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Z80

ASSEMBLY LANGUAGE PROGRAMMING



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Chapter 3

THE Z80 ASSEMBLY LANGUAGE INSTRUCTION SET

We are now ready to start writing assembly language programs. We begin in this chapter by defining the individual instructions of the Z80 assembly language instruction set, plus the syntax rules of the Zilog assembler.

We do not discuss any aspects of microcomputer hardware, signals, interfaces, or CPU architecture in this book. This information is described in detail in An Introduction to Microcomputers: Volume 2 — Some Real Microprocessors and Volume 3 — Some Real Support Devices, while Z80 Programming for Logic Design discusses assembly language as an extension of digital logic. In this book, **we look at programming techniques from the assembly language programmer's viewpoint, where pins and signals are irrelevant and there are no important differences between a minicomputer and a microcomputer.**

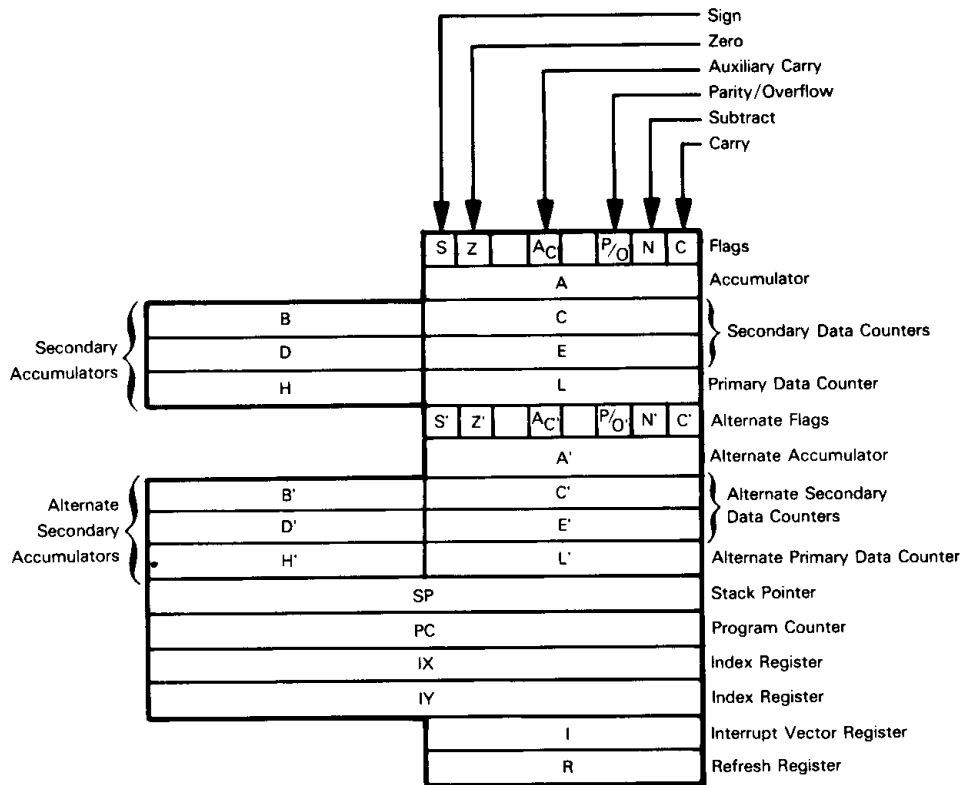
Interrupts, direct memory access, and the Stack architecture for the Z80 will be described in later chapters of this book, in conjunction with assembly language programming discussions of the same subjects.

This chapter contains a detailed definition of each assembly language instruction. These definitions are identical to those found in Chapter 6 of Z80 Programming for Logic Design.

The detailed description of individual instructions is preceded by a general discussion of the Z80 instruction set that divides instructions into those which are commonly used, infrequently used, and rarely used. If you are an experienced assembly language programmer, this categorization is not particularly important — and, depending on your own programming prejudices, it may not even be accurate. If you are a novice assembly language programmer, we recommend that you begin by writing programs using only instructions in the "commonly used" category. Once you have mastered the concepts of assembly language programming, you may examine other instructions and use them where appropriate.

CPU REGISTERS AND STATUS FLAGS

The CPU registers and status flags for the Z80 may be illustrated as follows:



The Accumulator is the primary source and destination for one-operand and two-operand instructions. For example, the shortest and fastest data transfers between the CPU and I/O devices are performed through the Accumulator. In addition, more Memory Reference instructions move data between the Accumulator and memory than between any other register and memory. All 8-bit arithmetic and Boolean instructions take one of the operands from the Accumulator and return the result to the Accumulator. An instruction must therefore **load the Accumulator before the Z80 can perform any 8-bit arithmetic or Boolean operations.**

The B, C, D, E, H, and L registers are all secondary registers. Data stored in any of these six registers may be accessed with equal ease; such data can be moved to any other register or can be used as the second operand in two-operand instructions.

There are, however, some important differences in the functions of Registers B, C, D, E, H, and L.

Registers H and L are the primary Data Pointer for the Z80. That is to say, you will normally use these two registers to hold the 16-bit memory address of data being accessed. Data may be transferred between any registers and the memory location addressed by H and L. Since HL is the primary Data Pointer, it often takes fewer bytes of object code and less instruction cycles to perform operations with it. The Z80 programmer should try to address data memory via Registers H and L whenever possible.

Within your program logic, always reserve Registers H and L to hold a data memory address.

Registers B, C, D, and E provide secondary data storage; frequently, the second operand for two-operand instructions is stored in one of these four registers. (The first operand is stored in the Accumulator, which is also the destination for the result.)

There are **a limited number of instructions** that **treat Registers B and C, or D and E, as 16-bit Data Pointers.** But these instructions move data between memory and the Accumulator only.

In your program logic you should normally use Registers B, C, D, and E as temporary storage for data or addresses.

Registers IX and IY are index registers. They provide a limited indexing capability of the type described in An Introduction to Microcomputers: Volume 1 for short instructions.

The alternate registers F', A', B', C', D', E', H', and L' provide a duplicate set of general purpose registers. Just two single-byte Exchange instructions select and deselect all alternate registers; one instruction exchanges AF and the alternate AF' as a register pair, and one instruction exchanges BC, DE, and HL with the alternate BC', DE', and HL'. Once selected, all subsequent register operations are performed on the active set until the next exchange selects the inactive set. **The alternate registers can be reserved for use when a fast interrupt response is required.** Or, they may be used in any desired way by the programmer.

There are a number of instructions that handle 16 bits of data at a time. These instructions refer to pairs of CPU registers as follows:

F	and	A
B	and	C
D	and	E
H	and	L
F'	and	A'
B'	and	C'
D'	and	E'
H'	and	L'
⏟		⏟
High-		Low-
order		order
byte		byte

The combination of the Accumulator and flags, treated as a 16-bit unit, is used only for Stack operations and alternate register switches. Arithmetic operations access B and C, D and E, or H and L as 16-bit data units.

The Carry status flag holds carries out of the most significant bit in any arithmetic operation. The Carry flag is also included in Shift instructions; it is reset by Boolean instructions.

The Subtract flag is designed for internal use during decimal adjust operations. This flag is set to 1 for all Subtract instructions and reset to 0 for all Add instructions.

The Parity/Overflow flag is a multiple use flag, depending on the operation being performed. For arithmetic operations, it is an overflow flag. For input, rotate, and Boolean operations, it is a parity flag, with 1 = even parity and 0 = odd parity. During block transfer and search operations, it remains set until the byte counter decrements to zero; then it is reset to zero. It is also set to the current state of the interrupt enable flip-flop (IFF2) when a LD A,I or LD A,R instruction is executed.

The Zero flag is set to 1 when any arithmetic or Boolean operation generates a zero result. The Zero status is set to 0 when such an operation generates a non-zero result.

The Sign status flag acquires the value of the most significant bit of the result following the execution of any arithmetic or Boolean instruction.

The Auxiliary Carry status flag holds any carry from bit 3 to 4 resulting from the execution of an arithmetic instruction. The purpose of this status flag is to simplify Binary-Coded-Decimal (BCD) operations; this is the standard use of an Auxiliary Carry status flag as described in An Introduction to Microcomputers: Volume 1, Chapter 3.

All of the above status flags keep their current value until an instruction that modifies them is executed. Merely changing the value of the Accumulator will not necessarily change the value of the status flags. For example, if the Zero flag is set, and a load immediate to the Accumulator is executed, that causes the Accumulator to acquire a non-zero value; the value of the Zero flag remains unchanged.

The 16-bit Stack Pointer allows you to implement a Stack anywhere in addressable memory. The size of the Stack is limited only by the amount of addressable memory present. In reality you will rarely use more than 256 bytes of memory for your Stack. You should use the Stack for accessing subroutines and processing interrupts. Do not use the Stack to pass parameters to subroutines. This is not very efficient within the limitations of the Z80 instruction set. The Z80 Stack is started at its highest address. A Push decrements the Stack Pointer contents; a Pop increments the Stack Pointer contents.

The Interrupt Vector register and the Refresh register are special-purpose registers not normally used by the programmer.

The Interrupt Vector register is used to store the page address of an interrupt response routine; the location on the page is provided by the interrupting device. This scheme allows the address of the interrupt response routine to be changed while still providing a very fast response time for the interrupting device.

The Refresh register contains a memory refresh counter in the low-order seven bits. This counter is incremented automatically after each instruction fetch and provides the next refresh address for dynamic memories. The high-order bit of the Refresh register will remain set or reset, depending on how it was loaded at the last LD R,A instruction.

Z80 MEMORY ADDRESSING MODES

The Z80 provides extensive addressing modes. These include:

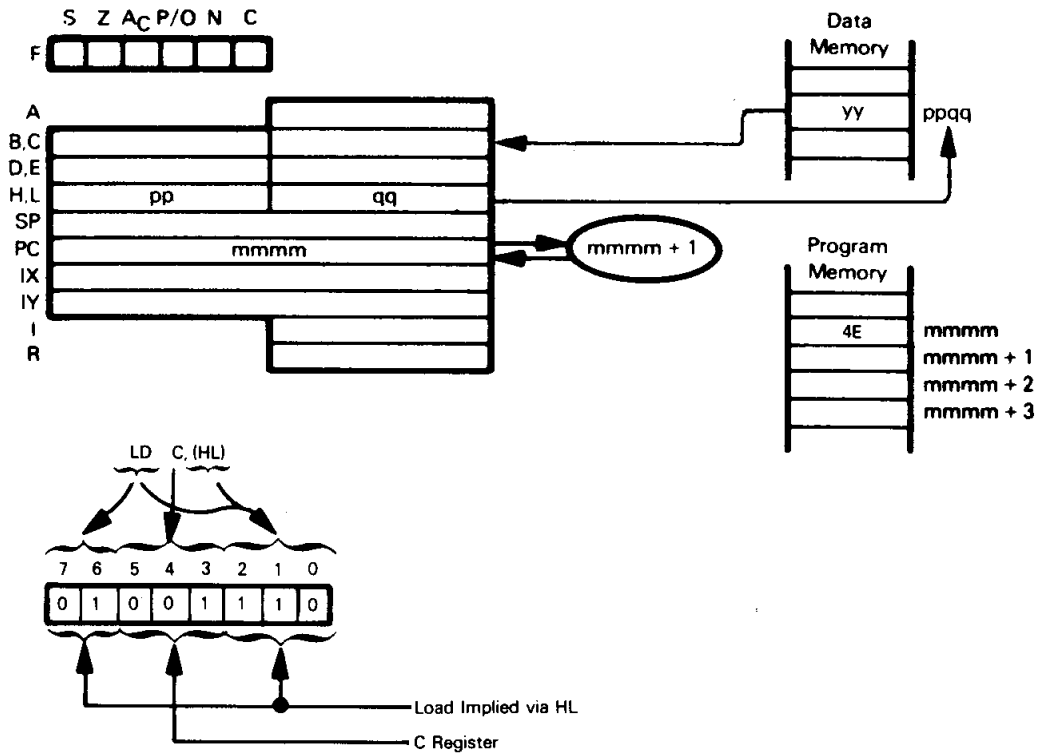
- **Implied**
- **Implied Block Transfer with Auto-Increment/Decrement**
- **Implied Stack**
- **Indexed**
- **Direct**
- **Program Relative**
- **Base Page**
- **Register Indirect**
- **Immediate**

Implied

In implied memory addressing, the H and L registers hold the address of the memory location being accessed. Data may be moved between the identified memory location and any one of the seven CPU registers A, B, C, D, E, H, or L. For example, the instruction

LD C,(HL)

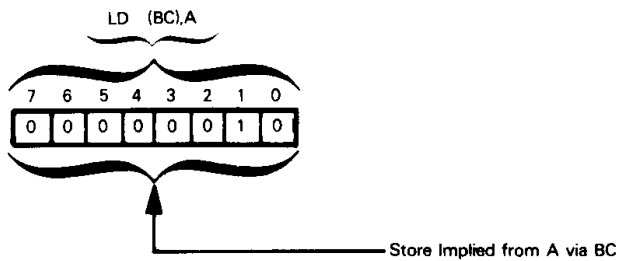
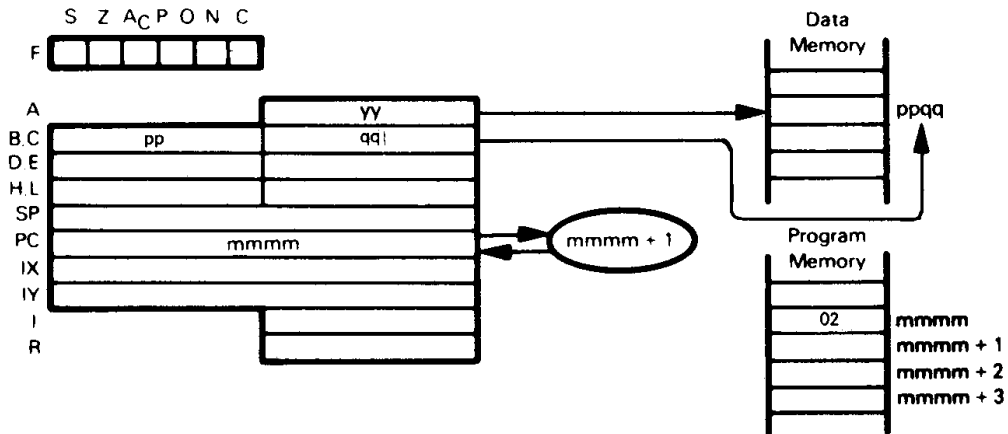
loads the C register with the contents of the memory location currently pointed to by HL. This is illustrated as follows:



A limited number of instructions use Registers B and C or D and E as the Data Pointer. These instructions move data between the Accumulator and the memory location addressed by Registers B and C or Registers D and E. The instruction

LD (BC),A

stores the contents of A into the memory location currently addressed by Register Pair BC. This is illustrated as follows:



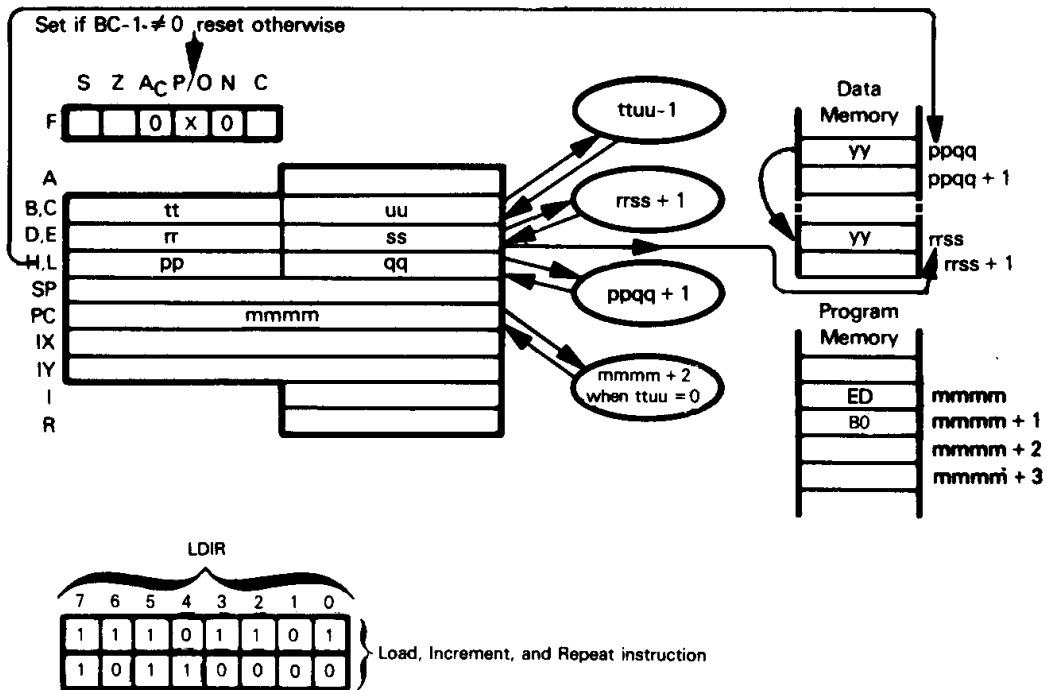
Implied Block Transfer With Auto-Increment/Decrement

Block Transfer and Search instructions operate on a block of data whose size is set by the programmer as the contents of the BC register pair. In this form of addressing, a byte of data is moved from the memory location addressed by HL to the memory location addressed by DE; then HL and DE are incremented and BC is decremented. Data transfer continues until BC reaches zero, at which point the instruction is terminated. Variations include allowing other instructions to follow each data transfer, with the programmer supplying the loopback; auto-decrementing HL and DE instead of auto-incrementing; and a complementary set of Block Search instructions that compare the memory byte addressed by HL with the contents of the A register, setting a flag if a match is found.

The Load, Increment, and Repeat instruction

LDIR

is illustrated as follows:



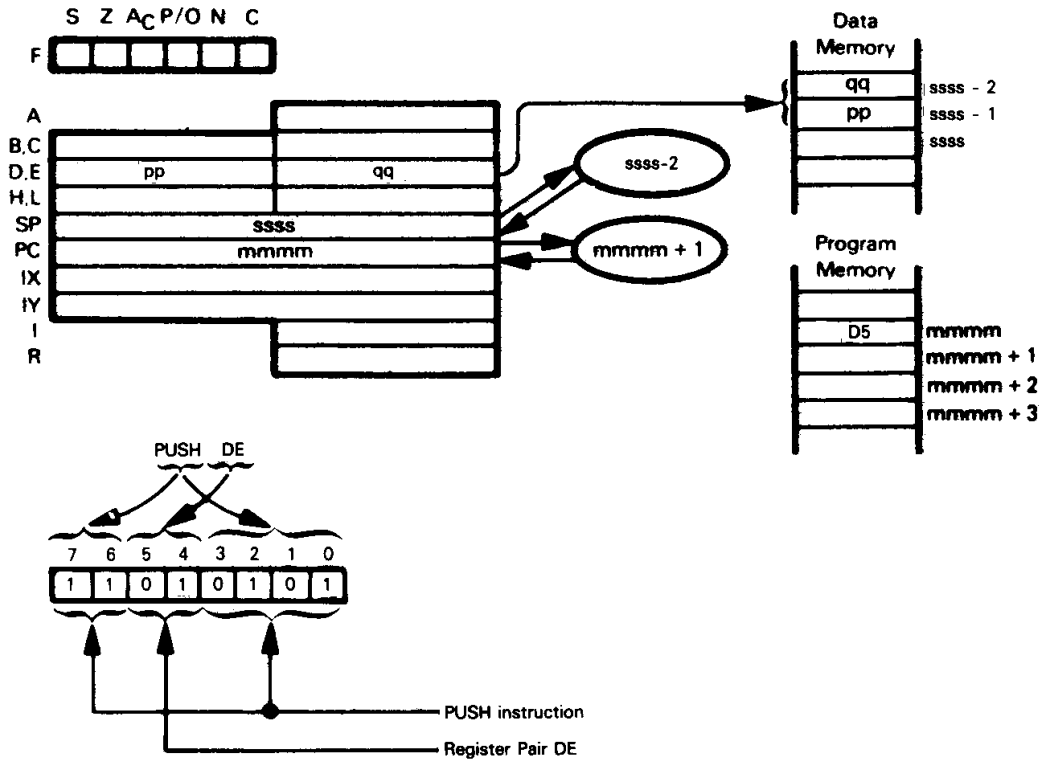
A similar group of Input/Output instructions is provided, allowing a block of data to be input or output between memory and an I/O device. The I/O port number is taken as the contents of the C register, with the single B register used as the byte counter. Memory is addressed by HL.

Implied Stack

Since the Stack is part of Read/Write memory, we must consider Stack instructions as Memory Reference instructions. **Push and Pop instructions move two bytes of data between a register pair and the addressed Stack Pointer location**, i.e., current top-of-stack. The Z80 Stack address is decremented with each Push and incremented with each Pop. The instruction

PUSH DE

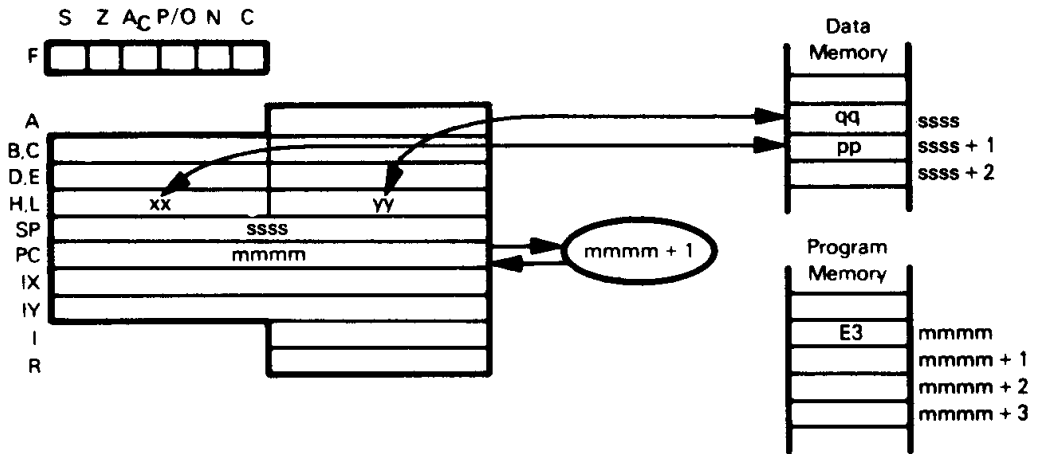
is illustrated as follows:



The Z80 also has instructions that exchange the two top-of-stack bytes with a 16-bit register — HL or one of the two index registers. The instruction

EX (SP),HL

is illustrated as follows:

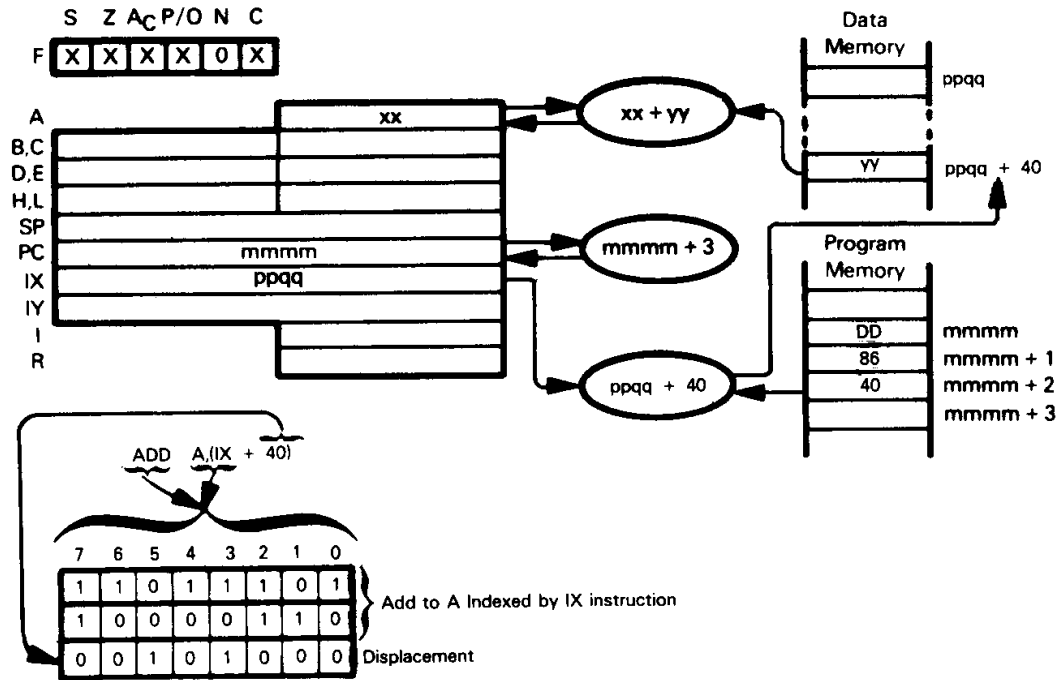


Indexed

The Z80 has two 16-bit index registers, called IX and IY. They may be used interchangeably. All memory reference operations for which (HL) can be specified can alternatively be specified as an indexed operation. The difference between implied addressing using HL and indexed addressing using IX and IY is that **the index operand includes a displacement value that is added to the index address.** In the instruction

ADD A,(IX+40H)

the memory address is the sum of the contents of the IX register and 40_{16} . This may be illustrated as follows:



Direct

Direct addressing can be used to load the Accumulator with any 8-bit value from memory, load BC, DE, HL, SP, IX, or IY with any 16-bit memory value, and jump or call subroutines direct at any memory location. The 16-bit direct address is stored in the last two bytes of the instruction, in low-byte high-byte order (this is the reverse of the standard high-low scheme).

