Move Command Line Block
	MLX	26	Move Line X to Line 7
Logical & Shifting	EBP	40	Extend Bit Pattern
	AMC	42	AND M & C
	MAC	00	Merge A into C
	AOC	46	AND OR Combined
	EXF	47	Extract Field
	NAD	20	Normalize and Decrement
	LSD	21	Left Shift and Decrement
	RSI	22	Right Shift and Increment
	SAI	23	Scale Right and Increment
	SBR	33	Shift B Right
Control	NOP	24	No Operation
	HLT	00	Halt
Input-Output	DIU	50	Disconnect Input Unit
	RTK	51	Read Typewriter Keyboard
	RPT	52	Read Paper Tape
	RFU	53	Read Fast Unit
	LAI	55	Load A From Input Buffer
	CIB	57	Clear Input Buffer
	WOC	6X	Write Output Character
	PTU	70	Pulse to Specified Unit
	BSO	72	Block Serial Output
	BSI	73	Block Serial Input

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