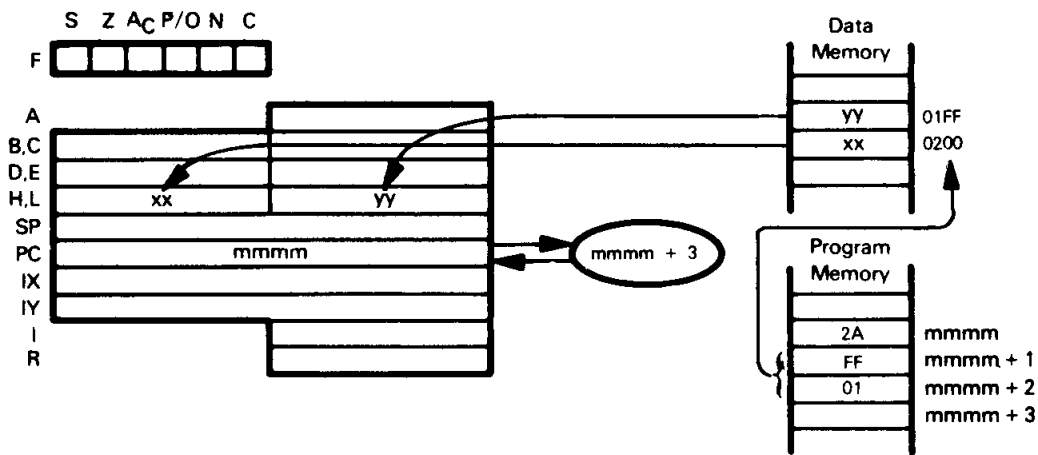
The instruction

LD A,(NETX)

loads the A register with the contents of the memory location addressed by the label NETX. The instruction

LD HL,(1FFH)

loads the L register with the contents of memory location $01FF_{16}$ and the H register with the contents of memory location 0200_{16} . This may be illustrated as follows:



LD HL,(1FFH)

	7	6	5	4	3	2	1	0	
	0	0	1	0	1	0	1	0	Load HL Direct instruction
	1	1	1	1	1	1	1	1	Direct address - low byte
	0	0	0	0	0	0	0	1	Direct address - High byte

The direct Jump instructions provide jumps and jumps-to-subroutines, both unconditional and conditional. These are all 3-byte instructions, with the direct address stored in the second and third bytes of the instruction, as shown above for Load Direct.

There are three additional addressing modes used by Z80 Branch instructions: program relative, base page, and register indirect. In general, they are shorter and/or faster than direct jumps but may have more limited addressing capabilities.

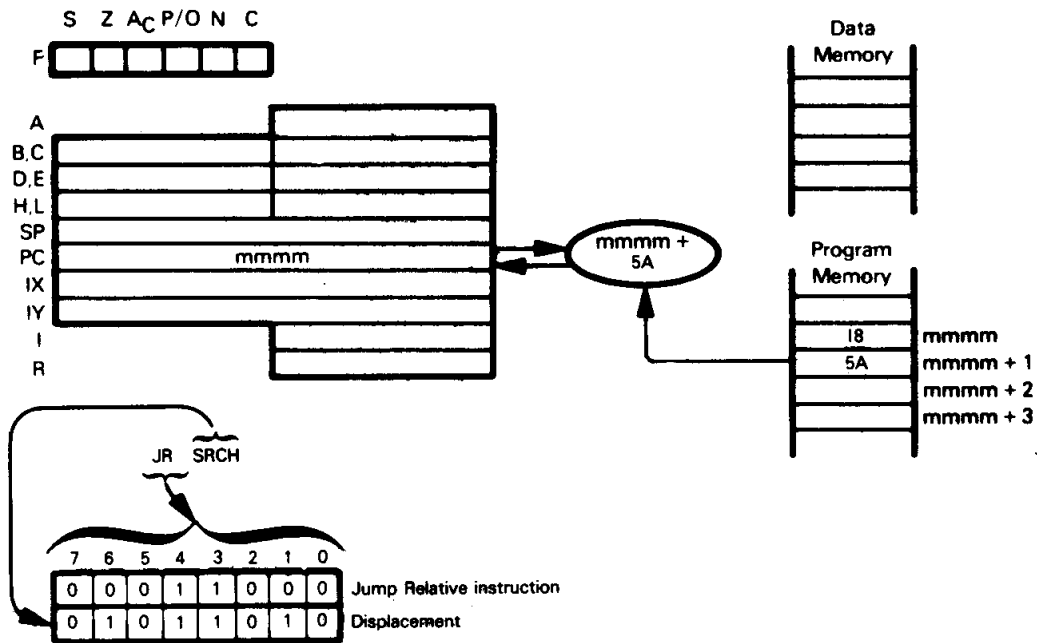
Program Relative

Jump Relative instructions provide program relative addressing in the range -126, +129 bytes from the first byte of the Program Relative instruction. These instructions are all 2-byte instructions, with the signed displacement value stored in the second byte of the instruction. **There are unconditional and conditional relative jumps, as well as a Decrement and Jump If Not Zero instruction (DJNZ) that facilitates loop control.**

Given the instruction

JR SRCH

assume that SRCH is a label addressing a location 5A₁₆ bytes up in memory from the JR op-code byte. The operation may be illustrated as follows:



Base Page

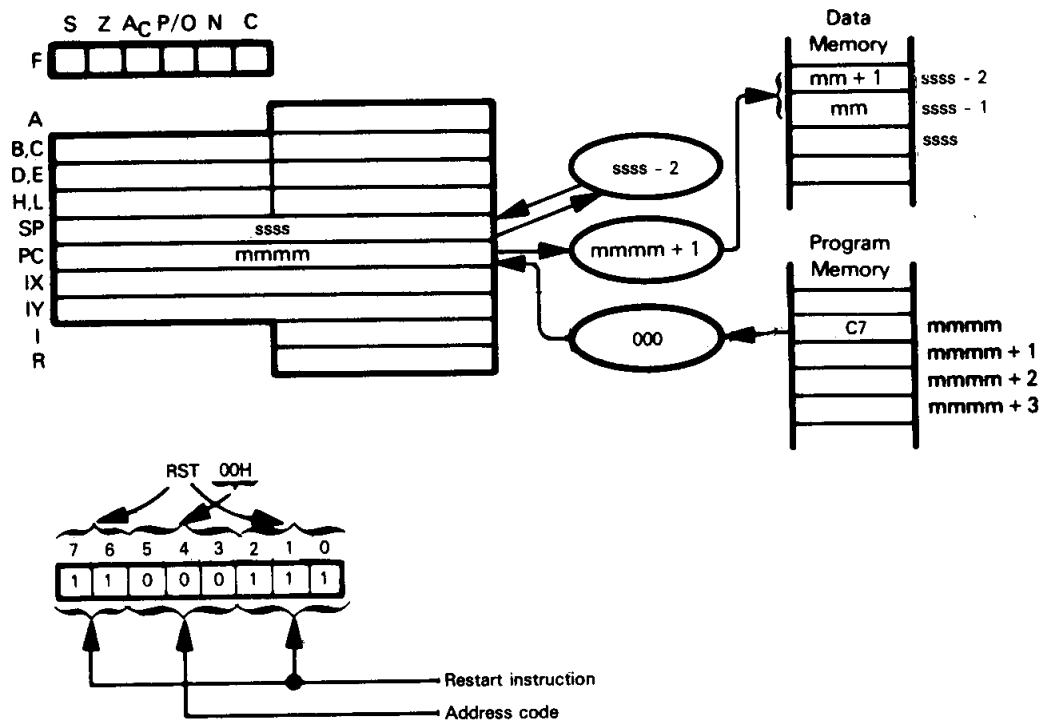
The Z80 has a **modified base page addressing** mode for the Restart instruction. This is a special Call instruction that **allows a single-byte instruction to jump to one of eight subroutines located at specific points in lower core**. The effective address is calculated from a 3-bit code stored in the instruction, as follows:

Lower Core Address	3-Bit Code
00H	000
08H	001
10H	010
18H	011
20H	100
28H	101
30H	110
38H	111

The decoded address value is loaded into the low-order byte of the Program Counter; the high-order byte of the Program Counter is set to zero. For example, the instruction

RST 00H

is illustrated as follows:



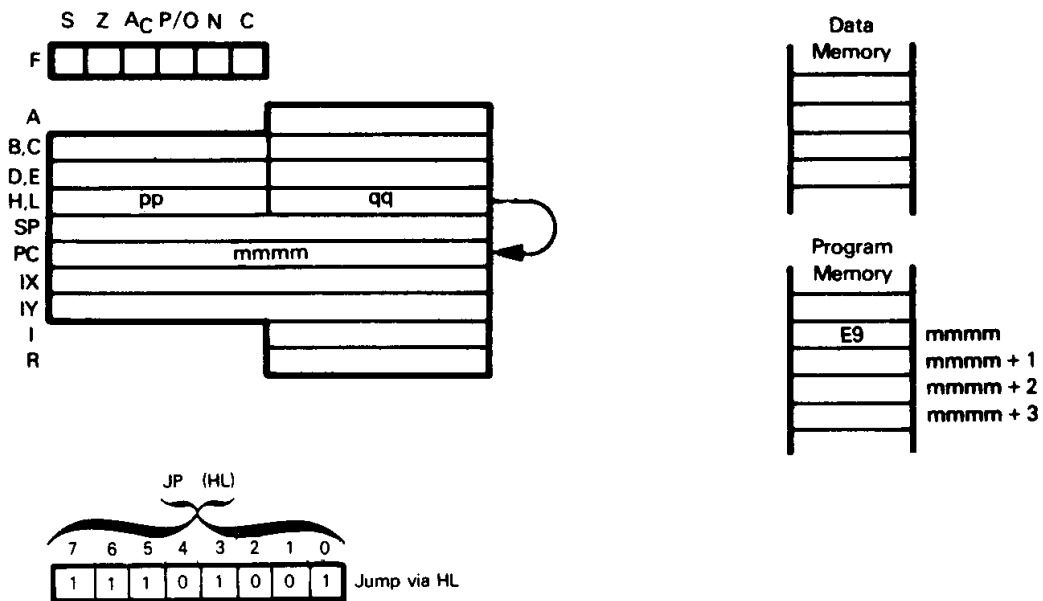
Register Indirect

In standard indirect addressing, a memory location contains the effective address, and the instruction specifies the address of the memory location containing the effective address. In register indirect addressing, a register contains the effective address, and the instruction specifies which of the registers contains the effective address. Note that for a Load, for instance, this is just another way of describing implied addressing. However, **the Z80 has Jump instructions that allow a jump to the memory location whose address is contained in the specified register.** This is a form of indirect addressing, and is described separately because, while most microcomputers have implied addressing, very few have register indirect jumps.

The instruction

JP (HL)

directs that a jump is to be taken to the memory location whose address is contained in HL. This may be illustrated as follows:



Immediate

Some texts identify Immediate instructions as Memory Reference instructions. An Immediate instruction is a 2-, 3-, or 4-byte instruction in which the last one or two bytes hold fixed data that is loaded into a register or memory location. **The Z80 provides Immediate instructions to:**

- **load 8-bit data into any of the 8-bit registers,**
- **load 16-bit data into any of the register pairs or 16-bit registers,**
- **store 8-bit data into any memory location using implied or indexed addressing,**
- **perform arithmetic and logical operations using the Accumulator and 8-bit immediate data.**

The instruction

LD BC,0BCH

loads the immediate data value BC₁₆ into Register Pair BC. This may be illustrated as follows:

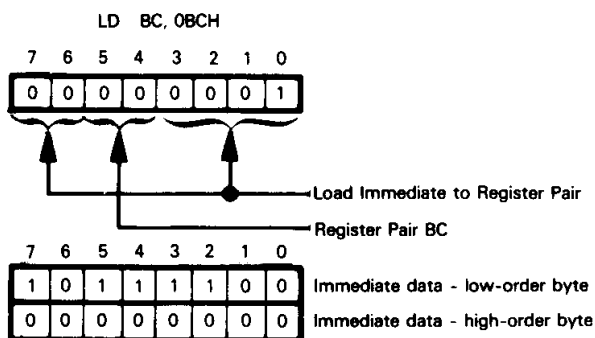
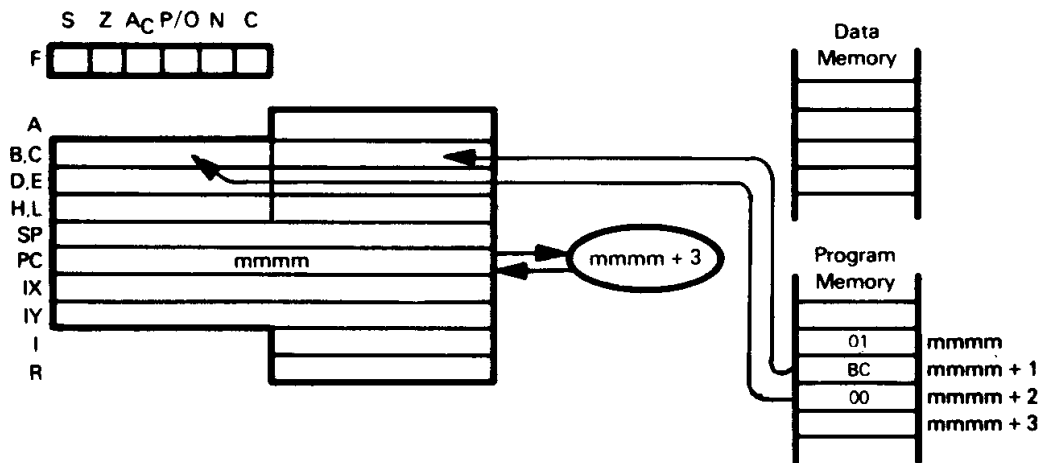


Table 3-1. Frequently Used Instructions of the Z80

Instruction Code	Meaning
ADC A	Add with Carry to Accumulator
ADD	Add
AND	Logical AND
CALL addr	Call Subroutine
CALL cond.addr	Call Conditional
CP	Compare
DEC	Decrement
DJNZ	Decrement and Jump If Not Zero
IN	Input
INC	Increment
JR	Jump Relative
JR cond.addr	Jump Relative Conditional
LD reg.(HL)	Load Register
LD A,(addr)	Load Accumulator Direct
LD data	Load Immediate
LD (HL),reg	Store Register
LD (addr),A	Store Accumulator Direct
LD dst.src	Move Register-to-Register
OUT	Output
POP	Pop from Stack
PUSH	Push to Stack
RET	Return from Subroutine
RET cond	Return Conditional
RLA	Rotate Accumulator Left Through Carry
RRA	Rotate Accumulator Right Through Carry
SLA	Shift Left Arithmetic
SRL	Shift Right Logical
SUB	Subtract

Table 3-2. Occasionally Used Instructions of the Z80

Instruction Code	Meaning
BIT	Test Bit
CPD, CPDR	Compare, Decrement, (Repeat)
CPI, CPIR	Compare, Increment, (Repeat)
CPL	Complement Accumulator
DAA	Decimal Adjust Accumulator
DI	Disable Interrupts
EI	Enable Interrupts
EX	Exchange
HALT	Halt
IND, INDR	Input, Decrement, (Repeat)
INI, INIR	Input, Increment, (Repeat)
JP	Jump
JP	Jump Conditional
LD	Load Accumulator Secondary
LD	Load HL Direct
LD	Load Register Indexed
LD	Load Register Pair Direct
LD	Load Index Register Direct
LD	Store Accumulator Secondary
LD	Store HL Direct
LD	Store Register Indexed
LD	Store Register Pair Direct
LD	Store Index Register Direct
LD	Store Immediate to Memory
LD	Store Immediate to Memory Indexed
LDD, LDDR	Load, Decrement, (Repeat)
LDI, LDIR	Load, Increment, (Repeat)
NEG	Negate (Twos Complement) Accumulator
NOP	No Operation
OR	Logical OR
OUTD, OTDR	Output, Decrement, (Repeat)
OUTI, OTIR	Output, Increment, (Repeat)
RES	Reset Bit
RETI	Return from Interrupt
RL	Rotate Left Through Carry
RLC	Rotate Left Circular
RLCA	Rotate Accumulator Left Circular
RR	Rotate Right Through Carry
RRC	Rotate Right Circular
RRCA	Rotate Accumulator Right Circular
SET	Set Bit
SRA	Shift Right Arithmetic
XOR	Logical Exclusive OR

Table 3-3. Seldom Used Instructions of the Z80

Instruction Code	Meaning
ADC HL,rp	Add Register Pair with Carry to HL
CCF	Complement Carry Flag
EXX	Exchange Register Pairs and Alternatives
IM n	Set Interrupt Mode
RETN	Return from Non-Maskable Interrupt
RLD	Rotate Accumulator and Memory Left Decimal
RRD	Rotate Accumulator and Memory Right Decimal
RST	Restart
SBC	Subtract with Carry (Borrow)
SCF	Set Carry Flag
LD A,I	Load Accumulator from Interrupt Vector Register
LD A,R	Load Accumulator from Refresh Register
LD I,A	Store Accumulator to Interrupt Vector Register
LD R,A	Store Accumulator to Refresh Register
LD SP,HL	Move HL to Stack Pointer
LD SP,xy	Move Index Register to Stack Pointer

ABBREVIATIONS

These are the abbreviations used in this chapter:

A,F,B,C,D,E,H,L	The 8-bit registers. A is the Accumulator and F is the Flag Word.
AF',BC',DE',HL'	The alternate register pairs
addr	A 16-bit memory address
x(b)	Bit b of 8-bit register or memory location x
cond	Condition for program branching. Conditions are: NZ - Non-Zero (Z = 0) Z - Zero (Z = 1) NC - Non-carry (C = 0) C - Carry (C = 1) PO - Parity Odd (P = 0) PE - Parity Even (P = 1) P - Positive Sign (S = 0) M - Negative Sign (S = 1)
data	An 8-bit binary data unit
data16	A 16-bit binary data unit
disp	An 8-bit signed binary address displacement
xx(HI)	The high-order 8 bits of a 16-bit quantity xx
I	Interrupt Vector register (8 bits)
IX IY	The Index registers (16 bits each)
label	A 16-bit instruction memory address
xx(LO)	The low-order 8 bits of a 16-bit quantity xx
LSB	Least Significant Bit (Bit 0)
MSB	Most Significant Bit (Bit 7)
PC	Program Counter
port	An 8-bit I/O port address

pr	Any of the following register pairs: BC DE HL AF
R	The Refresh register (8 bits)
reg	Any of the following registers: A B C D E H L
rp	Any of the following register pairs: BC DE HL SP
SP	Stack Pointer (16 bits)
xy	Either one of the Index registers (IX or IY)
Object Code	bbb Bit number 000 (LSB) to 111 (MSB) ccc Condition code 000 = non-zero 001 = zero 010 = no carry 011 = carry 100 = parity odd 101 = parity even 110 = positive sign 111 = negative sign ddd Destination register — same coding as rrr ppqq A 16-bit memory address rrr Register 111 = A 000 = B 001 = C 010 = D 011 = E 100 = H 101 = L sss Source register — same coding as rrr x Index register 0 = IX 1 = IY xx Register pair 00 = BC 01 = DE 10 = HL 11 = SP (rp) or AF (pr) xxx Restart code (000 to 111) yy An 8-bit binary data unit yyyy A 16-bit binary data unit

Statuses

The Z80 has the following status flags:

- C - Carry status
- Z - Zero status
- S - Sign status
- P/O - Parity/Overflow status
- AC - Auxiliary Carry status
- N - Subtract status

The following symbols are used in the status columns:

- X - flag is affected by operation
- (blank) - flag is not affected by operation
- 1 - flag is set by operation
- 0 - flag is reset by operation
- U - flag is unknown after operation
- P - flag shows parity status
- O - flag shows overflow status
- I - flag shows interrupt enabled/disabled status

[[]]

Memory addressing: 1) the contents of the memory location whose address is contained in the designated register, 2) an I/O port whose address is contained in the designated register.

[]

The contents of a register or memory location.

For example:

$$[[HL]] \leftarrow [[HL]] + 1$$

indicates that the contents of the memory location addressed by the contents of HL are incremented, whereas:

$$[HL] \leftarrow [HL] + 1$$

indicates that the contents of the HL register itself are incremented.

Λ

Logical AND

V

Logical OR

⊕

Logical Exclusive-OR

←

Data is transferred in the direction of the arrow

← →

Data is exchanged between the two locations designated on either side of the arrows.

INSTRUCTION MNEMONICS

Table 3-4 summarizes the Z80 instruction set. The **MNEMONIC** column shows the instruction mnemonic (IN, OUT, LD). The **OPERAND** column shows the operands, if any, used with the instruction mnemonic.

The fixed part of an assembly language instruction is shown in **UPPER CASE**. The variable part (immediate data, I/O device number, register name, label or address) is shown in **lower case**.

For closely related operands, each type is listed separately without repeating the mnemonic. For instance, examples of the format entry

```
LD rp,(addr)
   xy,(addr)
are: LD BC,(DAT2)
     LD IX,(MEM)
```

INSTRUCTION OBJECT CODES

The object code and instruction length in bytes are shown in Table 3-4 for each instruction variation. Table 3-5 lists the object codes in numerical order.

For instruction bytes without variations, object codes are represented as two hexadecimal digits (e.g., 3F).

For instruction bytes with variations in one of the two digits, the object code is shown as one 4-bit binary digit and one hexadecimal digit (e.g., 11 x 1 D) in Table 3-5. For other instruction bytes with variations, the object code is shown as eight binary digits (e.g., 01sss001).

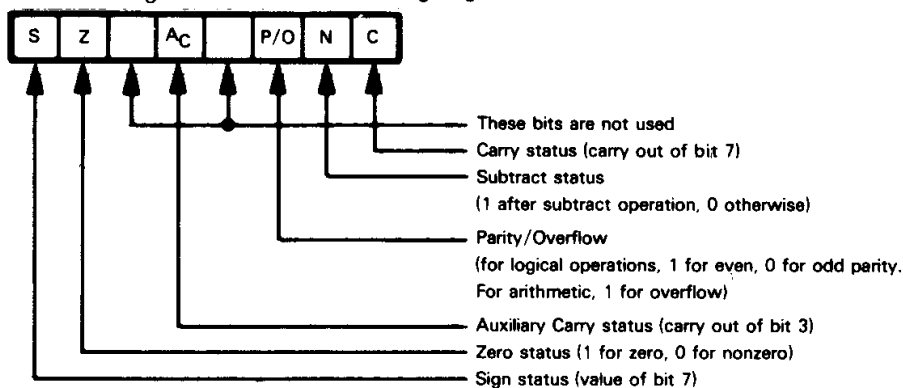
INSTRUCTION EXECUTION TIMES

Table 3-4 lists the instruction execution times in clock periods. Real time can be obtained by dividing the given number of clock periods by the clock frequency. For example, for an instruction that requires 7 clock periods, a 4 MHz clock will result in a 1.75 microsecond execution time.

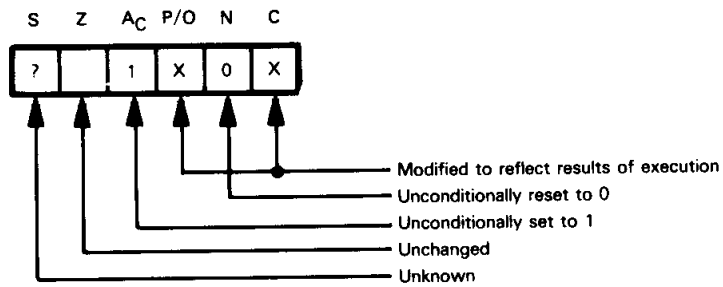
When two possible execution times are shown (i.e., 5/11), it indicates that the number of clock periods depends on condition flags. The first time is for "condition not met," whereas the second is for "condition met."

STATUS

The six status flags are stored in the Flag register (F) as follows:



In the individual instruction descriptions, the effect of instruction execution on status is illustrated as follows:



An X identifies a status that is set or reset. A 0 identifies a status that is always cleared. A 1 identifies a status that is always set. A blank means the status does not change. A question mark (?) means the status is not known.

**STATUS
CHANGES
WITH
INSTRUCTION
EXECUTION**

** Address Bus: A0-A7: [C]
A8-A15: [B]

Table 3-4. A Summary of the Z80 Instruction Set

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status						Operation Performed:
						C	Z	S	P/O	AC	N	
	IN	A,(port)	DB YY	2	10							[A] ← [port] Input to Accumulator from directly addressed I/O port. Address Bus: A0-A7: port A8-A15: [A]
	IN	reg,(C)	ED 01ddd000	2	11	X	X	P	X	O		[reg] ← [C] Input to register from I/O port addressed by the contents of C.** If second byte is 70 ₁₆ only the flags will be affected.
	INIR		ED B2	2	20/15**	1	?	?	?	1		Repeat until [B] = 0: [[HL]] ← [C] [B] ← [B] - 1 [HL] ← [HL] + 1 Transfer a block of data from I/O port addressed by contents of C to memory location addressed by contents of HL, going from low addresses to high. Contents of B serve as a count of bytes remaining to be transferred.**
O/I	INDR		ED BA	2	20/15**	1	?	?	?	1		Repeat until [B] = 0: [[HL]] ← [C] [B] ← [B] - 1 [HL] ← [HL] - 1 Transfer a block of data from I/O port addressed by contents of C to memory location addressed by contents of HL, going from high addresses to low. Contents of B serve as a count of bytes remaining to be transferred.**
	INI		ED A2	2	15	X	?	?	?	1		[[HL]] ← [C] [B] ← [B] - 1 [HL] ← [HL] + 1 Transfer a byte of data from I/O port addressed by contents of C to memory location addressed by contents of HL. Decrement byte count and increment destination address.**

**Address Bus: A0-A7: [C]
A8-A15: [B]

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed	
						C	Z	S	P/O	AC		N
I/O (Continued)	IND		ED AA	2	15		X	?	?	?	1	<p>[[HL]] ← [[C]] [B] ← [B] - 1 [HL] ← [HL] - 1</p> <p>Transfer a byte of data from I/O port addressed by contents of C to memory location addressed by contents of HL. Decrement both byte count and destination address.**</p> <p>{port} ← [A]</p> <p>Output from Accumulator to directly addressed I/O port. Address Bus: A0-A7: port A8-A15: [A]</p>
	OUT	{port},A	D3 yy	2	11							
	OUT	(C),reg	ED 01sss001	2	12							
	OTIR		ED B3	2	20/15**		1	?	?	?	1	<p>[[C]] ← [reg]</p> <p>Output from register to I/O port addressed by the contents of C.**</p> <p>Repeat until [B] = 0: [[C]] ← [[HL]] [B] ← [B] - 1 [HL] ← [HL] + 1</p>
	OTDR		ED BB	2	20/15**		1	?	?	?	1	<p>Transfer a block of data from memory location addressed by contents of HL to I/O port addressed by contents of C, going from low memory to high. Contents of B serve as a count of bytes remaining to be transferred.**</p> <p>Repeat until [B] = 0: [[C]] ← [[HL]] [B] ← [B] - 1 [HL] ← [HL] - 1</p> <p>Transfer a block of data from memory location addressed by contents of HL to I/O port addressed by contents of C, going from high memory to low. Contents of B serve as a count of bytes remaining to be transferred.**</p>

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

**Address Bus: A0-A7: [C]
A8-A15: [B]

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed		
						C	Z	S	P/O	AC		N	
I/O (Continued)	OUTI		ED A3	2	15		X	?	?	?	1	$[[C]] \leftarrow [[HL]]$ $[B] \leftarrow [B] - 1$ $[HL] \leftarrow [HL] + 1$ Transfer a byte of data from memory location addressed by contents of HL to I/O port addressed by contents of C. Decrement byte count and increment source address.**	
	OUTD		ED AB	2	15		X	?	?	?	1	$[[C]] \leftarrow [[HL]]$ $[B] \leftarrow [B] - 1$ $[HL] \leftarrow [HL] - 1$ Transfer a byte of data from memory location addressed by contents of HL to I/O port addressed by contents of C. Decrement both byte count and source address.**	
Primary Memory Reference	LD	A,(addr)	3A ppqq	3	13							$[A] \leftarrow [addr]$ Load Accumulator from directly addressed memory location.	
	LD	HL,(addr)	2A ppqq	3	16							$[H] \leftarrow [addr + 1]$, $[L] \leftarrow [addr]$ Load HL from directly addressed memory.	
	LD	rp,(addr)	ED 01xx1011 ppqq	4	20							$[rp(HI)] \leftarrow [addr + 1]$, $[rp(LO)] \leftarrow [addr]$ or $[xy(HI)] \leftarrow [addr + 1]$, $[xy(LO)] \leftarrow [addr]$ Load register pair or index register from directly addressed memory.	
	LD	(addr),A	32 ppqq	3	13							$[addr] \leftarrow [A]$ Store Accumulator contents in directly addressed memory location.	
	LD	(addr),HL	22 ppqq	3	16							$[addr + 1] \leftarrow [H]$, $[addr] \leftarrow [L]$ Store contents of HL to directly addressed memory location.	
	LD	(addr),rp	ED 01xx0011 ppqq	4	20							$[addr + 1] \leftarrow [rp(HI)]$, $[addr] \leftarrow [rp(LO)]$ or $[addr + 1] \leftarrow [xy(HI)]$, $[addr] \leftarrow [xy(LO)]$ Store contents of register pair or index register to directly addressed memory.	
	LD	(addr),xy	11x11101 22 ppqq	4	20								
	LD	A,(BC)	0A	1	7								$[A] \leftarrow [[BC]]$ or $[A] \leftarrow [[DE]]$ Load Accumulator from memory location addressed by the contents of the specified register pair.
	LD	A,(DE)	1A	1	7								

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed
						C	Z	S	P/O	AC	
Primary Memory Reference	LD	reg,(HL)	01ddd110	1	7						$[reg] \leftarrow [(HL)]$ Load register from memory location addressed by contents of HL.
	LD	(BC),A	02	1	7						$[(BC)] \leftarrow [A]$ or $[(DE)] \leftarrow [A]$ Store Accumulator to memory location addressed by the contents of the specified register pair.
	LD	(DE),A	12	1	7						$[(HL)] \leftarrow [reg]$ Store register contents to memory location addressed by the contents of HL.
	LD	(HL),reg	01110sss	1	7						$[reg] \leftarrow [xy] + disp$ Load register from memory location using base relative addressing.
	LD	reg,(xy+disp)	11x11101 01ddd110 disp	3	19						$[(xy) + disp] \leftarrow [reg]$ Store register to memory location addressed relative to contents of index register.
Block Transfer and Search	LDIR		ED B0	2	20/16**			0	0	0	Repeat until $[BC] = 0$: $[(DE)] \leftarrow [(HL)]$ $[DE] \leftarrow [DE] + 1$ $[HL] \leftarrow [HL] + 1$ $[BC] \leftarrow [BC] - 1$
	LDDR		ED B8	2	20/16**			0	0	0	Transfer a block of data from the memory location addressed by the contents of HL to the memory location addressed by the contents of DE, going from low addresses to high. Contents of BC serve as a count of bytes to be transferred. Repeat until $[BC] = 0$: $[(DE)] \leftarrow [(HL)]$ $[DE] \leftarrow [DE] - 1$ $[HL] \leftarrow [HL] - 1$ $[BC] \leftarrow [BC] - 1$

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed
						C	Z	S	P/O	AC	
Block Transfer and Search (Continued)	LDI		ED A0	2	16			X	0	0	$[[DE]] \leftarrow [[HL]]$ $[DE] \leftarrow [DE] + 1$ $[HL] \leftarrow [HL] + 1$ $[BC] \leftarrow [BC] - 1$ Transfer one byte of data from the memory location addressed by the contents of HL to the memory location addressed by the contents of DE. Increment source and destination addresses and decrement byte count.
	LDD		ED A8	2	16			X	0	0	$[[DE]] \leftarrow [[HL]]$ $[DE] \leftarrow [DE] - 1$ $[HL] \leftarrow [HL] - 1$ $[BC] \leftarrow [BC] - 1$ Transfer one byte of data from the memory location addressed by the contents of HL to the memory location addressed by the contents of DE. Decrement source and destination addresses and byte count.
	CPIR		ED B1	2	20/16**		X	X	X	1	Repeat until $[A] = [[HL]]$ or $[BC] = 0$: $[A] - [[HL]]$ (only flags are affected) $[HL] \leftarrow [HL] + 1$ $[BC] \leftarrow [BC] - 1$ Compare contents of Accumulator with those of memory block addressed by contents of HL, going from low addresses to high. Stop when a match is found or when the byte count becomes zero.
	CPDR		ED B9	2	20/16**		X	X	X	1	Repeat until $[A] = [[HL]]$ or $[BC] = 0$: $[A] - [[HL]]$ (only flags are affected) $[HL] \leftarrow [HL] - 1$ $[BC] \leftarrow [BC] - 1$ Compare contents of Accumulator with those of memory block addressed by contents of HL, going from high addresses to low. Stop when a match is found or when the byte count becomes zero.

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status						Operation Performed
						C	Z	S	P/O	AC	N	
Block Transfer and Search (Continued)	CPI		ED A1	2	16		X	X	X	X	1	[A] - [[HL]] (only flags are affected) [HL] ← [HL] + 1 [BC] ← [BC] - 1 Compare contents of Accumulator with those of memory location addressed by contents of HL. Increment address and decrement byte count.
	CPD		ED A9	2	16		X	X	X	X	1	[A] - [[HL]] (only flags are affected) [HL] ← [HL] - 1 [BC] ← [BC] - 1 Compare contents of Accumulator with those of memory location addressed by contents of HL. Decrement address and byte count.
Secondary Memory Reference	ADD	A,(HL) A,(xy + disp)	86 11x11101 86 disp	1 3	7 19	X	X	X	O	X	0	[A] ← [A] + [[HL]] or [A] ← [A] + [[xy] + disp] Add to Accumulator using implied addressing or base relative addressing.
	ADC	A,(HL) A,(xy + disp)	8E 11x11101 8E disp	1 3	7 19	X	X	X	O	X	0	[A] ← [A] + [[HL]] + C or [A] ← [A] + [[xy] + disp] + C Add with Carry using implied addressing or base relative addressing.
	SUB	(HL) (xy + disp)	96 11x11101 96 disp	1 3	7 19	X	X	X	O	X	1	[A] ← [A] - [[HL]] or [A] ← [A] - [[xy] + disp] Subtract from Accumulator using implied addressing or base relative addressing.
	SBC	A,(HL) A,(xy + disp)	9E 11x11101 9E disp	1 3	7 19	X	X	X	O	X	1	[A] ← [A] - [[HL]] - C or [A] ← [A] - [[xy] + disp] - C Subtract with Carry using implied addressing or base relative addressing.
	AND	(HL) (xy + disp)	A6 11x11101 A6 disp	1 3	7 19	0	X	X	P	1	0	[A] ← [A] ∧ [[HL]] or [A] ← [A] ∧ [[xy] + disp] AND with Accumulator using implied addressing or base relative addressing.
	OR	(HL) (xy + disp)	B6 11x11101 B6 disp	1 3	7 19	0	X	X	P	1	0	[A] ← [A] ∨ [[HL]] or [A] ← [A] ∨ [[xy] + disp] OR with Accumulator using implied addressing or base relative addressing.

Table 3-4. A Summary of the Z80 Instruction Set (Continued)



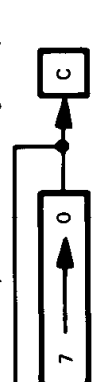
Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed
						C	Z	S	P/O	AC	
Secondary Memory Reference (Continued)	XOR	(HL) (xy + disp)	AE 11x1101 AE disp	1 3	7 19	0	X	P	1	0	$[A] \leftarrow [A] \oplus [[HL]]$ or $[A] \leftarrow [A] \oplus [(xy) + disp]$ Exclusive-OR with Accumulator using implied addressing or base relative addressing.
	CP	(HL) (xy + disp)	BE 11x1101 BE disp	1 3	7 19	X	X	O	X	1	$[A] \leftarrow [[HL]]$ or $[A] \leftarrow [(xy) + disp]$ Compare with Accumulator using implied addressing or base relative addressing. Only the flags are affected.
	INC	(HL) (xy + disp)	34 11x1101 34 disp	1 3	11 23	X	X	O	X	0	$[[HL]] \leftarrow [[HL]] + 1$ or $[[xy] + disp] \leftarrow [[xy] + disp] + 1$ Increment using implied addressing or base relative addressing.
	DEC	(HL) (xy + disp)	35 11x1101 35 disp	1 3	11 23	X	X	O	X	1	$[[HL]] \leftarrow [[HL]] - 1$ or $[[xy] + disp] \leftarrow [[xy] + disp] - 1$ Decrement using implied addressing or base relative addressing.
Memory Shift and Rotate	RLC	(HL) (xy + disp)	CB 06 11x1101 CB disp 06	2 4	15 23	X	X	P	0	0	 $[[HL]]$ or $[[xy] + disp]$ Rotate contents of memory location (implied or base relative addressing) left with branch Carry.
	RL	(HL) (xy + disp)	CB 16 11x1101 CB disp 16	2 4	15 23	X	X	P	0	0	 $[[HL]]$ or $[[xy] + disp]$ Rotate contents of memory location left through Carry.
	RRC	(HL) (xy + disp)	CB 0E 11x1101 CB disp 0E	2 4	15 23	X	X	P	0	0	 $[[HL]]$ or $[[xy] + disp]$ Rotate contents of memory location right with branch Carry.

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed
						C	Z	S	P/O	AC	
Memory Shift and Rotate (Continued)	RR	(HL) (xy + disp)	CB 1E 11x11101 CB disp 1E	2 4	15 23	X	X	P	0	0	<p>Rotate contents of memory location right through Carry [[HL]] or [[xy] + disp]</p>
	SLA	(HL) (xy + disp)	CB 26 11x11101 CB disp 26	2 4	15 23	X	X	P	0	0	<p>Shift contents of memory location left and clear LSB (Arithmetic Shift). [[HL]] or [[xy] + disp]</p>
	SRA	(HL) (xy + disp)	CB 2E 11x11101 CB disp 2E	2 4	15 23	X	X	P	0	0	<p>Shift contents of memory location right and preserve MSB (Arithmetic Shift). [[HL]] or [[xy] + disp]</p>
	SRL	(HL) (xy + disp)	CB 3E 11x11101 CB disp 3E	2 4	15 23	X	X	P	0	0	<p>Shift contents of memory location right and clear MSB (Logical Shift). [[HL]] or [[xy] + disp]</p>

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed	
						C	Z	S	P/O	Ac		N
Immediate	LD	reg,data	00ddd110 yy	2	7						[reg] ← data Load immediate into register.	
	LD	rp,data16	00xx0001 yyy	3	10						[rp] ← data16 or [xy] ← data16	
	LD	xy,data16	11x11101 21 yyy	4	14							Load 16 bits of immediate data into register pair or Index register.
		(HL),data	36 yy	2	10							[HL] ← data or [xy] + disp] ← data
		(xy + disp), data	11x11101 36 disp yy	4	19						Load immediate into memory location using implied or base relative addressing.	
Jump	JP	label	C3 ppqq	3	10						[PC] ← label Jump to instruction at address represented by label.	
	JR	disp	18 (disp-2)	2	12						[PC] ← [PC] + 2 + (disp-2) Jump relative to present contents of Program Counter.	
	JP	(HL)	E9	1	4							[PC] ← [HL] or [PC] ← [xy]
		(xy)	11x11101 E9	2	8							Jump to address contained in HL or Index register.
Subroutine Call and Return	CALL	label	CD ppqq	3	17						[[SP] - 1] ← [PC(HI)] [[SP] - 2] ← [PC(LO)] [SP] ← [SP] - 2 [PC] ← label Jump to subroutine starting at address represented by label.	
	CALL	cond,label	11ccc100 ppqq	3	10/17						Jump to subroutine if condition is satisfied; otherwise, continue in sequence.	
	RET		C9	1	10						[PC(LO)] ← [SP] [PC(HI)] ← [[SP] + 1] [SP] ← [SP] + 2 Return from subroutine.	
	RET	cond	11ccc000	1	5/11						Return from subroutine if condition is satisfied; otherwise, continue in sequence.	

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed	
						C	Z	S	P/O	AC		N
Immediate Operate	ADD	A,data	C6 YV	2	7	X	X	0	X	0	$[A] \leftarrow [A] + \text{data}$ Add immediate to Accumulator.	
	ADC	A,data	CE YV	2	7	X	X	0	X	0	$[A] \leftarrow [A] + \text{data} + C$ Add immediate with Carry.	
	SUB	data	D6 YV	2	7	X	X	0	X	1	$[A] \leftarrow [A] - \text{data}$ Subtract immediate from Accumulator.	
	SBC	A,data	DE YV	2	7	X	X	0	X	1	$[A] \leftarrow [A] - \text{data} - C$ Subtract immediate with Carry.	
	AND	data	E6 YV	2	7	0	X	P	1	0	$[A] \leftarrow [A] \wedge \text{data}$ AND immediate with Accumulator.	
	OR	data	F6 YV	2	7	0	X	P	1	0	$[A] \leftarrow [A] \vee \text{data}$ OR immediate with Accumulator.	
	XOR	data	EE YV	2	7	0	X	P	1	0	$[A] \leftarrow [A] \oplus \text{data}$ Exclusive-OR immediate with Accumulator.	
	CP	data	FE YV	2	7	X	X	0	X	1	$[A] - \text{data}$ Compare immediate data with Accumulator contents; only the flags are affected.	
	Jump on Condition	JP	cond,label	11cc010 ppqq	3	10						If cond, then $[PC] \leftarrow \text{label}$ Jump to instruction at address represented by label if the condition is true.
JR		C,disp	38 (disp-2)	2	7/12						If C = 1, then $[PC] \leftarrow [PC] + 2 + (\text{disp} - 2)$ Jump relative to contents of Program Counter if Carry flag is set.	
JR		NC,disp	30 (disp-2)	2	7/12						If C = 0, then $[PC] \leftarrow [PC] + 2 + (\text{disp} - 2)$ Jump relative to contents of Program Counter if Carry flag is reset.	
JR		Z,disp	28 (disp-2)	2	7/12						If Z = 1, then $[PC] \leftarrow [PC] + 2 + (\text{disp} - 2)$ Jump relative to contents of Program Counter if Zero flag is set.	
JR		NZ,disp	20 (disp-2)	2	7/12						If Z = 0, then $[PC] \leftarrow [PC] + 2 + (\text{disp} - 2)$ Jump relative to contents of Program Counter if Zero flag is reset.	
DJNZ		disp	disp	10 (disp-2)	2	8/13						$[B] \leftarrow [B] - 1$ If $[B] \neq 0$, then $[PC] + 2 + (\text{disp} - 2)$ Decrement contents of B and Jump relative to contents of Program Counter if result is not 0.

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed
						C	Z	S	P/O	AC	
	LD	dst,src	01ddsss	1	4						[dst] ← [src] Move contents of source register to destination register. Register designations src and dst may each be A, B, C, D, E, H or L.
	LD	A,I	ED 57	2	9	X	X	I	0	0	[A] ← [I] Move contents of Interrupt Vector register to Accumulator.
	LD	A,R	ED 5F	2	9	X	X	I	0	0	[A] ← [R] Move contents of Refresh register to Accumulator.
	LD	I,A	ED 47	2	9						[I] ← [A] Load Interrupt Vector register from Accumulator.
	LD	R,A	ED 4F	2	9						[R] ← [A] Load Refresh register from Accumulator.
	LD	SP,HL	F9	1	6						[SP] ← [HL] Move contents of HL to Stack Pointer.
	LD	SP,xy	11x11101 F9	2	10						[SP] ← [xy] Move contents of index register to Stack Pointer.
	EX	DE,HL	EB	1	4						[DE] ↔ [HL] Exchange contents of DE and HL.
	EX	AF,AF'	08	1	4						[AF] ↔ [AF'] Exchange program status and alternate program status.
	EXX		D9	1	4						$\begin{pmatrix} [BC'] \\ [DE] \end{pmatrix} \leftrightarrow \begin{pmatrix} [BC'] \\ [DE'] \\ [HL'] \end{pmatrix}$ Exchange register pairs and alternate register pairs.

Register-Register Move

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status						Operation Performed
						C	Z	S	P/O	AC	N	
Register-Register Operate	ADD	A,reg	10000rrr	1	4	X	X	X	O	X	0	$[A] \leftarrow [A] + [\text{reg}]$ Add contents of register to Accumulator.
	ADC	A,reg	10001rrr	1	4	X	X	X	O	X	0	$[A] \leftarrow [A] + [\text{reg}] + C$ Add contents of register and Carry to Accumulator.
	SUB	reg	10010rrr	1	4	X	X	X	O	X	1	$[A] \leftarrow [A] - [\text{reg}]$ Subtract contents of register from Accumulator.
	SBC	A,reg	10011rrr	1	4	X	X	X	O	X	1	$[A] \leftarrow [A] - [\text{reg}] - C$ Subtract contents of register and Carry from Accumulator.
	AND	reg	10000rrr	1	4	0	X	X	P	1	0	$[A] \leftarrow [A] \wedge [\text{reg}]$ AND contents of register with contents of Accumulator.
	OR	reg	10110rrr	1	4	0	X	X	P	1	0	$[A] \leftarrow [A] \vee [\text{reg}]$ OR contents of register with contents of Accumulator.
	XOR	reg	10101rrr	1	4	0	X	X	P	1	0	$[A] \leftarrow [A] \oplus [\text{reg}]$ Exclusive-OR contents of register with contents of Accumulator.
	CP	reg	10111rrr	1	4	X	X	X	O	X	1	$[A] - [\text{reg}]$ Compare contents of register with contents of Accumulator. Only the flags are affected.
	ADD	HL,rp	00xx1001	1	11	X				?	0	$[HL] \leftarrow [HL] + [rp]$ 16-bit add register pair contents to contents of HL.
	ADC	HL,rp	ED 01xx1010	2	15	X	X	X	O	?	0	$[HL] \leftarrow [HL] + [rp] + C$ 16-bit add with Carry register pair contents to contents of HL.
	SBC	HL,rp	ED 01xx0010	2	15	X	X	X	O	?	1	$[HL] \leftarrow [HL] - [rp] - C$ 16-bit subtract with Carry register pair contents from contents of HL.
	ADD	IX,pp	DD 00xx1001	2	15	X				?	0	$[IX] \leftarrow [IX] + [pp]$ 16-bit add register pair contents to contents of Index register IX (pp = BC, DE, IX, SP).
	ADD	IY,rr	FD 00xx1001	2	15	X				?	0	$[IY] \leftarrow [IY] + [rr]$ 16-bit add register pair contents to contents of Index register IY (rr = BC, DE, IY, SP).

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

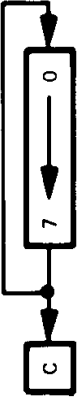

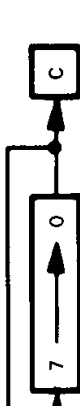
Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed		
						C	Z	S	P/O	AC		N	
Register Operate	DAA		27	1	4	X	X	P	X	1	1	Decimal adjust Accumulator, assuming that Accumulator contents are the sum or difference of BCD operands. [A] ← [A]	
	CPL		2F	1	4	X						Complement Accumulator (ones complement). [A] ← [A] + 1	
	NEG		ED 44	2	8	X	X	O	X	1	1	Negate Accumulator (twos complement). [reg] ← [reg] + 1	
	INC	reg	00rrr100	1	4	X	X	O	X	0	0	Increment register contents. [rp] ← [rp] + 1 or [xy] ← [xy] + 1	
	INC	rp xy	00xx0011 11x11101 23	1 2	6 10	X						Increment contents of register or Index register.	
	DEC	reg	0urr101	1	4	X	X	O	X	1	1	Decrement register contents. [reg] ← [reg] - 1	
	DEC	rp xy	00xx1011 11x11101 2B	1 2	6 10	X						Decrement contents of register pair or Index register.	
	Register Shift and Rotate	RLCA		07	1	4	X				0	0	
		RLA		17	1	4	X				0	0	
		RRCA		0F	1	4	X				0	0	

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

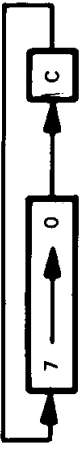





Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed
						C	Z	S	P/O	AC	
	RRA		1F	1	4	X					 <p>Rotate Accumulator right through Carry.</p>
	RLC	reg	CB 00000rrr	2	8	X	X	P			 <p>Rotate contents of register left with branch Carry.</p>
	RL	reg	CB 00010rrr	2	8	X	X	P			 <p>Rotate contents of register left through Carry.</p>
	RRC	reg	CB 00001rrr	2	8	X	X	P			 <p>Rotate contents of register right through Carry.</p>
	RR	reg	CB 00011rrr	2	8	X	X	P			 <p>Rotate contents of register right with branch Carry.</p>
	SLA	reg	CB 00100rrr	2	8	X	X	P			 <p>Shift contents of register left and clear LSB (Arithmetic Shift).</p>

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed	
						C	Z	S	P/O	AC		N
Register Shift and Rotate (Continued)	SRA	reg	CB 00101rrr	2	8	X	X	X	P	0	0	<p>Shift contents of register right and preserve MSB (Arithmetic Shift).</p>
	SRL	reg	CB 00111rrr	2	8	X	X	X	P	0	0	<p>Shift contents of register right and clear MSB (Logical Shift).</p>
	RLD		ED 6F	2	18	X	X	X	P	0	0	<p>Rotate one BCD digit left between the Accumulator and memory location (implied addressing). Contents of the upper half of the Accumulator are not affected.</p>
	RRD		ED 67	2	18	X	X	X	P	0	0	<p>Rotate one BCD digit right between the Accumulator and memory location (implied addressing). Contents of the upper half of the Accumulator are not affected.</p>

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status						Operation Performed
						C	Z	S	P/O	AC	N	
Bit Manipulation	BIT	b,reg	CB 01bbrrr	2	8		X	?	?	1	0	Z ← reg(b) Zero flag contains complement of the selected register bit.
	BIT	b,(HL) b,(xy + disp)	CB 01bb110 11x11101 CB disp 01bbb110	2 4	12 20		X	?	?	1	0	Z ← [(HL)(b) or Z ← [(xy) + disp](b) Zero flag contains complement of selected bit of the memory location (implied addressing or base relative addressing). reg(b) ← 1
	SET	b,reg	CB 11bbrrr	2	8							Set indicated register bit.
	SET	b,(HL) b,(xy + disp)	CB 11bb110 11x11101 CB disp 11bbb110	2 4	15 23							Set indicated bit of memory location (implied addressing or base relative addressing). reg(b) ← 0
	RES	b,reg	CB 10bbrrr	2	8							Reset indicated register bit.
	RES	b,(HL) b,(xy + disp)	CB 10bb110 11x11101 CB disp 10bbb110	2 4	15 23							Reset indicated bit in memory location (implied addressing or base relative addressing).
Stack	PUSH	pr xy	11xx0101 11x11101 E5	1 2	11 15							[[SP]-1] ← [pr(HI)] [[SP]-2] ← [pr(LO)] [SP] ← [SP]-2 Put contents of register pair or index register on top of Stack and decrement Stack Pointer.
	POP	pr xy	11xx0001 11x11101 E1	1 2	10 14							[pr(LO)] ← [[SP]] [pr(HI)] ← [[SP] + 1] [SP] ← [SP] + 2 Put contents of top of Stack in register pair or index register and increment Stack Pointer.
	EX	(SP),HL (SP),xy	E3 11x11101 E3	1 2	19 23							[H] ↔ [[SP] + 1] [L] ↔ [[SP]] Exchange contents of HL or Index register and top of Stack.

Table 3-4. A Summary of the Z80 Instruction Set (Continued)

Type	Mnemonic	Operand	Object Code	Bytes	Clock Cycles	Status					Operation Performed
						C	Z	S	P/O	AC	
Interrupt	DI		F3	1	4						Disable interrupts.
	EI		FB	1	4						Enable interrupts.
	RST	n	11xxx111	1	11						[[SP]-1] ← [PC(HI)] [[SP]-2] ← [PC(LO)] [SP] ← [SP]-2 [PC] ← (8-n)16
	RETI		ED 4D	2	14						Restart at designated location.
	RETN		ED 45	2	14						Return from interrupt.
	IM	0 1 2	ED 46 ED 56 ED 5E	2 2 2	8 8 8						Return from nonmaskable interrupt. Set interrupt mode 0, 1, or 2.
Status	SCF		37	1	4	1				0	C ← 1 Set Carry flag.
	CCF		3F	1	4	X				?	C ← \bar{C} Complement Carry flag.
	NOP		00	1	4						No operation — volatile memories are refreshed.
	HALT		76	1	4						CPU halts. executes NOPs to refresh volatile memories.

**Execution time shown is for one iteration.

Table 3-5. Instruction Object Codes in Numerical Order

OBJECT CODE	INSTRUCTION		OBJECT CODE	INSTRUCTION	
00	NOP		39	ADD	HL,SP
01 yyyy	LD	BC,data16	3A ppqq	LD	A,(addr)
02	LD	(BC),A	3B	DEC	SP
03	INC	BC	3C	INC	A
04	INC	B	3D	DEC	A
05	DEC	B	3E yy	LD	A,data
06 yy	LD	B,data	3F	CCF	
07	RLCA		4 0sss	LD	B,reg
08	EX	AF,AF'	46	LD	B,(HL)
09	ADD	HL,BC	4 1sss	LD	C,reg
0A	LD	A,(BC)	4E	LD	C,(HL)
0B	DEC	BC	5 0sss	LD	D,reg
0C	INC	C	56	LD	D,(HL)
0D	DEC	C	5 1sss	LD	E,reg
0E yy	LD	C,data	5E	LD	E,(HL)
0F	RRCA		6 0sss	LD	H,reg
10 disp-2	DJNZ	disp	66	LD	H,(HL)
11 yyyy	LD	DE,data16	6 1sss	LD	L,reg
12	LD	(DE),A	6E	LD	L,(HL)
13	INC	DE	7 0sss	LD	(HL),reg
14	INC	D	76	HALT	
15	DEC	D	7 1sss	LD	A,reg
16 yy	LD	D,data	7E	LD	A,(HL)
17	RLA		8 0rrr	ADD	A,reg
18 disp-2	JR	disp	86	ADD	A,(HL)
19	ADD	HL,DE	8 1rrr	ADC	A,reg
1A	LD	A,(DE)	8E	ADC	A,(HL)
1B	DEC	DE	9 0rrr	SUB	reg
1C	INC	E	96	SUB	(HL)
1D	DEC	E	9 1rrr	SBC	A,reg
1E yy	LD	E,data	9E	SBC	A,(HL)
1F	RRA		A 0rrr	AND	reg
20 disp-2	JR	NZ,disp	A6	AND	(HL)
21 yyyy	LD	HL,data16	A 1rrr	XOR	reg
22 ppqq	LD	(addr),HL	AE	XOR	(HL)
23	INC	HL	B 0rrr	OR	reg
24	INC	H	B6	OR	(HL)
25	DEC	H	B 1rrr	CP	reg
26 yy	LD	H,data	BE	CP	(HL)
27	DAA		C0	RET	NZ
28 disp-2	JR	Z,disp	C1	POP	BC
29	ADD	HL,HL	C2 ppqq	JP	NZ,addr
2A ppqq	LD	HL,(addr)	C3 ppqq	JP	addr
2B	DEC	HL	C4 ppqq	CALL	NZ,addr
2C	INC	L	C5	PUSH	BC
2D	DEC	L	C6 yy	ADD	A,data
2E	LD	L,data	C7	RST	00H
2F	CPL		C8	RET	Z
30 disp-2	JR	NC,disp	C9	RET	
31 yyyy	LD	SP,data16	CA ppqq	JP	Z,addr
32 ppqq	LD	(addr),A	CB 0 0rrr	RLC	reg
33	INC	SP	CB 06	RLC	(HL)
34	INC	(HL)	CB 0 1rrr	RRC	reg
35	DEC	(HL)	CB 0E	RRC	(HL)
36 yy	LD	(HL),data	CB 1 0rrr	RL	reg
37	SCF		CB 16	RL	(HL)
38	JR	C,disp	CB 1 1rrr	RR	reg

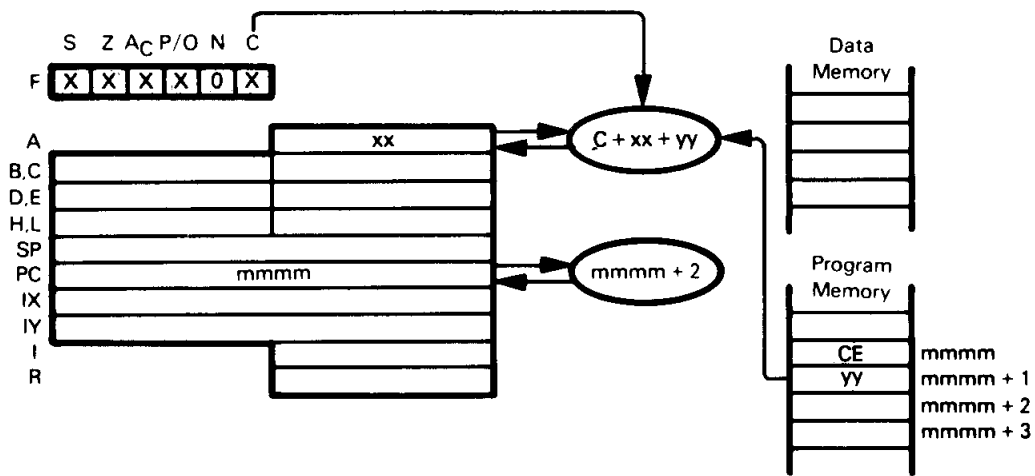
Table 3-5. Instruction Object Codes in Numerical Order (Continued)

OBJECT CODE	INSTRUCTION	OBJECT CODE	INSTRUCTION
CB 1E	RR (HL)	DD CB disp 10bbb110	RES b,(IX + disp)
CB 2 0rrr	SLA reg	DD CB disp 11bbb110	SET b,(IX + disp)
CB 26	SLA (HL)	DD E1	POP IX
CB 2 1rrr	SRA reg	DD E3	EX (SP),IX
CB 2E	SRA (HL)	DD E5	PUSH IX
CB 3 1rrr	SRL reg	DD E9	JP (IX)
CB 3E	SRL (HL)	DD F9	LD SP,IX
CB 01bbbrrr	BIT b,reg	DE yy	SBC A,data
CB 01bbb110	BIT b,(HL)	DF	RST 18H
CB 10bbbrrr	RES b,reg	E0	RET PO
CB 10bbb110	RES b,(HL)	E1	POP HL
CB 11bbbrrr	SET b,reg	E2 ppqq	JP PO,addr
CB 11bbb110	SET b,(HL)	E3	EX (SP),HL
CC ppqq	CALL Z,addr	E4 ppqq	CALL PO,addr
CD ppqq	CALL addr	E5	PUSH HL
CE yy	ADC A,data	E6 yy	AND data
CF	RST 08H	E7	RST 20H
D0	RET NC	E8	RET PE
D1	POP DE	E9	JP (HL)
D2 ppqq	JP NC,addr	EA ppqq	JP PE,addr
D3 yy	OUT (port),A	EB	EX DE,HL
D4 ppqq	CALL NC,addr	EC ppqq	CALL PE,addr
D5	PUSH DE	ED 01ddd000	IN reg,(C)
D6 yy	SUB data	ED 01sss001	OUT (C),reg
D7	RST 10H	ED 01xx 2	SBC HL,rp
D8	RET C	ED 01xx 3 ppqq	LD (addr),rp
D9	EXX	ED 44	NEG
DA ppqq	JP C,addr	ED 45	RETN
DB yy	IN A,(port)	ED 010nn110	IM m
DC ppqq	CALL C,addr	ED 47	LD I,A
DD 00xx 9	ADD IX,pp	ED 01xx A	ADC HL,rp
DD 21 yyyy	LD IX,data 16	ED 01xx B ppqq	LD rp,(addr)
DD 22 ppqq	LD (addr),IX	ED 4D	RETI
DD 23	INC IX	ED 4F	LD R,A
DD 2A ppqq	LD IX,(addr)	ED 57	LD A,I
DD 2B	DEC IX	ED 5F	LD A,R
DD 34 disp	INC (IX + disp)	ED 67	RRD
DD 35 disp	DEC (IX + disp)	ED 6F	RLD
DD 36 disp yy	LD (IX + disp),data	ED A0	LDI
DD 01ddd110 disp	LD reg,(IX + disp)	ED A1	CPI
DD / 0ess disp	LD (IX + disp),reg	ED A2	INI
DD 86 disp	ADD A,(IX + disp)	ED A3	OUTI
DD 8E disp	ADC A,(IX + disp)	ED A8	LDD
DD 96 disp	SUB (IX + disp)	ED A9	CPD
DD 9E disp	SBC A,(IX + disp)	ED AA	IND
DD A8 disp	AND (IX + disp)	ED AB	OUTD
DD AE disp	XOR (IX + disp)	ED B0	LDIR
DD B8 disp	OR (IX + disp)	ED B1	CPIR
DD BE disp	CP (IX + disp)	ED B2	INIR
DD CB disp 06	RLC (IX + disp)	ED B3	OTIR
DD CB disp 0E	RRC (IX + disp)	ED B8	LDDR
DD CB disp 16	RL (IX + disp)	ED B9	CPDR
DD CB disp 1E	RR (IX + disp)	ED BA	INDR
DD CB disp 26	SLA (IX + disp)	ED B8	OTDR
DD CB disp 2E	SRA (IX + disp)	EE yy	XOR data
DD CB disp 3E	SRL (IX + disp)	EF	RST 28H
DD CB disp 01bbb110	BIT b,(IX + disp)		

Table 3-5. Instruction Object Codes in Numerical Order (Continued)

OBJECT CODE	INSTRUCTION	OBJECT CODE	INSTRUCTION
F0	RET P	FD 8E disp	ADC A,(IY + disp)
F1	POP AF	FD 96 disp	SUB (IY + disp)
F2 ppqq	JP P,addr	FD 9E disp	SBC A,(IY + disp)
F3	DI	FD A6 disp	AND (IY + disp)
F4 ppqq	CALL P,addr	FD AE disp	XOR (IY + disp)
F5	PUSH AF	FD B6 disp	OR (IY + disp)
F6 yy	OR data	FD BE disp	CP (IY + disp)
F7	RST 30H	FD CB disp 06	RLC (IY + disp)
F8	RET M	FD CB disp 0E	RRC (IY + disp)
F9	LD SP,HL	FD CB disp 16	RL (IY + disp)
FA ppqq	JP M,addr	FD CB disp 1E	RR (IY + disp)
FB	EI	FD CB disp 26	SLA (IY + disp)
FC ppqq	CALL M,addr	FD CB disp 2E	SRA (IY + disp)
FD 00xx 9	ADD IY,rr	FD CB disp 3E	SRL (IY + disp)
FD 21 yyyy	LD IY,data16	FD CB disp 01bbb110	BIT b,(IY + disp)
FD 22 ppqq	LD (addr),IY	FD CB disp 10bbb110	RES b,(IY + disp)
FD 23	INC IY	FD CB disp 11bbb110	SET b,(IY + disp)
FD 2A ppqq	LD IY,(addr)	FD E1	POP IY
FD 2B	DEC IY	FD E3	EX (SP),IY
FD 34 disp	INC (IY + disp)	FD E5	PUSH IY
FD 35 disp	DEC (IY + disp)	FD E9	JP (IY)
FD 36 disp yy	LD (IY + disp),data	FD F9	LD SP,IY
FD 01ddd110 disp	LD reg,(IY + disp)	FE yy	CP data
FD 7 0sss disp	LD (IY + disp),reg	FF	RST 38H
FD 86 disp	ADD A,(IY + disp)		

ADC A,data — ADD IMMEDIATE WITH CARRY TO ACCUMULATOR



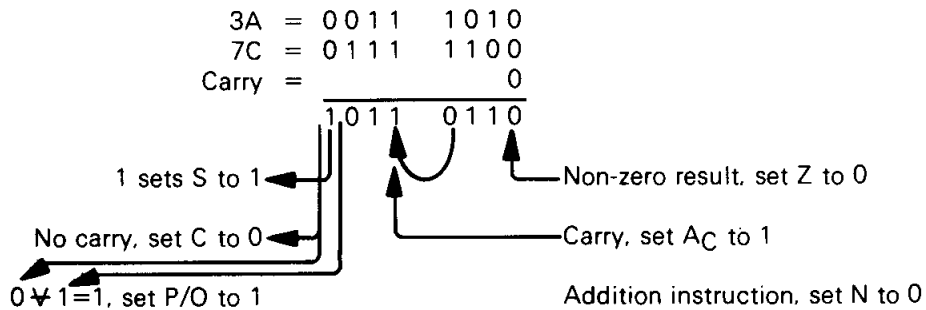
ADC A, data
CE yy

Add the contents of the next program memory byte and the Carry status to the Accumulator.

Suppose $xx=3A_{16}$, $yy=7C_{16}$, and Carry=0. After the instruction

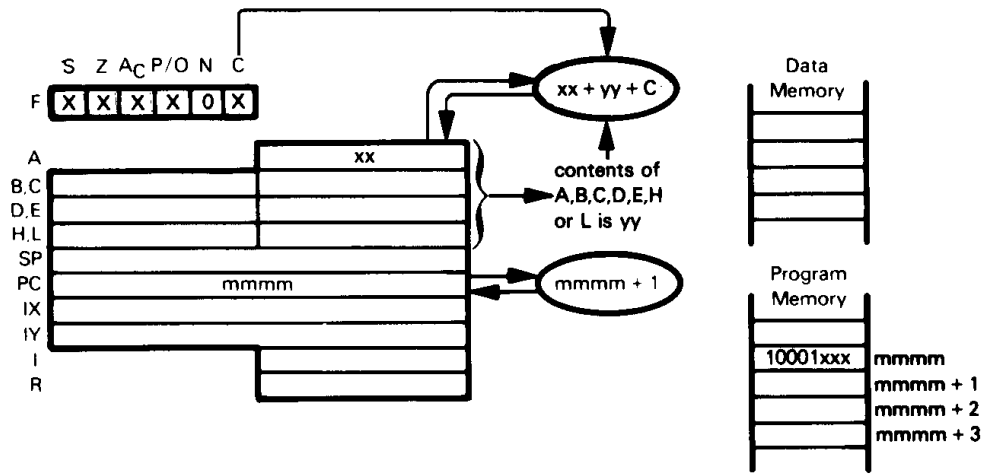
ADC A,7CH

has executed, the Accumulator will contain $B6_{16}$:



The ADC instruction is frequently used in multibyte addition for the second and subsequent bytes.

ADC A,reg — ADD REGISTER WITH CARRY TO ACCUMULATOR



ADC A, reg
 10001 xxx
 000 for reg=B
 001 for reg=C
 010 for reg=D
 011 for reg=E
 100 for reg=H
 101 for reg=L
 111 for reg=A

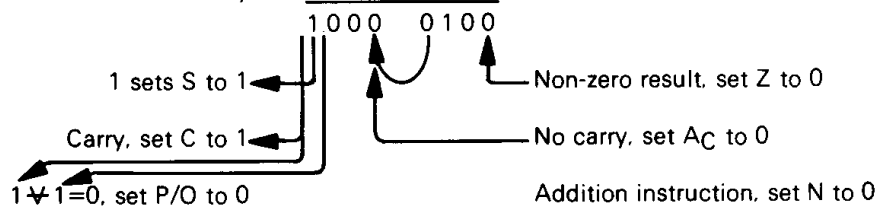
Add the contents of Register A, B, C, D, E, H or L and the Carry status to the Accumulator.

Suppose $xx = E3_{16}$, Register E contains $A0_{16}$, and Carry=1. After the instruction

ADC A,E

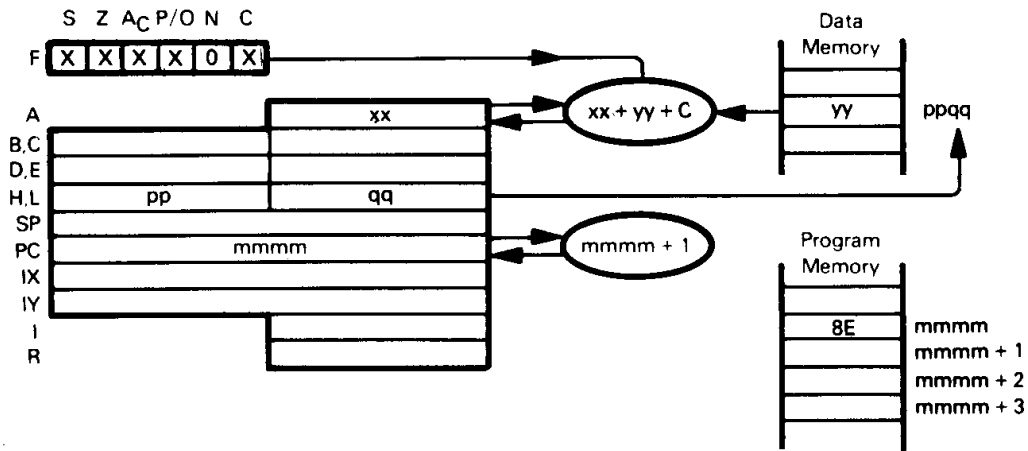
has executed, the Accumulator will contain 84_{16} :

E3 = 1110 0011
 A0 = 1010 0000
 Carry = 1



The ADC instruction is most frequently used in multibyte addition for the second and subsequent bytes.

**ADC A,(HL) — ADD MEMORY AND CARRY TO
 ADC A,(IX+disp) ACCUMULATOR
 ADC A,(IY+disp)**



The illustration shows execution of ADC A,(HL):

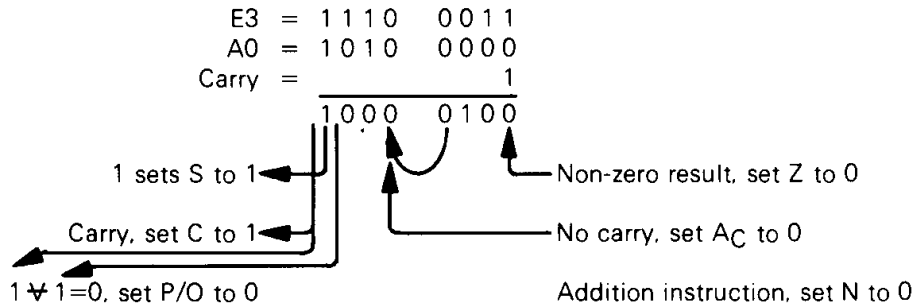
ADC A,(HL)
 8E

Add the contents of memory location (specified by the contents of the HL register pair) and the Carry status to the Accumulator.

Suppose $xx=E3_{16}$, $yy=A0_{16}$, and Carry=1. After the instruction

ADC A,(HL)

has executed, the Accumulator will contain 84_{16} :



ADC A,(IX+disp)

DD 8E d

Add the contents of memory location (specified by the sum of the contents of the IX register and the displacement digit d) and the Carry to the Accumulator.

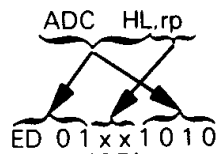
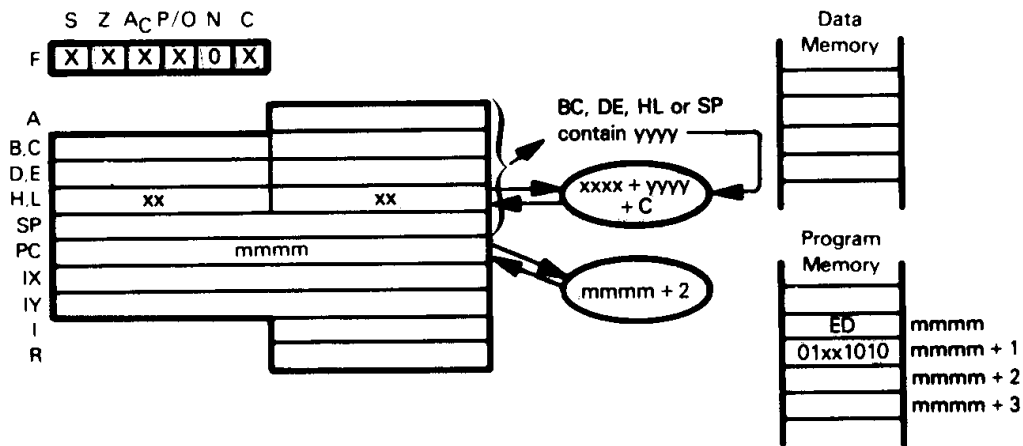
ADC A,(IY+disp)

FD 8E d

This instruction is identical to ADC A,(IX+disp), except that it uses the IY register instead of the IX register.

The ADC instruction is most frequently used in multibyte addition for the second and subsequent bytes.

ADC HL, rp — ADD REGISTER PAIR WITH CARRY TO H AND L



00 for rp is register pair BC
01 for rp is register pair DE
10 for rp is register pair HL
11 for rp is Stack Pointer

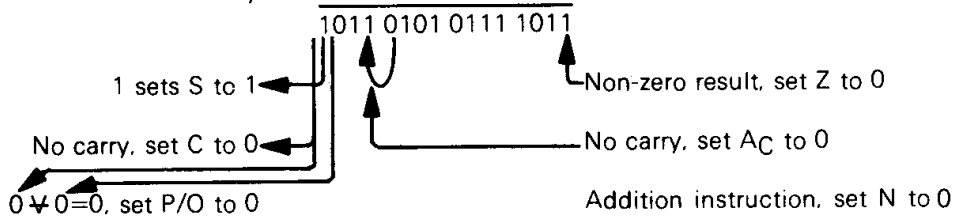
Add the 16-bit value from either the BC, DE, HL register pair or the Stack Pointer, and the Carry status, to the HL register pair.

Suppose HL contains $A536_{16}$, BC contains 1044_{16} , and Carry=1. After execution of
ADC HL,BC

the HL register pair will contain:

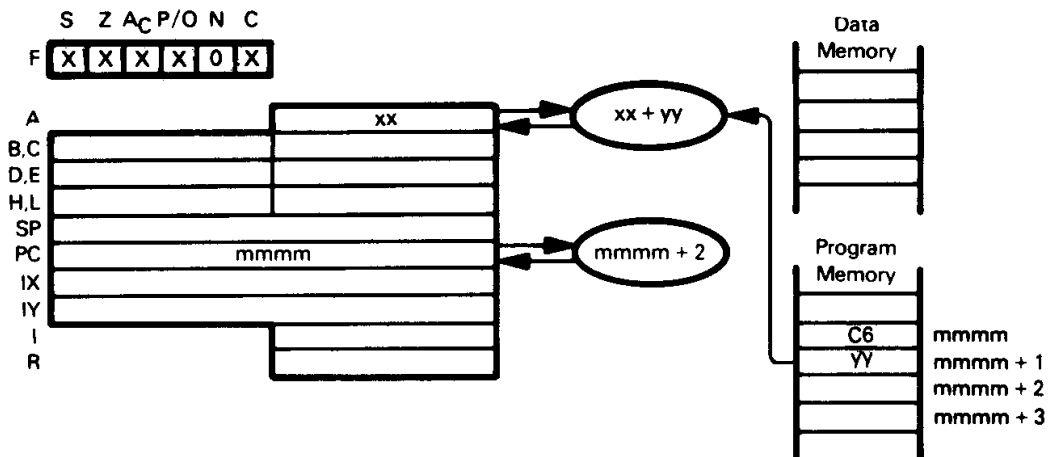
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A536 = 1010 0101 0011 0110
1044 = 0001 0000 0100 0100
Carry = 1
    
```



The ADC instruction is most frequently used in multibyte addition for the second and subsequent bytes.

ADD A,data — ADD IMMEDIATE TO ACCUMULATOR



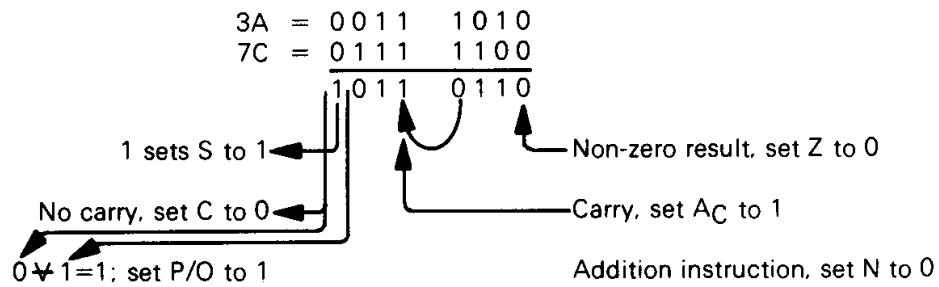
$\underbrace{\text{ADD A, data}}_{\text{C6}} \quad \underbrace{\text{data}}_{\text{yy}}$

Add the contents of the next program memory byte to the Accumulator.

Suppose $xx=3A_{16}$, $yy=7C_{16}$, and $\text{Carry}=0$. After the instruction

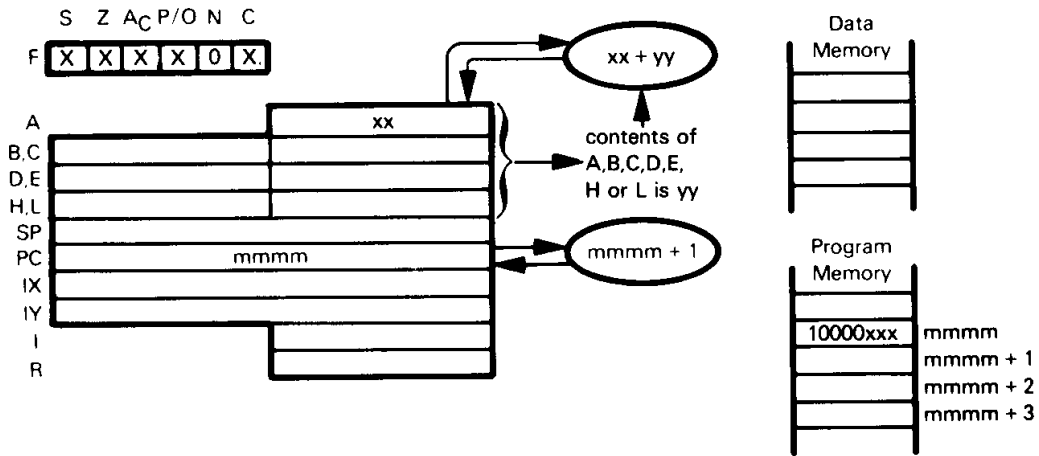
ADD A,7CH

has executed, the Accumulator will contain $B6_{16}$:



This is a routine data manipulation instruction.

ADD A,reg — ADD CONTENTS OF REGISTER TO ACCUMULATOR



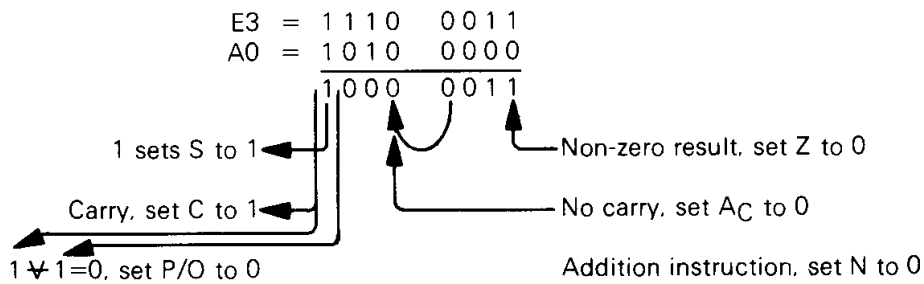
ADD reg
 10000 xxx
 000 for reg=B
 001 for reg=C
 010 for reg=D
 011 for reg=E
 100 for reg=H
 101 for reg=L
 111 for reg=A

Add the contents of Register A, B, C, D, E, H or L to the Accumulator.

Suppose $xx = E3_{16}$. Register E contains $A0_{16}$. After execution of

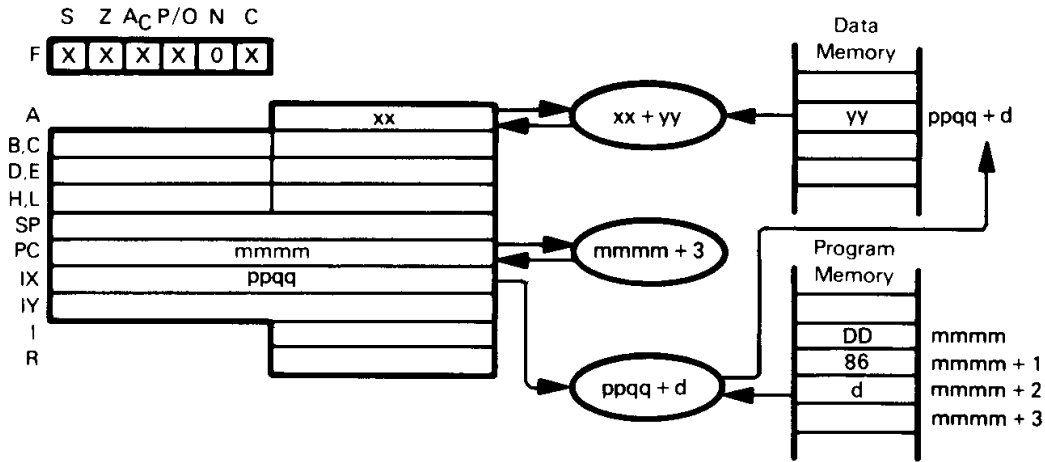
ADD A,E

the Accumulator will contain 83_{16} :



This is a routine data manipulation instruction

ADD A,(HL) — ADD MEMORY TO ACCUMULATOR
ADD A,(IX+disp)
ADD A,(IY+disp)



The illustration shows execution of ADD A,(IX+disp).

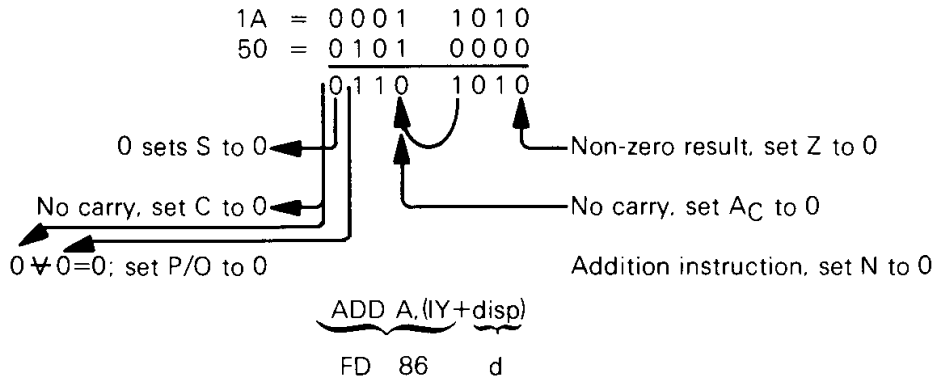
ADD A,(IX+disp)
 DD 86 d

Add the contents of memory location (specified by the sum of the contents of the IX register and the displacement digit d) to the contents of the Accumulator.

Suppose $ppqq = 4000_{16}$, $xx = 1A_{16}$, and memory location $400F_{16}$ contains 50_{16} . After the instruction

ADD A,(IX+0FH)

has executed, the Accumulator will contain $6A_{16}$.



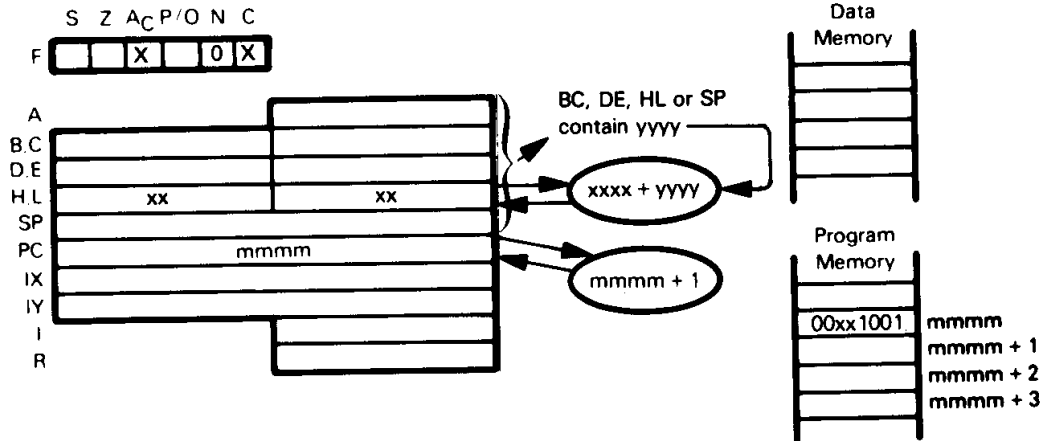
This instruction is identical to ADD A,(IX+disp), except that it uses the IY register instead of the IX register.

ADD A,(HL)
 86

This version of the instruction adds the contents of memory location, specified by the contents of the HL register pair, to the Accumulator.

The ADD instruction is a routine data manipulation instruction.

ADD HL,rp — ADD REGISTER PAIR TO H AND L



00 for rp is register pair BC
 01 for rp is register pair DE
 10 for rp is register pair HL
 11 for rp is Stack Pointer

Add the 16-bit value from either the BC, DE, HL register pair or the Stack Pointer to the HL register pair.

Suppose HL contains $034A_{16}$ and BC contains $214C_{16}$. After the instruction

ADD HL,BC

has executed, the HL register pair will contain 2496_{16} .

$$\begin{array}{r} 034A = 0000\ 0011\ 0100\ 1010 \\ 214C = 0010\ 0001\ 0100\ 1100 \\ \hline 0010\ 0100\ 1001\ 0110 \end{array}$$

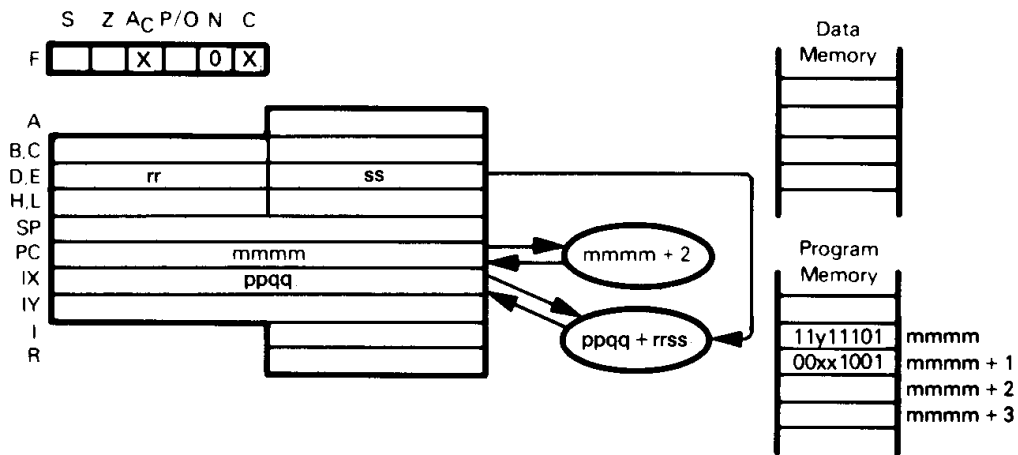
No carry, set C to 0

No carry, set AC to 0

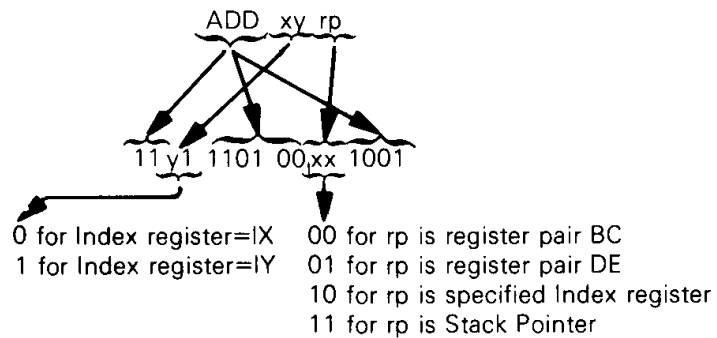
Addition instruction, set N to 0

The ADD HL,HL instruction is equivalent to a 16-bit left shift.

ADD xy,rp — ADD REGISTER PAIR TO INDEX REGISTER



The illustration shows execution of ADD IX,DE.



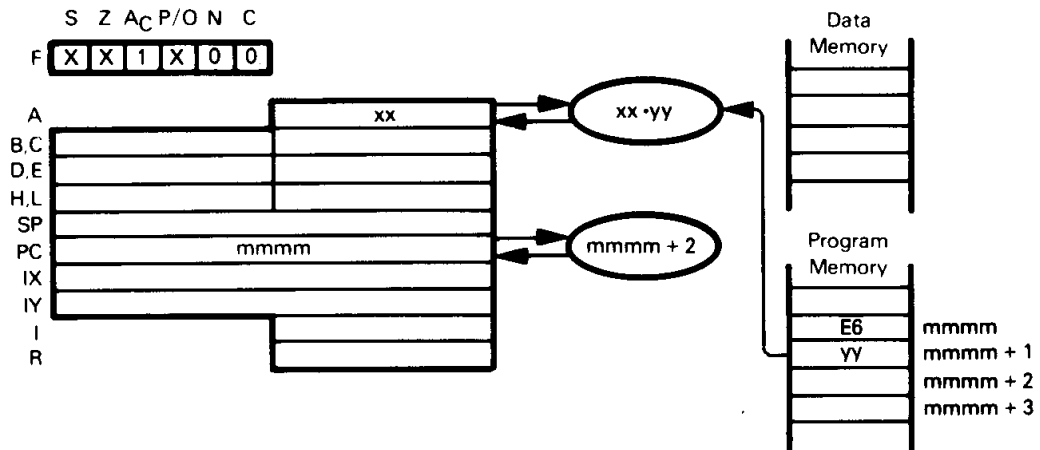
Add the contents of the specified register pair to the contents of the specified Index register.

Suppose IY contains $4FF0_{16}$ and BC contains $000F_{16}$. After the instruction

ADD IY,BC

has executed, Index Register IY will contain $4FFF_{16}$.

AND data — AND IMMEDIATE WITH ACCUMULATOR



$\underbrace{\text{AND}}_{\text{E6}}$ $\underbrace{\text{data}}_{\text{yy}}$

AND the contents of the next program memory byte to the Accumulator.

Suppose $xx=3A_{16}$. After the instruction

AND 7CH

has executed, the Accumulator will contain 38_{16} .

3A	=	0011	1010
7C	=	0111	1100

		0011	1000

0 sets S to 0 ←

Three 1 bits, set P/O to 0

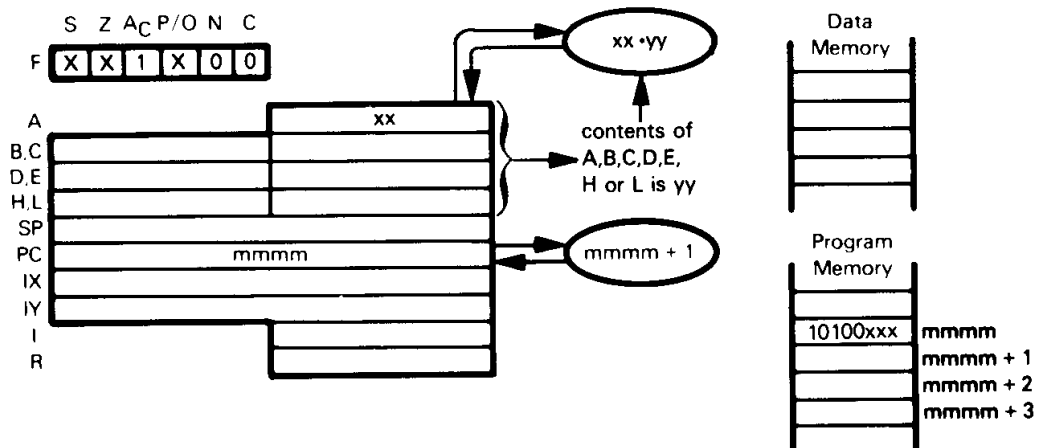
Non-zero result, set Z to 0

This is a routine logical instruction; it is often used to turn bits "off". For example, the instruction

AND 7FH

will unconditionally set the high order Accumulator bit to 0.

AND reg — AND REGISTER WITH ACCUMULATOR



AND	reg
<u>10100</u>	<u>xxx</u>
	000 for reg=B
	001 for reg=C
	010 for reg=D
	011 for reg=E
	100 for reg=H
	101 for reg=L
	111 for reg=A

AND the Accumulator with the contents of Register A, B, C, D, E, H or L. Save the result in the Accumulator.

Suppose $xx = E3_{16}$, and Register E contains $A0_{16}$. After the instruction

AND E

has executed, the Accumulator will contain $A0_{16}$.

$$\begin{array}{r}
 E3 = 1110\ 0011 \\
 A0 = 1010\ 0000 \\
 \hline
 \text{Result} = 1010\ 0000
 \end{array}$$

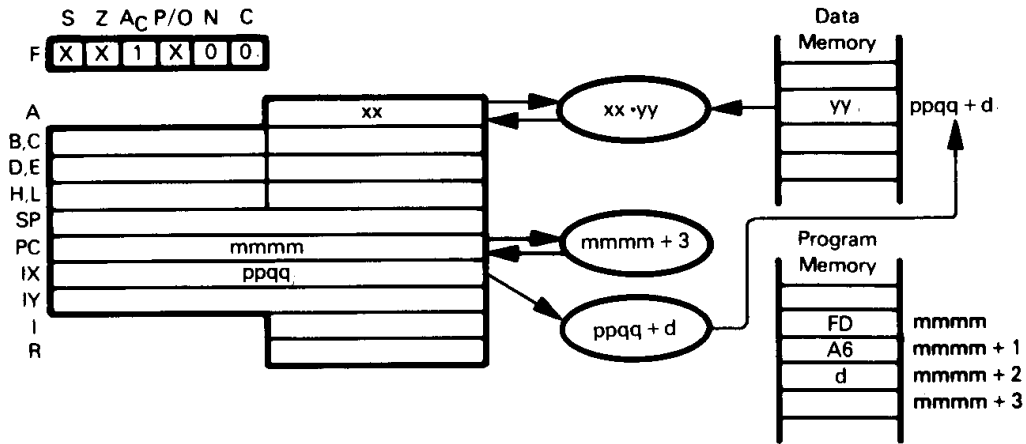
1 sets S to 1

Two 1 bits, set P/O to 1

Non-zero result, set Z to 0

AND is a frequently used logical instruction.

AND (HL) — AND MEMORY WITH ACCUMULATOR
AND (IX+disp)
AND (IY+disp)



The illustration shows execution of AND (IY+disp).

$$\underbrace{\text{AND (IY+disp)}}_{\text{FD A6 d}}$$

AND the contents of memory location (specified by the sum of the contents of the IY register and the displacement digit d) with the Accumulator.

Suppose $xx = E3_{16}$, $ppqq = 4000_{16}$, and memory location $400F_{16}$ contains $A0_{16}$. After the instruction

$$\text{AND (IY+0FH)}$$

has executed, the Accumulator will contain $A0_{16}$.

$$\begin{array}{r} E3 = 1110 \ 0111 \\ A0 = 1010 \ 0000 \\ \hline 1010 \ 0000 \end{array}$$

1 sets S to 1

Two 1 bits, set P/O to 1

Non-zero result, set Z to 0

$$\underbrace{\text{AND (IX+disp)}}_{\text{DD A6 d}}$$

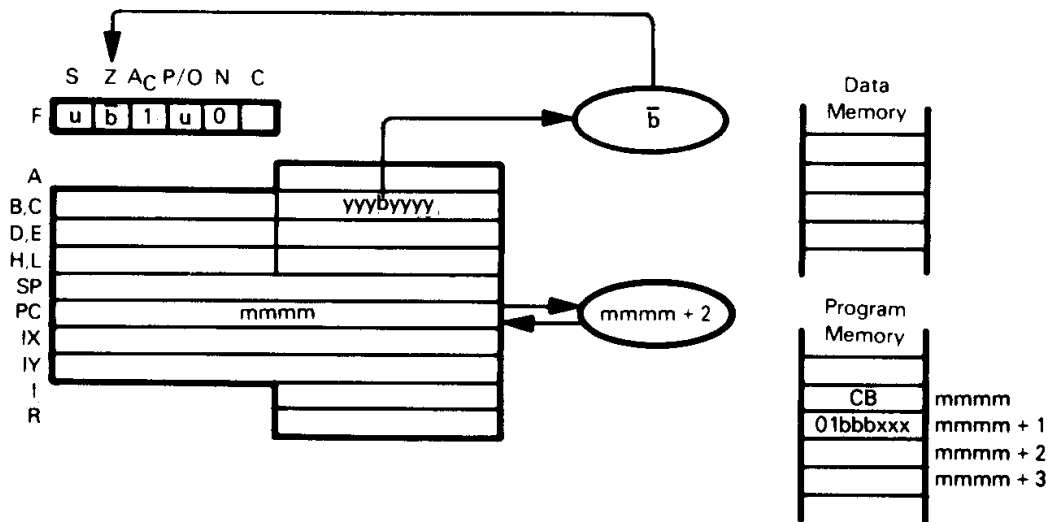
This instruction is identical to AND (IY+disp), except that it uses the IX register instead of the IY register.

$$\underbrace{\text{AND (HL)}}_{\text{A6}}$$

AND the contents of the memory location (specified by the contents of the HL register pair) with the Accumulator.

AND is a frequently used logical instruction.

BIT b,reg — TEST BIT b IN REGISTER reg

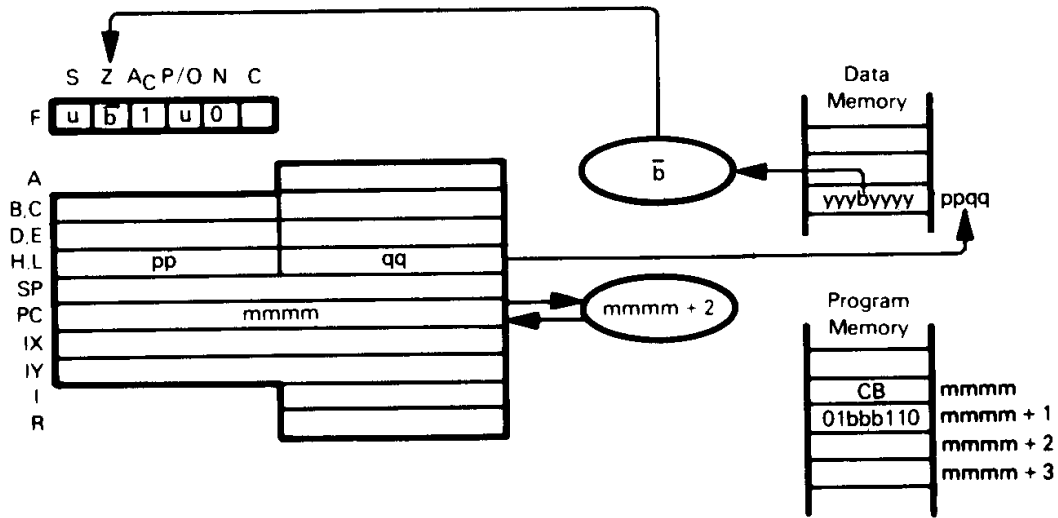


<u>BIT</u>	<u>b</u>	<u>reg</u>	
CB 01	<u>bbb</u>	<u>xxx</u>	
<u>Bit Tested</u>			<u>Register</u>
0	000	000	B
1	001	001	C
2	010	010	D
3	011	011	E
4	100	100	H
5	101	101	L
6	110	111	A
7	111		

Place complement of indicated register's specified bit in Z flag of F register.

Suppose Register C contains 1110 1111. The instruction BIT 4,C will then set the Z flag to 1, while bit 4 in Register C remains 0. Bit 0 is the least significant bit.

BIT b,(HL) — TEST BIT b OF INDICATED MEMORY POSITION
BIT b,(IX+disp)
BIT b,(IY+disp)



The illustration shows execution of BIT 4,(HL). Bit 0 is the least significant bit.

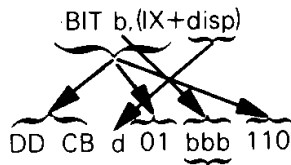
BIT	b, (HL)
CB 01	bbb 110
Bit Tested	bbb
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Test indicated bit within memory position specified by the contents of Register HL, and place bit's complement in Z flag of the F register.

Suppose HL contains 4000H and bit 3 in memory location 4000H contains 1. The instruction

BIT 3,(HL)

will then set the Z flag to 0, while bit 3 in memory location 4000H remains 1.



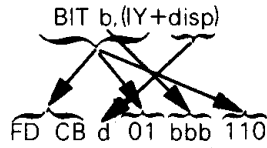
bbb is the same as in BIT b,(HL)

Examine specified bit within memory location indicated by the sum of Index Register IX and disp. Place the complement in the Z flag of the F register.

Suppose Index Register IX contains 4000H and bit 4 of memory location 4004H is 0. The instruction

BIT 4,(IX+4H)

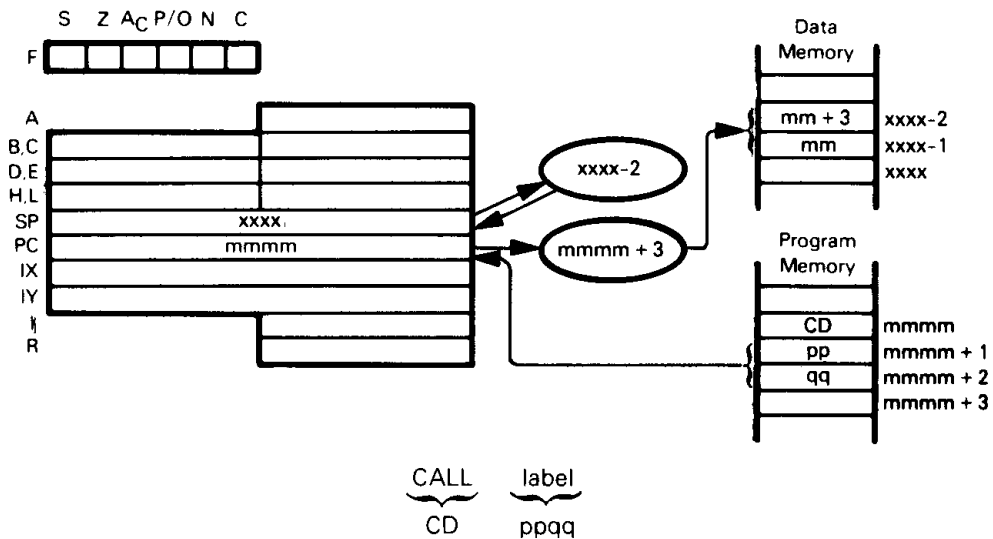
will then set the Z flag to 1, while bit 4 of memory location 4004H remains 0.



bbb is the same as in BIT b,(HL)

This instruction is identical to BIT b,(IX+disp), except that it uses the IY register instead of the IX register.

CALL label — CALL THE SUBROUTINE IDENTIFIED IN THE OPERAND



Store the address of the instruction following the CALL on the top of the stack: the top of the stack is a data memory byte addressed by the Stack Pointer. Then subtract 2 from the Stack Pointer in order to address the new top of stack. Move the 16-bit address contained in the second and third CALL instruction object program bytes to the Program Counter. The second byte of the CALL instruction is the low-order half of the address, and the third byte is the high-order byte.

Consider the instruction sequence:

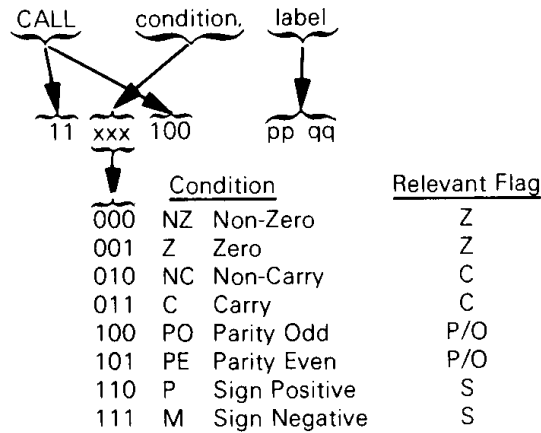
```

CALL  SUBR
AND   7CH
-
-
-
SUBR

```

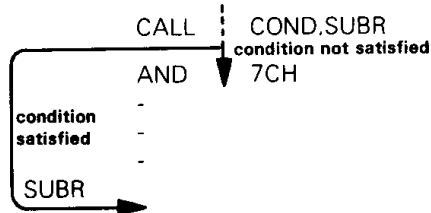
After the instruction has executed, the address of the AND instruction is saved at the top of the stack. The Stack Pointer is decremented by 2. The instruction labeled SUBR will be executed next.

CALL condition,label — CALL THE SUBROUTINE IDENTIFIED IN THE OPERAND IF CONDITION IS SATISFIED



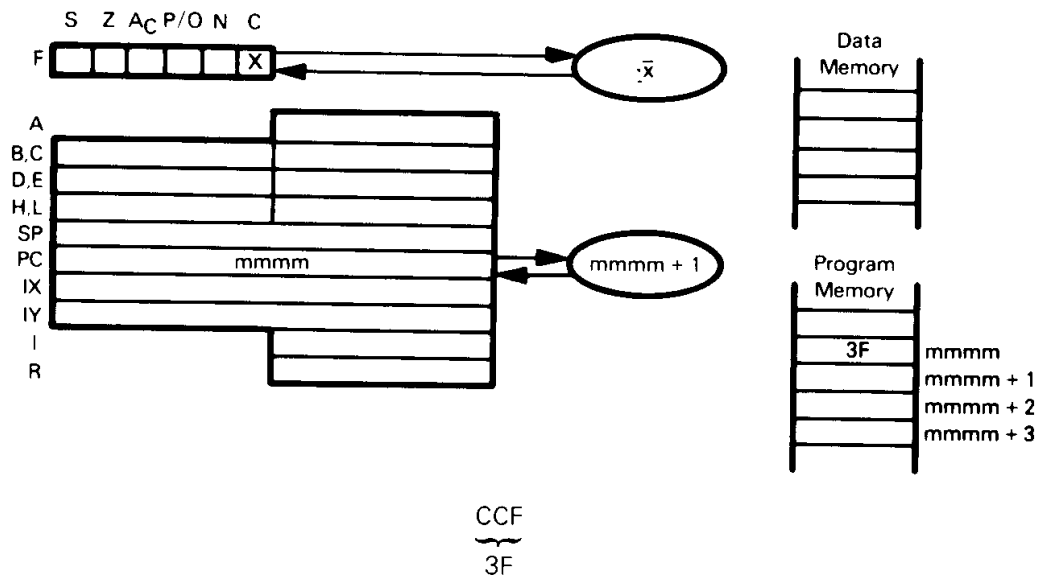
This instruction is identical to the CALL instruction, except that the identified subroutine will be called only if the condition is satisfied; otherwise, the instruction sequentially following the CALL condition instruction will be executed.

Consider the instruction sequence:



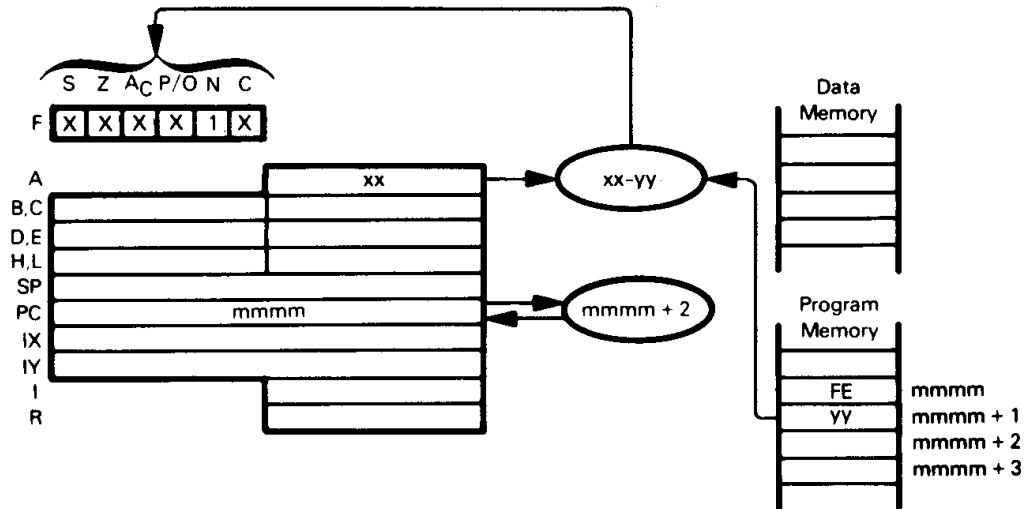
If the condition is not satisfied, the AND instruction will be executed after the CALL COND,SUBR instruction has executed. If the condition is satisfied, the address of the AND instruction is saved at the top of the stack, and the Stack Pointer is decremented by 2. The instruction labeled SUBR will be executed next.

CCF — COMPLEMENT CARRY FLAG



Complement the Carry flag. No other status or register contents are affected.

CP data — COMPARE IMMEDIATE DATA WITH ACCUMULATOR



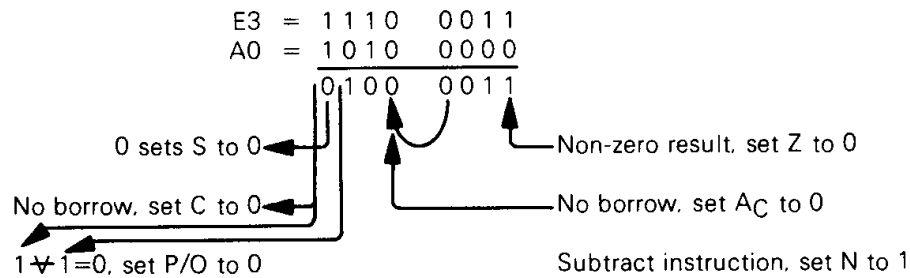
$\underbrace{\text{CP}}_{\text{FE}}$ $\underbrace{\text{data}}_{\text{yy}}$

Subtract the contents of the second object code byte from the contents of the Accumulator, treating both numbers as simple binary data. Discard the result; i.e., leave the Accumulator alone, but modify the status flags to reflect the result of the subtraction.

Suppose $xx = E3_{16}$ and the second byte of the CP instruction object code contains $A0_{16}$. After the instruction

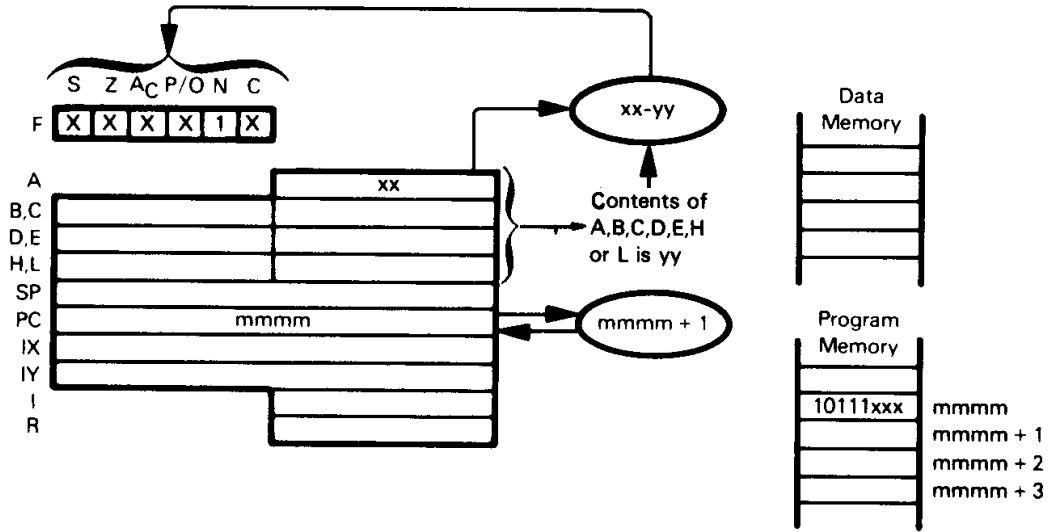
CP 0A0H

has executed, the Accumulator will still contain $E3_{16}$, but statuses will be modified as follows:



Notice that the resulting carry is complemented.

CP reg — COMPARE REGISTER WITH ACCUMULATOR



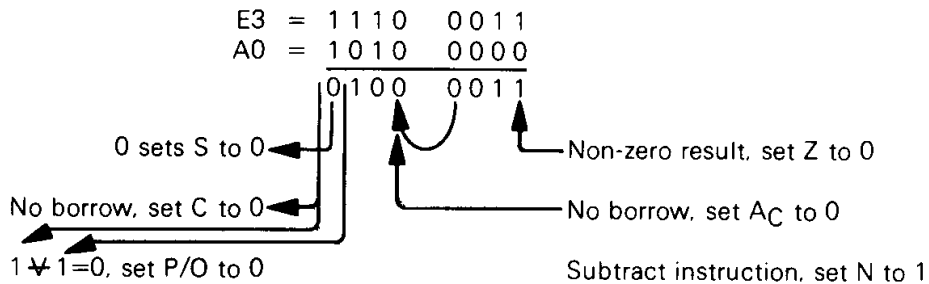
CP	reg	
10111	xxx	
	000	for reg=B
	001	for reg=C
	010	for reg=D
	011	for reg=E
	100	for reg=H
	101	for reg=L
	111	for reg=A

Subtract the contents of Register A, B, C, D, E, H or L from the contents of the Accumulator, treating both numbers as simple binary data. Discard the result; i.e., leave the Accumulator alone, but modify status flags to reflect the result of the subtraction.

Suppose $xx=E3_{16}$ and Register B contains $A0_{16}$. After the instruction

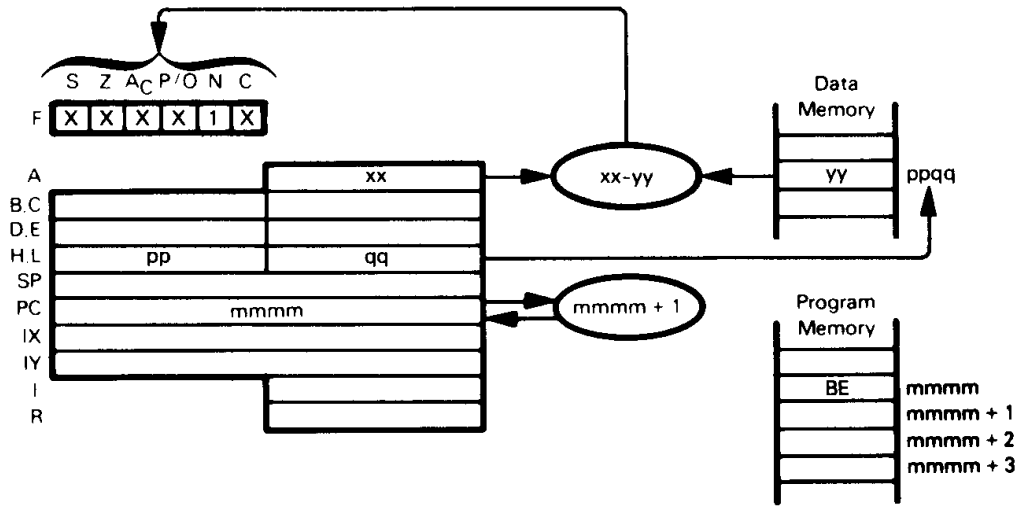
CP B

has executed, the Accumulator will still contain $E3_{16}$, but statuses will be modified as follows:



Notice that the resulting carry is complemented.

CP (HL) — COMPARE MEMORY WITH ACCUMULATOR
CP (IX+disp)
CP (IY+disp)



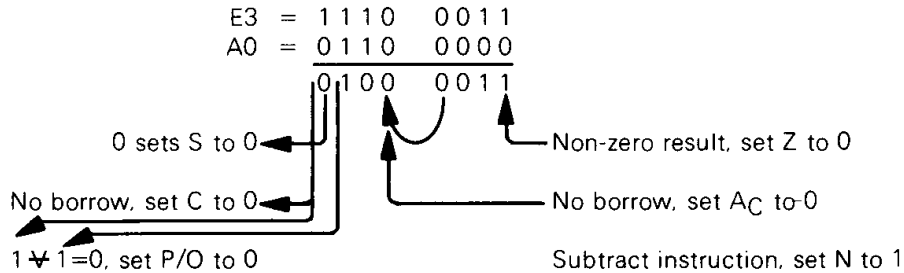
The illustration shows execution of CP (HL):

CP (HL)
 └──────────┘
 BE

Subtract the contents of memory location (specified by the contents of the HL register pair) from the contents of the Accumulator, treating both numbers as simple binary data. Discard the result; i.e., leave the Accumulator alone, but modify status flags to reflect the result of the subtraction.

Suppose $xx=E3_{16}$ and $yy=A0_{16}$. After execution of CP (HL)

the Accumulator will still contain $E3_{16}$, but statuses will be modified as follows:



Notice that the resulting carry is complemented.

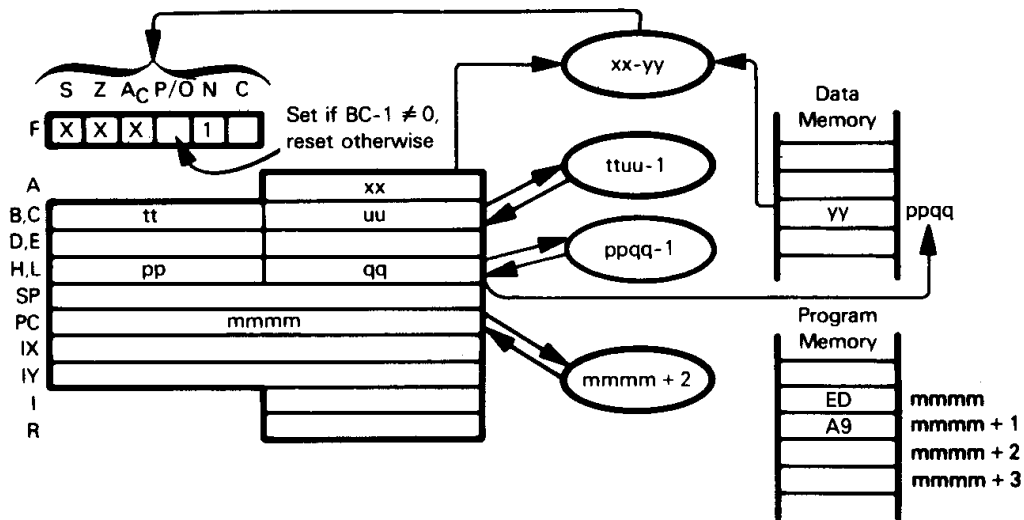
CP (IX+disp)
 └──────────┘ └──────────┘
 DD BE d

Subtract the contents of memory location (specified by the sum of the contents of the IX register and the displacement value d) from the contents of the Accumulator, treating both numbers as simple binary data. Discard the result; i.e., leave the Accumulator alone, but modify status flags to reflect the result of the subtraction.

CP (IY+disp)
FD BE d

This instruction is identical to CP (IX+disp), except that it uses the IY register instead of the IX register.

**CPD — COMPARE ACCUMULATOR WITH MEMORY.
DECREMENT ADDRESS AND BYTE COUNTER**



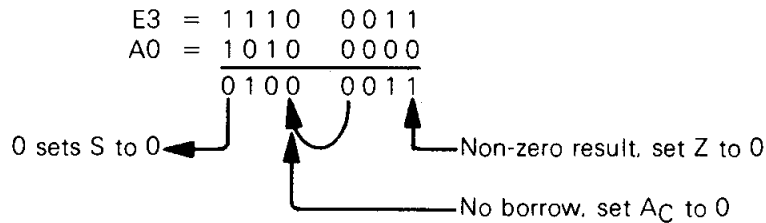
CPD
ED A9

Compare the contents of the Accumulator with the contents of memory location (specified by the HL register pair). If A is equal to memory, set Z flag. Decrement the HL and BC register pairs. (BC is used as the Byte Counter.)

Suppose $xx=E3_{16}$, $ppqq=4000_{16}$, BC contains 0001_{16} , and $yy=A0_{16}$. After the instruction

CPD

has executed, the Accumulator will still contain $E3_{16}$, but statuses will be modified as follows:



The P/O flag will be reset because $BC-1=0$

Subtract instruction involved, set N to 1

Carry not affected.

The HL register pair will contain $3FFF_{16}$, and $BC=0$.

**CPDR — COMPARE ACCUMULATOR WITH MEMORY.
DECREMENT ADDRESS AND BYTE COUNTER.
CONTINUE UNTIL MATCH IS FOUND OR BYTE
COUNTER IS ZERO**

CPDR
ED B9

This instruction is identical to CPD, except that it is repeated until a match is found or the byte counter is zero. After each data transfer, interrupts will be recognized and two refresh cycles will be executed.

Suppose the HL register pair contains 5000_{16} , the BC register pair contains $00FF_{16}$, the Accumulator contains $F9_{16}$, and memory has contents as follows:

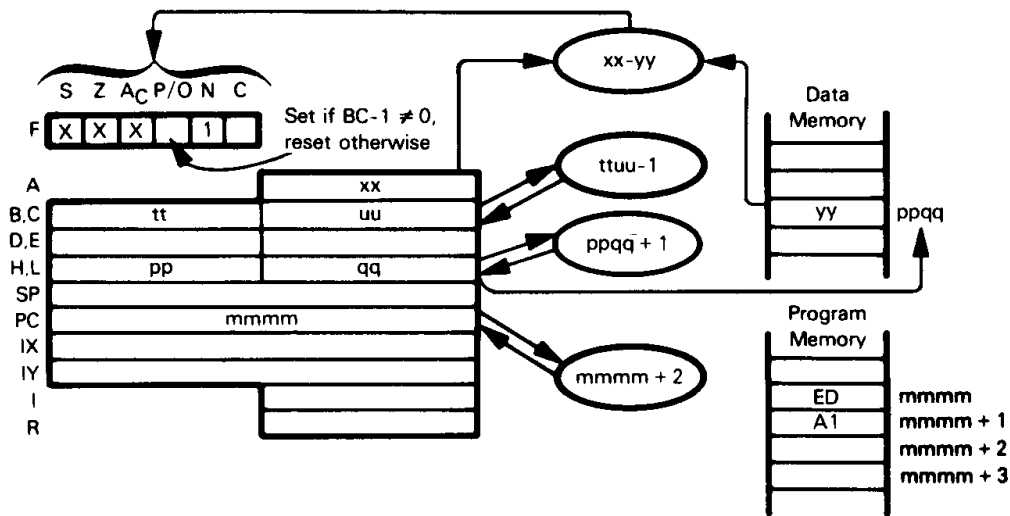
Location	Contents
5000_{16}	AA_{16}
$4FFF_{16}$	BC_{16}
$4FFE_{16}$	19_{16}
$4FFD_{16}$	$7A_{16}$
$4FFC_{16}$	$F9_{16}$
$4FFB_{16}$	DD_{16}

After execution of

CPDR

the P/O flag will be 1, the Z flag will be 1, the HL register pair will contain $4FFB_{16}$, and the BC register pair will contain $00FA_{16}$.

**CPI — COMPARE ACCUMULATOR WITH MEMORY.
DECREMENT BYTE COUNTER.
INCREMENT ADDRESS**



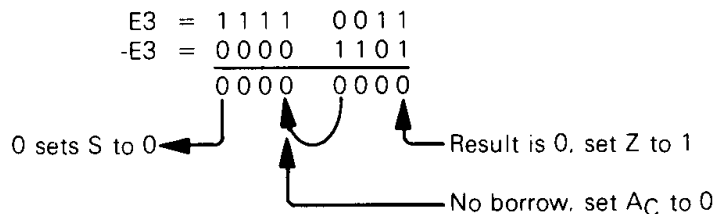
CPI
ED A1

Compare the contents of the Accumulator with the contents of memory location (specified by the HL register pair). If A is equal to memory, set the Z flag. Increment the HL register pair and decrement the BC register pair (BC is used as Byte Counter).

Suppose $xx = E3_{16}$, $ppqq = 4000_{16}$, BC contains 0032_{16} , and $yy = E3_{16}$. After the instruction

CPI

has executed, the Accumulator will still contain $E3_{16}$, but statuses will be modified as follows:



The P/O flag will be set because $BC-1 \neq 0$.

Subtract instruction involved, set N to 1.

Carry not affected.

The HL register pair will contain 4001_{16} , and BC will contain 0031_{16} .

**CPIR — COMPARE ACCUMULATOR WITH MEMORY.
DECREMENT BYTE COUNTER.
INCREMENT ADDRESS.
CONTINUE UNTIL MATCH IS FOUND
OR BYTE COUNTER IS ZERO**

CPIR
ED B1

This instruction is identical to CPI, except that it is repeated until a match is found or the byte counter is zero. After each data transfer interrupts will be recognized and two refresh cycles will be executed.

Suppose the HL register pair contains 4500_{16} , the BC register pair contains $00FF_{16}$, the Accumulator contains $F9_{16}$, and memory has contents as follows:

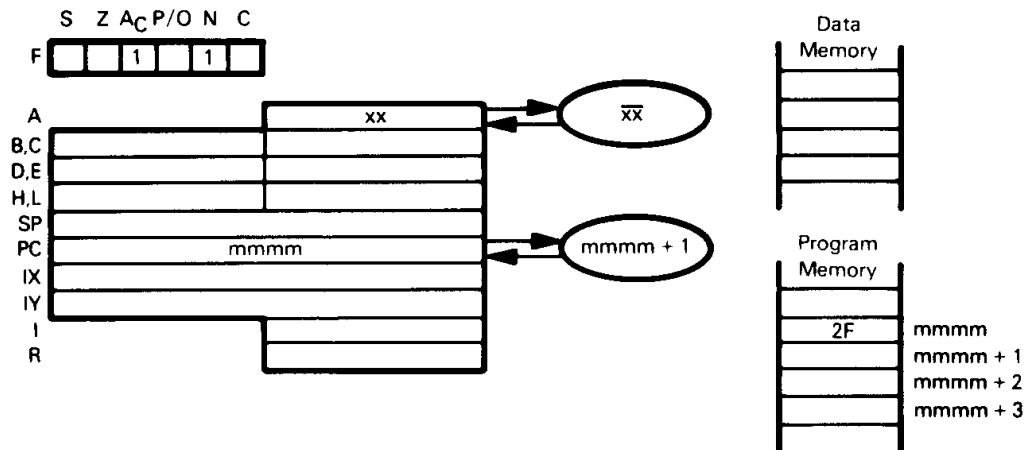
<u>Location</u>	<u>Contents</u>
4500_{16}	AA_{16}
4501_{16}	15_{16}
4502_{16}	$F9_{16}$

After execution of

CPIR

the P/O flag will be 1, and the Z flag will be 1. The HL register pair will contain 4503_{16} , and the BC register pair will contain $00FC_{16}$.

CPL — COMPLEMENT THE ACCUMULATOR



CPL
2F

Complement the contents of the Accumulator. No other register's contents are affected.

Suppose the Accumulator contains $3A_{16}$. After the instruction

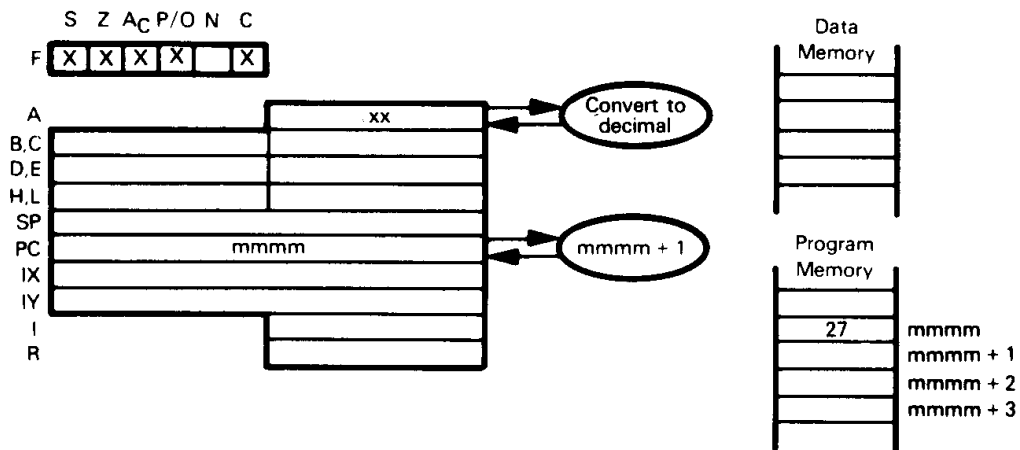
CPL

has executed, the Accumulator will contain $C5_{16}$.

$$\begin{aligned} 3A &= 0011 \quad 1010 \\ \text{Complement} &= 1100 \quad 0101 \end{aligned}$$

This is a routine logical instruction. You need not use it for binary subtraction; there are special subtract instructions (SUB, SBC).

DAA — DECIMAL ADJUST ACCUMULATOR



DAA
27

Convert the contents of the Accumulator to binary-coded decimal form. This instruction should only be used after adding or subtracting two BCD numbers: i.e., look upon ADD DAA or ADC DAA or INC DAA or SUB DAA or SBC DAA or DEC DAA or NEG DAA as compound, decimal arithmetic instructions which operate on BCD sources to generate BCD answers.

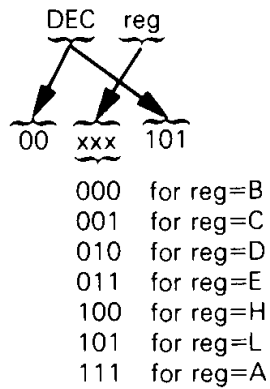
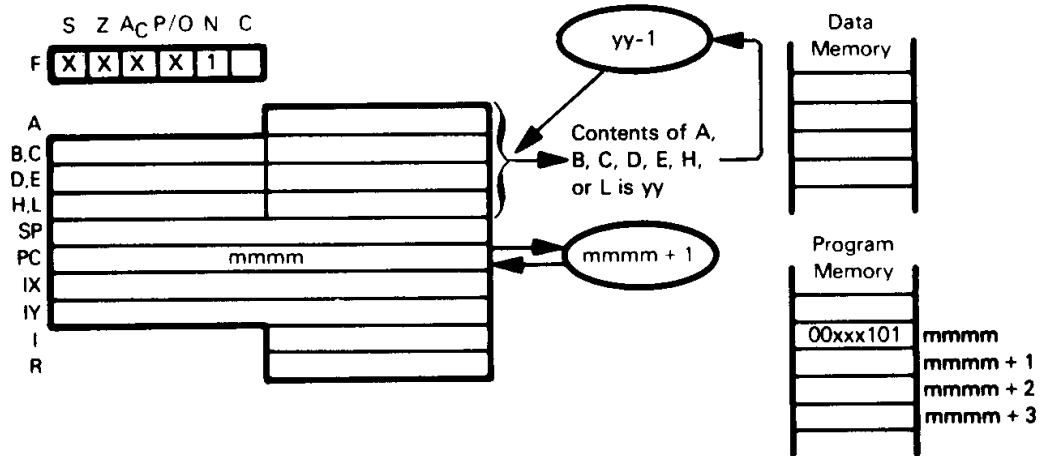
Suppose the Accumulator contains 39_{16} and the B register contains 47_{16} . After the instructions

ADD B
DAA

have executed, the Accumulator will contain 86_{16} , not 80_{16} .

Z80 CPU logic uses the values in the Carry and Auxiliary Carry, as well as the Accumulator contents, in the Decimal Adjust operation.

DEC reg — DECREMENT REGISTER CONTENTS

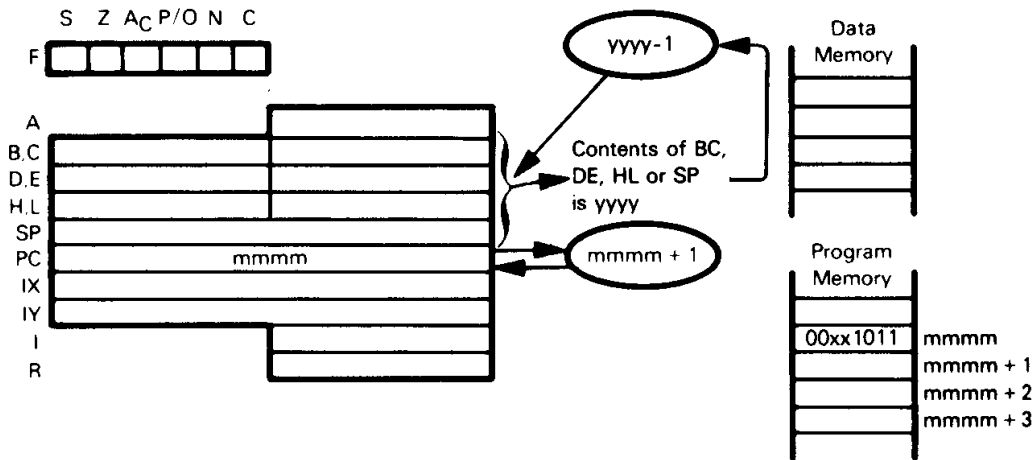


Subtract 1 from the contents of the specified register.

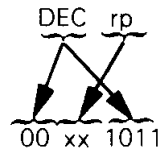
Suppose Register A contains 50_{16} . After execution of
DEC A

Register A will contain $4F_{16}$.

DEC rp — DECREMENT CONTENTS OF SPECIFIED REGISTER
DEC IX PAIR
DEC IY



The illustration shows execution of DEC rp:



- 00 for rp is register pair BC
- 01 for rp is register pair DE
- 10 for rp is register pair HL
- 11 for rp is Stack Pointer

Subtract 1 from the 16-bit value contained in the specified register pair. No status flags are affected.

Suppose the H and L registers contain $2F00_{16}$. After the instruction

DEC HL

has executed, the H and L registers will contain $2EFF_{16}$.

DEC IX
 DD 2B

Subtract 1 from the 16-bit value contained in the IX register.

DEC IY
 FD 2B

Subtract 1 from the 16-bit value contained in the IY register.

Neither DEC rp, DEC IX nor DEC IY affects any of the status flags. This is a defect in the Z80 instruction set, inherited from the 8080. Whereas the DEC reg instruction is used in iterative instruction loops that use a counter with a value of 256 or less, the DEC rp (DEC IX or DEC IY) instruction must be used if the counter value is more than 256. Since the DEC rp instruction sets no status flags, other instructions must be added to simply

test for a zero result. This is a typical loop form:

```

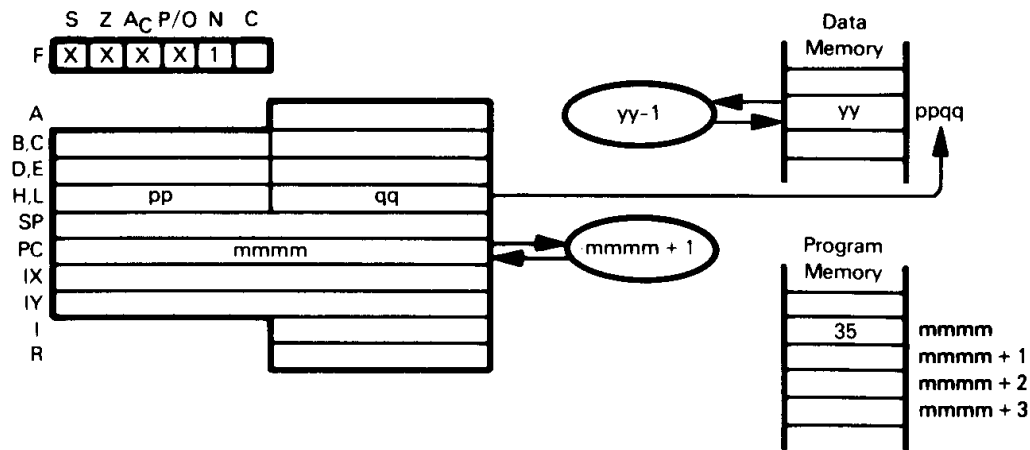
LD      DE,DATA ;LOAD INITIAL 16-BIT COUNTER VALUE
LOOP   -          ;FIRST INSTRUCTION OF LOOP
-
-
DEC    DE       ;DECREMENT COUNTER
LD     A,D      ;TO TEST FOR ZERO, MOVE D TO A
OR     E        ;THEN OR A WITH E
JP     NZ,LOOP  ;RETURN IF NOT ZERO

```

DEC (HL) — DECREMENT MEMORY CONTENTS

DEC (IX+disp)

DEC (IY+disp)



The illustration shows execution of DEC (HL):

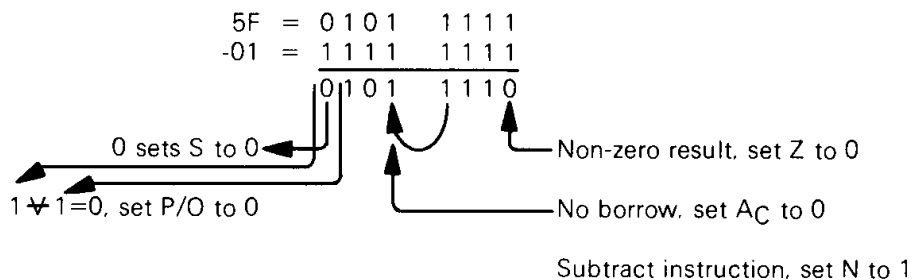
$$\underbrace{\text{DEC (HL)}}_{35}$$

Subtract 1 from the contents of memory location (specified by the contents of the HL register pair).

Suppose $ppqq = 4500_{16}$, $yy = 5F_{16}$. After execution of

DEC (HL)

memory location 4500_{16} will contain $5E_{16}$.



DEC (IX+disp)

DD 35 d

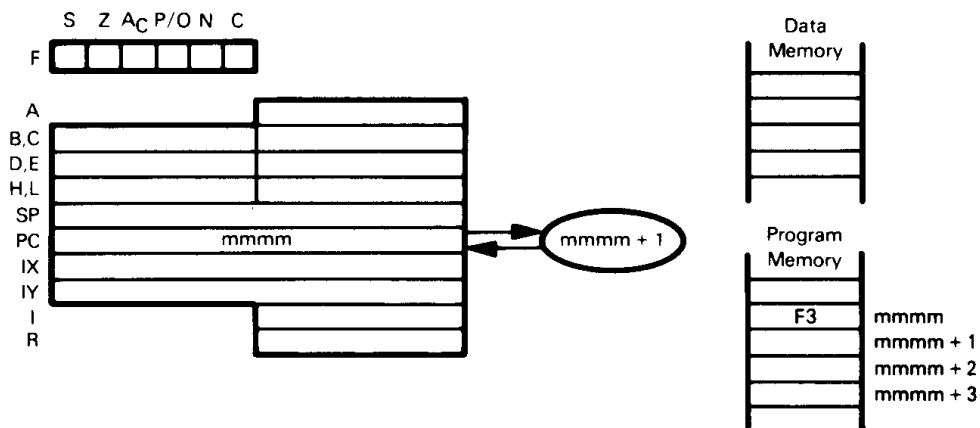
Subtract 1 from the contents of memory location (specified by the sum of the contents of the IX register and the displacement value d).

DEC (IY+disp)

FD 35 d

This instruction is identical to DEC (IX+disp), except that it uses the IY register instead of the IX register.

DI — DISABLE INTERRUPTS



DI

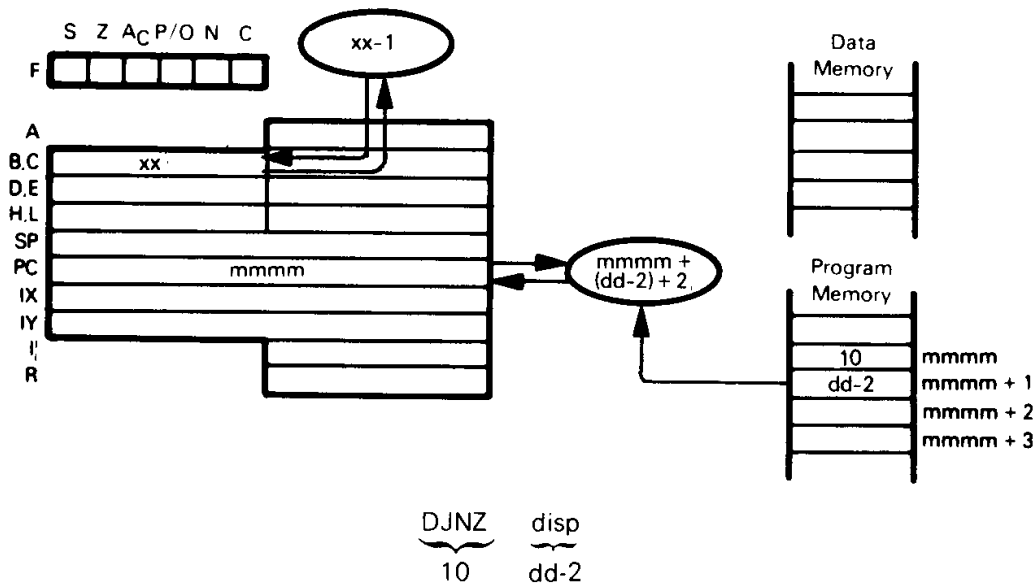
F3

When this instruction is executed, the maskable interrupt request is disabled and the $\overline{\text{INT}}$ input to the CPU will be ignored. Remember that when an interrupt is acknowledged, the maskable interrupt is automatically disabled.

The maskable interrupt request remains disabled until it is subsequently enabled by an EI instruction.

No registers or flags are affected by this instruction.

DJNZ disp — JUMP RELATIVE TO PRESENT CONTENTS OF PROGRAM COUNTER IF REG B IS NOT ZERO

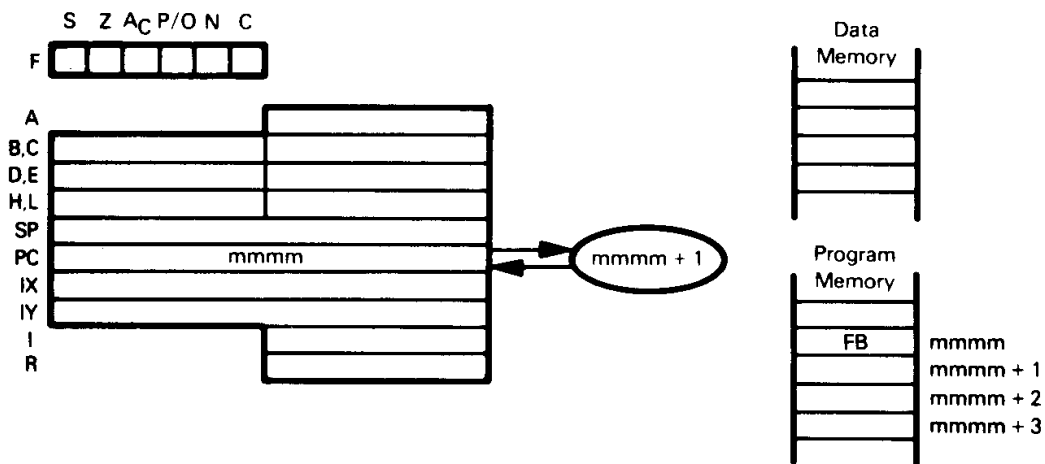


Decrement Register B. If remaining contents are not zero, add the contents of the DJNZ instruction object code second byte and 2 to the Program Counter. The jump is measured from the address of the instruction operation code, and has a range of -126 to +129 bytes. The Assembler automatically adjusts for the twice-incremented PC.

If the contents of B are zero after decrementing, the next sequential instruction is executed.

The DJNZ instruction is extremely useful for any program loop operation, since the one instruction replaces the typical "decrement-then-branch on condition" instruction sequence.

EI — ENABLE INTERRUPTS



```

EI
  }
FB

```

Execution of this instruction causes interrupts to be enabled, but not until one more instruction executes.

Most interrupt service routines end with the two instructions:

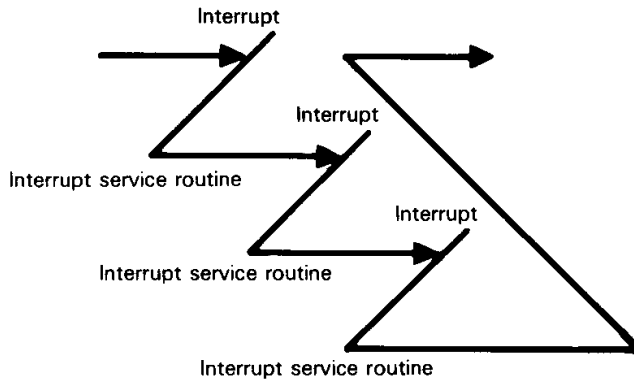
```

EI          ;ENABLE INTERRUPTS
RET        ;RETURN TO INTERRUPTED PROGRAM

```

If interrupts are processed serially, then for the entire duration of the interrupt service routine all maskable interrupts are disabled — which means that in a multi-interrupt application there is a significant possibility for one or more interrupts to be pending when any interrupt service routine completes execution.

If interrupts were acknowledged as soon as the EI instructions had executed, then the Return instruction would not be executed. Under these circumstances, returns would stack up one on top of the other — and unnecessarily consume stack memory space. This may be illustrated as follows:



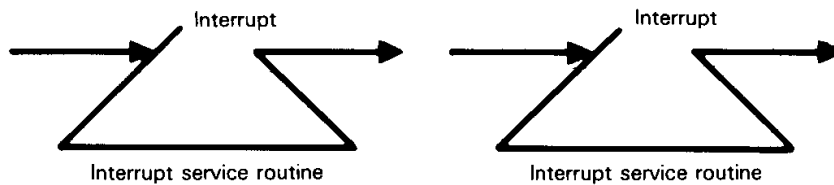
By inhibiting interrupts for one more instruction following execution of EI, the Z80 CPU ensures that the RET instruction gets executed in the sequence:

```

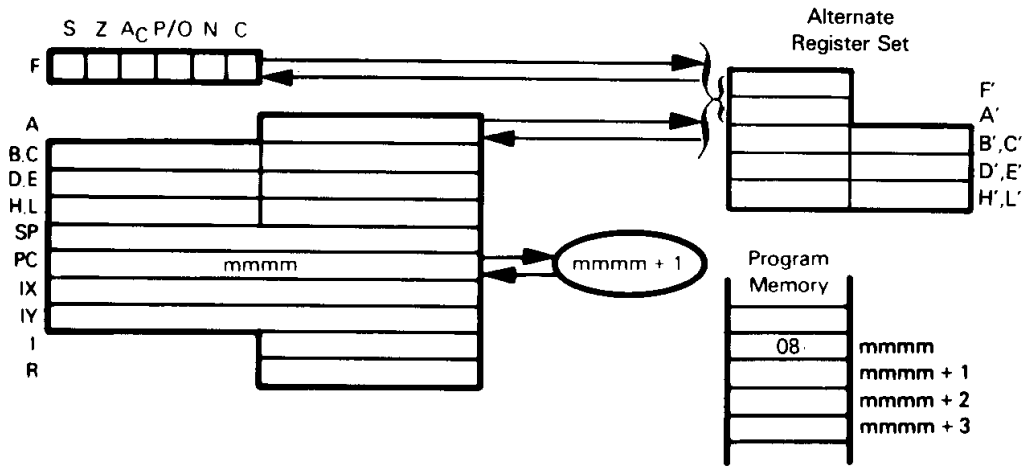
-
-
-
EI          ;ENABLE INTERRUPTS
RET        ;RETURN FROM INTERRUPT

```

It is not uncommon for interrupts to be kept disabled while an interrupt service routine is executing. Interrupts are processed serially:



EX AF,AF' — EXCHANGE PROGRAM STATUS AND ALTERNATE PROGRAM STATUS



EX AF,AF'
08

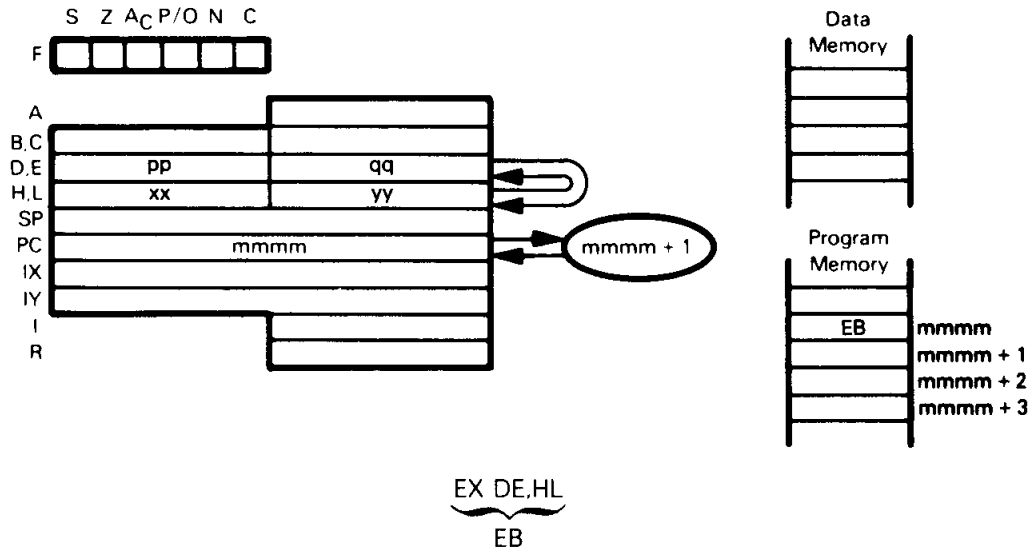
The two-byte contents of register pairs AF and A'F' are exchanged.

Suppose AF contains $4F99_{16}$ and A'F' contains $10AA_{16}$. After execution of

EX AF,AF'

AF will contain $10AA_{16}$ and A'F' will contain $4F99_{16}$.

EX DE,HL — EXCHANGE DE AND HL CONTENTS



The D and E registers' contents are swapped with the H and L registers' contents.

Suppose $pp=03_{16}$, $qq=2A_{16}$, $xx=41_{16}$ and $yy=FC_{16}$. After the instruction

```
EX DE,HL
```

has executed, H will contain 03_{16} , L will contain $2A_{16}$, D will contain 41_{16} and E will contain FC_{16} .

The two instructions:

```
EX DE,HL
LD A,(HL)
```

are equivalent to:

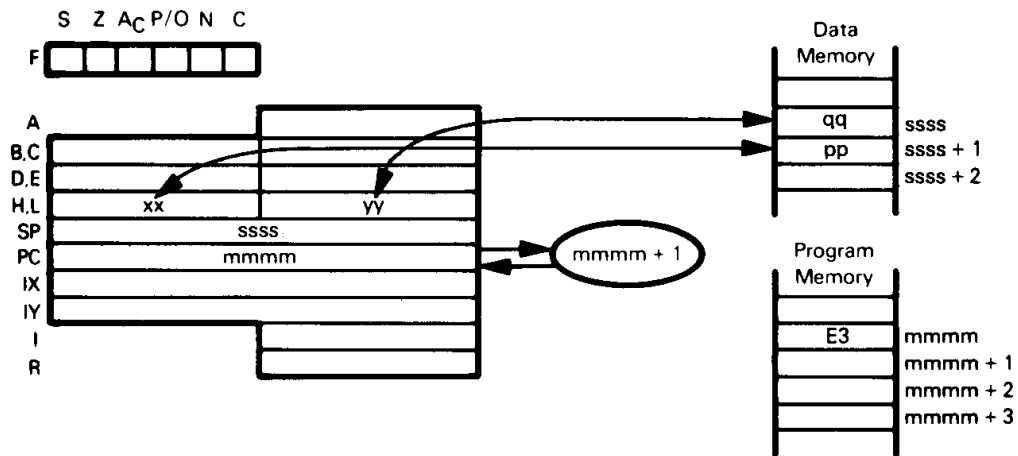
```
LD A,(DE)
```

but if you want to load data addressed by the D and E register into the B register,

```
EX DE,HL
LD B,(HL)
```

has no single instruction equivalent.

**EX (SP),HL — EXCHANGE CONTENTS OF REGISTER AND
 EX (SP),IX TOP OF STACK
 EX (SP),IY**



The illustration shows execution of EX (SP),HL.

EX (SP),HL
 ───────────
 E3

Exchange the contents of the L register with the top stack byte. Exchange the contents of the H register with the byte below the stack top.

Suppose $xx=21_{16}$, $yy=FA_{16}$, $pp=3A_{16}$, $qq=E2_{16}$. After the instruction

EX (SP),HL

has executed, H will contain $3A_{16}$, L will contain $E2_{16}$ and the two top stack bytes will contain FA_{16} and 21_{16} respectively.

The EX (SP),HL instruction is used to access and manipulate data at the top of the stack.

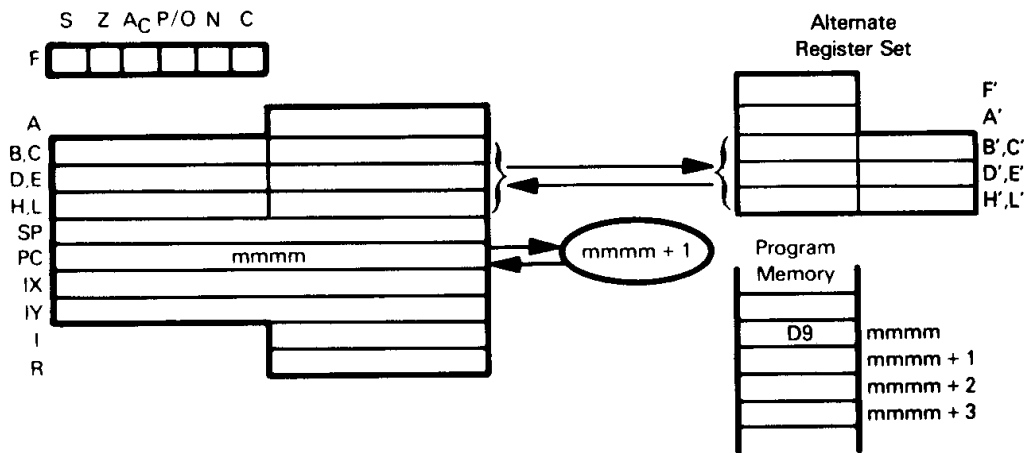
EX (SP),IX
 ───────────
 DD E3

Exchange the contents of the IX register's low-order byte with the top stack byte. Exchange the IX register's high-order byte with the byte below the stack top.

EX (SP),IY
 ───────────
 FD E3

This instruction is identical to EX (SP),IX, but uses the IY register instead of the IX register.

EXX — EXCHANGE REGISTER PAIRS AND ALTERNATE REGISTER PAIRS



EXX
D9

The contents of register pairs BC, DE and HL are swapped with the contents of register pairs B'C', D'E', and H'L'.

Suppose register pairs BC, DE and HL contain 4901_{16} , $5F00_{16}$ and 7251_{16} respectively, and register pairs B'C', D'E', H'L' contain 0000_{16} , $10FF_{16}$ and 3333_{16} respectively. After the execution of

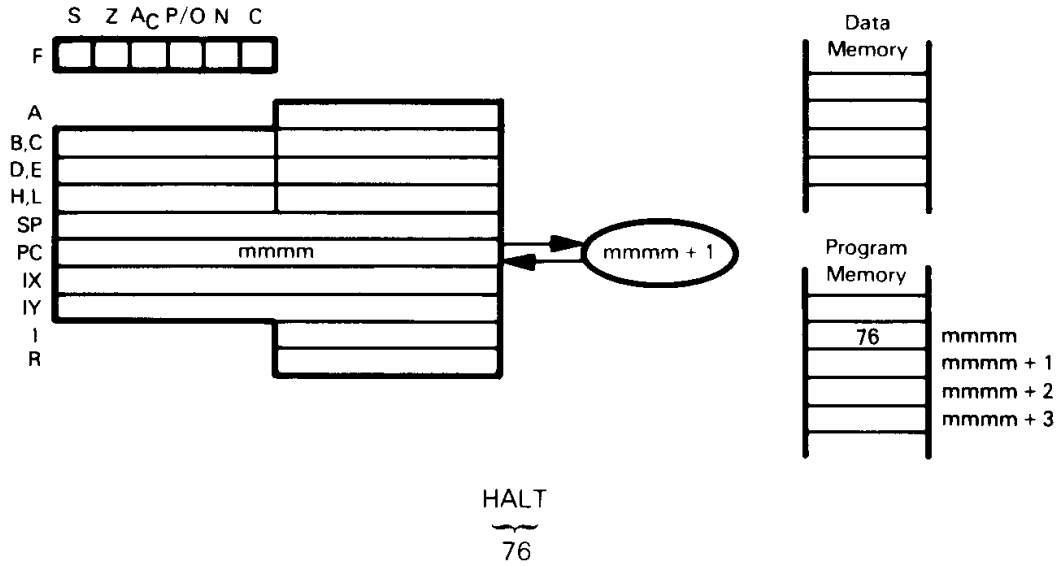
EXX

the registers will have the following contents:

BC: 0000_{16} ; DE: $10FF_{16}$; HL: 3333_{16} ;
B'C': 4901_{16} ; D'E': $5F00_{16}$; H'L': 7251_{16}

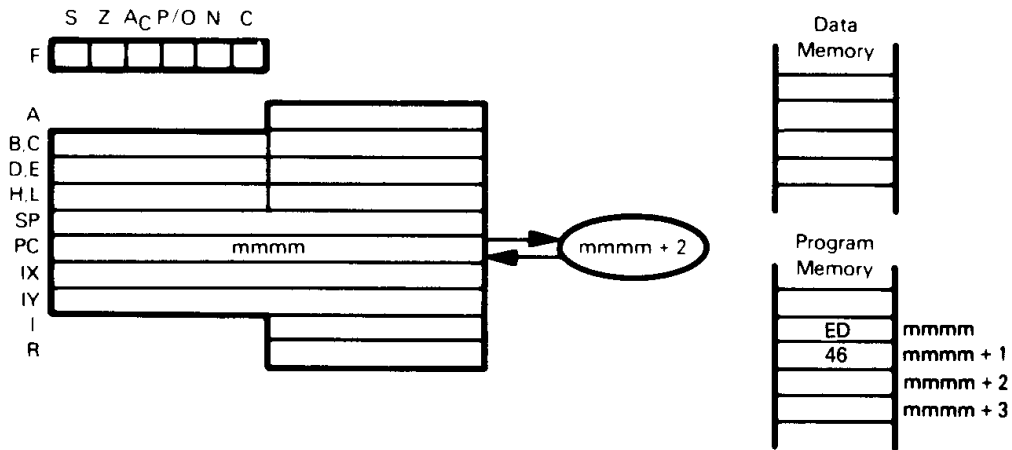
This instruction can be used to exchange register banks to provide very fast interrupt response times.

HALT



When the HALT instruction is executed, program execution ceases. The CPU requires an interrupt or a reset to restart execution. No registers or statuses are affected; however, memory refresh logic continues to operate.

IM 0 — INTERRUPT MODE 0



IM 0
ED 46

This instruction places the CPU in interrupt mode 0. In this mode, the interrupting device will place an instruction on the Data Bus and the CPU will then execute that instruction. No registers or statuses are affected.

IM 1 — INTERRUPT MODE 1

IM 1
ED 56

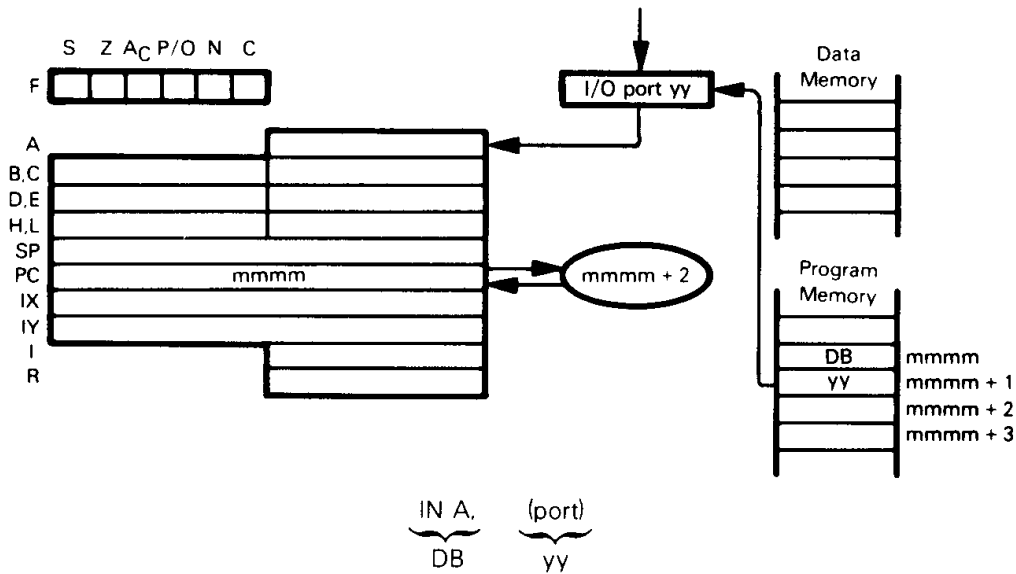
This instruction places the CPU in interrupt mode 1. In this mode, the CPU responds to an interrupt by executing a restart (RST) to location 0038₁₆.

IM 2 — INTERRUPT MODE 2

IM 2
ED 5E

This instruction places the CPU in interrupt mode 2. In this mode, the CPU performs an indirect call to any specified location in memory. A 16-bit address is formed using the contents of the Interrupt Vector (I) register for the upper eight bits, while the lower eight bits are supplied by the interrupting device. Refer to Chapter 12 for a full description of interrupt modes. No registers or statuses are affected by this instruction.

IN A,(port) — INPUT TO ACCUMULATOR



Load a byte of data into the Accumulator from the I/O port (identified by the second IN instruction object code byte).

Suppose 36_{16} is held in the buffer of I/O port $1A_{16}$. After the instruction

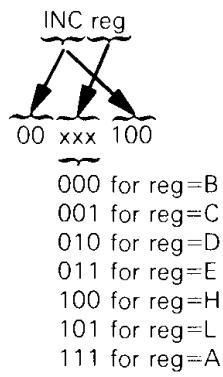
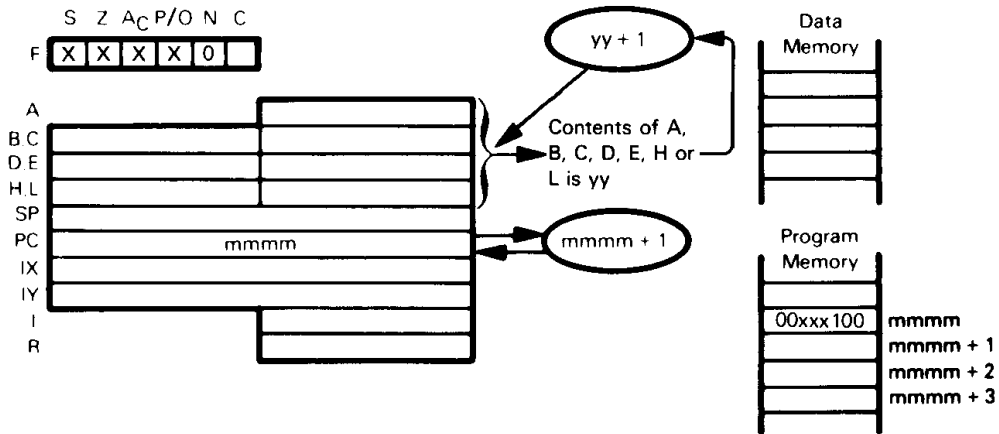
`IN A,(1AH)`

has executed, the Accumulator will contain 36_{16} .

The IN instruction does not affect any statuses.

Use of the IN instruction is very hardware dependent. Valid I/O port addresses are determined by the way in which I/O logic has been implemented. It is also possible to design a microcomputer system that accesses external logic using memory reference instructions with specific memory addresses.

INC reg — INCREMENT REGISTER CONTENTS



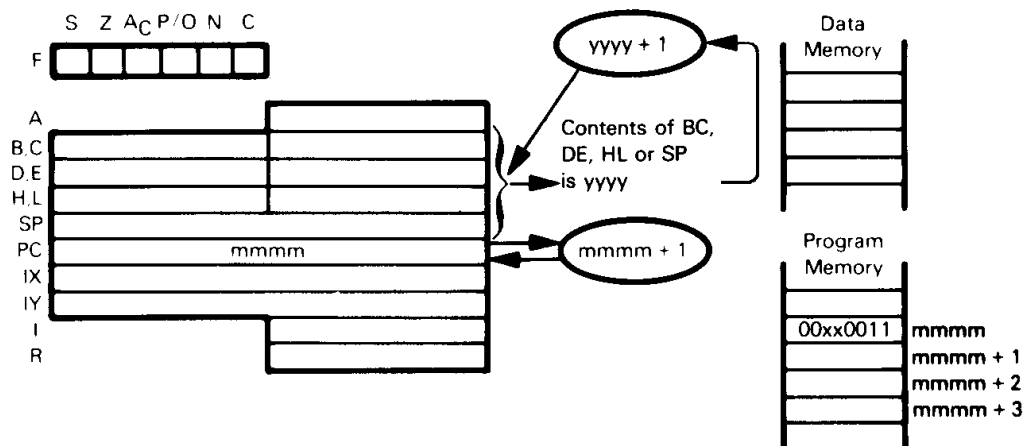
Add 1 to the contents of the specified register.

Suppose Register E contains $A8_{16}$. After execution of

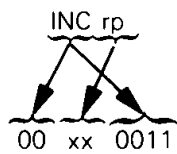
INC E

Register E will contain $A9_{16}$.

INC rp — INCREMENT CONTENTS OF SPECIFIED REGISTER PAIR
INC IX
INC IY



The illustration shows execution of INC rp:



- 00 for rp is register pair BC
- 01 for rp is register pair DE
- 10 for rp is register pair HL
- 11 for rp is Stack Pointer

Add 1 to the 16-bit value contained in the specified register pair. No status flags are affected.

Suppose the D and E registers contain $2F7A_{16}$. After the instruction

INC DE

has executed, the D and E registers will contain $2F7B_{16}$.

INC IX
 DD 23

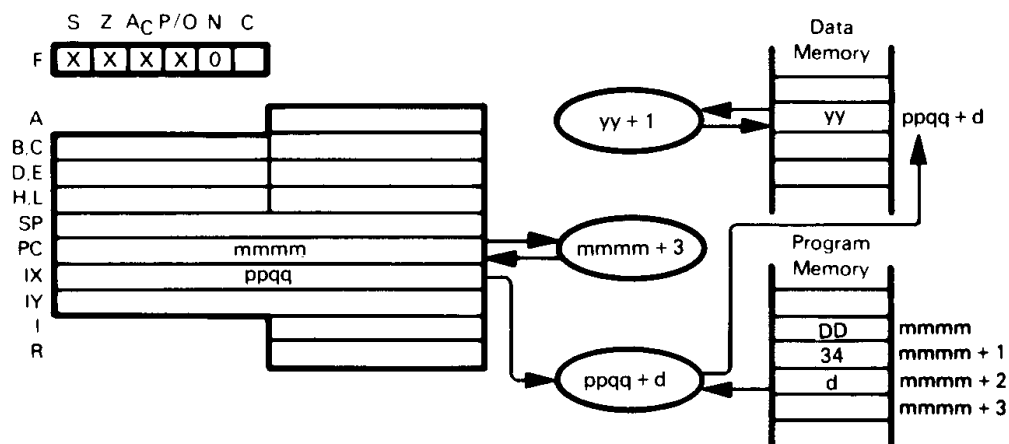
Add 1 to the 16-bit value contained in the IX register.

INC IY
 FD 23

Add 1 to the 16-bit value contained in the IY register.

Just like the DEC rp, DEC IX and DEC IY, neither INC rp, INC IX nor INC IY affects any status flags. This is a defect in the Z80 instruction set inherited from the 8080.

INC (HL) — INCREMENT MEMORY CONTENTS
INC (IX+disp)
INC (IY+disp)



The illustration shows execution of INC (IX+d):

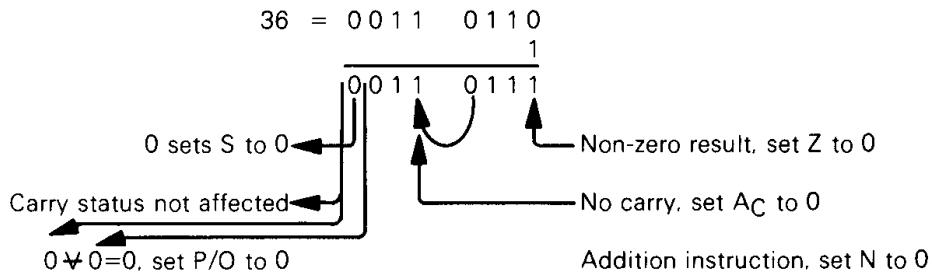
INC (IX+disp)
 DD 34 d

Add 1 to the contents of memory location (specified by the sum of the contents of Register IX and the displacement value d).

Suppose ppqq=4000₁₆ and memory location 400F₁₆ contains 36₁₆. After execution of the instruction

INC (IX+0FH)

memory location 400F₁₆ will contain 37₁₆.



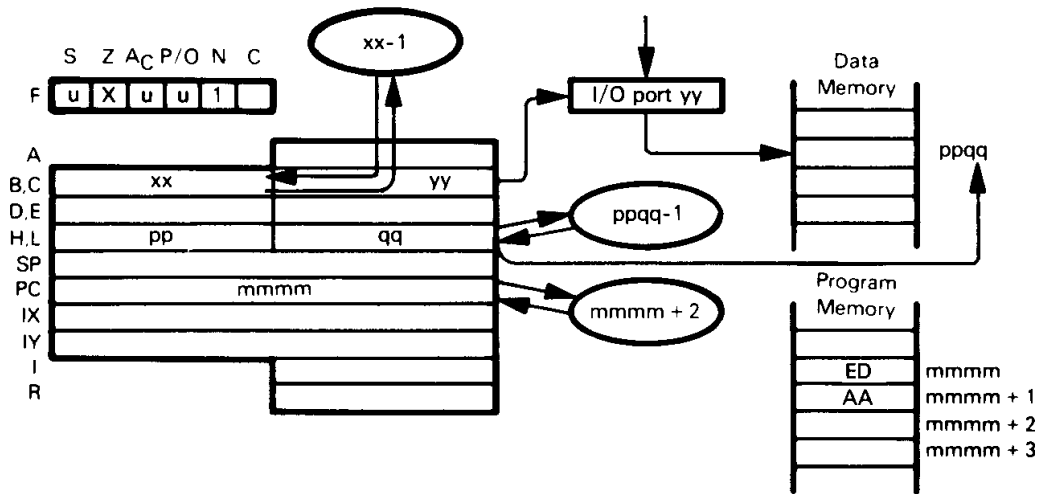
INC (IY+disp)
 FD 34 d

This instruction is identical to INC (IX+disp), except that it uses the IY register instead of the IX register.

INC (HL)
 34

Add 1 to the contents of memory location (specified by the contents of the HL register pair).

IND — INPUT TO MEMORY AND DECREMENT POINTER



IND
ED AA

Input from I/O port (addressed by Register C) to memory location (specified by HL).
Decrement Registers B and HL.

Suppose $xx=05_{16}$, $yy=15_{16}$, $ppqq=2400_{16}$, and 19_{16} is held in the buffer of I/O port 15_{16} . After the instruction

IND

has executed, memory location 2400_{16} will contain 19_{16} . The B register will contain 04_{16} and the HL register pair $23FF_{16}$.

INDR — INPUT TO MEMORY AND DECREMENT POINTER UNTIL BYTE COUNTER IS ZERO

INDR
ED BA

INDR is identical to IND, but is repeated until Register B=0.

Suppose Register B contains 03_{16} , Register C contains 15_{16} , and HL contains 2400_{16} . The following sequence of bytes is available at I/O port 15_{16} :

17_{16} , 59_{16} and AE_{16}

After the execution of

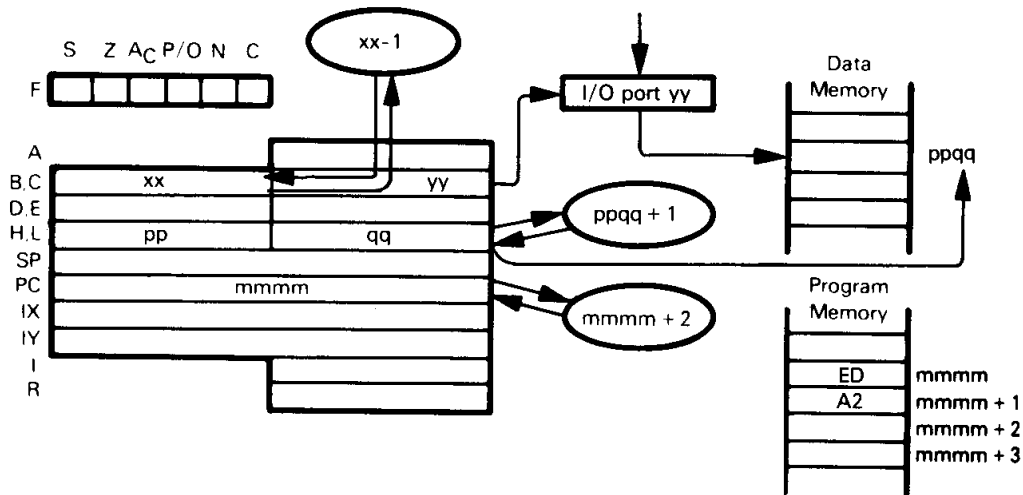
INDR

the HL register pair will contain $23FD_{16}$ and Register B will contain zero, and memory locations will have contents as follows:

Location	Contents
2400	17_{16}
23FF	59_{16}
23FE	AE_{16}

This instruction is extremely useful for loading blocks of data from an input device into memory.

INI — INPUT TO MEMORY AND INCREMENT POINTER



INI
ED A2

Input from I/O port (addressed by Register C) to memory location (specified by HL).
Decrement Register B; increment register pair HL.

Suppose $xx=05_{16}$, $yy=15_{16}$, $ppqq=2400_{16}$, and 19_{16} is held in the buffer of I/O port 15_{16} .

After the instruction

INI

has executed, memory location 2400_{16} will contain 19_{16} . The B register will contain 04_{16} and the HL register pair 2401_{16} .

INIR — INPUT TO MEMORY AND INCREMENT POINTER UNTIL BYTE COUNTER IS ZERO

INIR
ED B2

INIR is identical to INI, but is repeated until Register B=0.

Suppose Register B contains 03_{16} , Register C contains 15_{16} , and HL contains 2400_{16} .
The following sequence of bytes is available at I/O port 15_{16} :

17_{16} , 59_{16} and AE_{16}

After the execution of

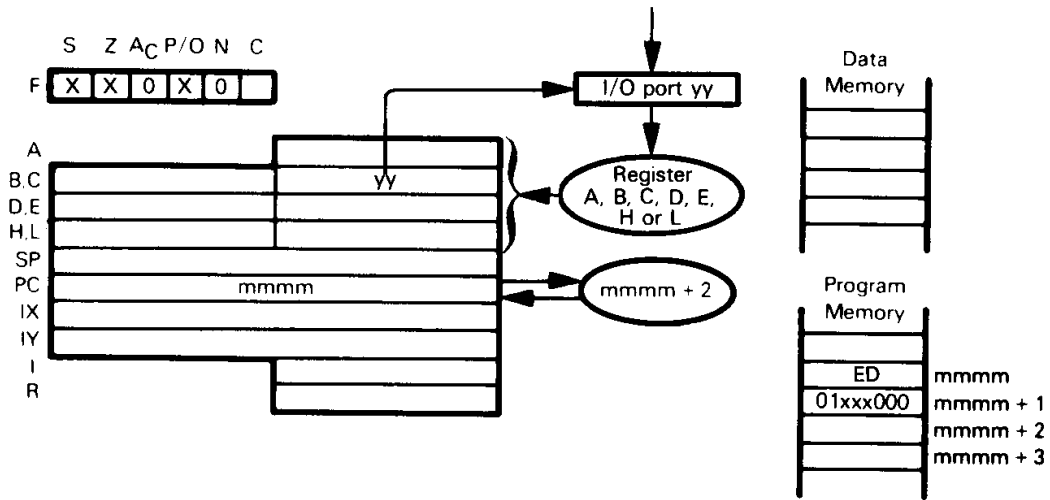
INIR

the HL register pair will contain 2403_{16} and Register B will contain zero, and memory locations will have contents as follows:

<u>Location</u>	<u>Contents</u>
2400	17_{16}
2401	59_{16}
2402	AE_{16}

This instruction is extremely useful for loading blocks of data from a device into memory.

IN reg.(C) — INPUT TO REGISTER



- 000 for reg=B
- 001 for reg=C
- 010 for reg=D
- 011 for reg=E
- 100 for reg=H
- 101 for reg=L
- 111 for reg=A
- 110 for setting of status flags without changing registers

Load a byte of data into the specified register (reg) from the I/O port (identified by the contents of the C register).

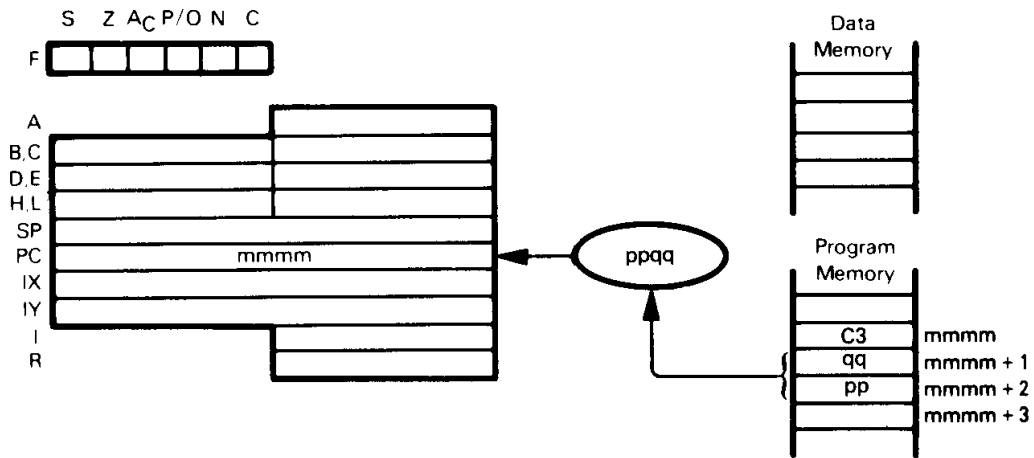
Suppose 42_{16} is held in the buffer of I/O port 36_{16} , and Register C contains 36_{16} . After the instruction

`IN D.(C)`

has executed, the D register will contain 42_{16} .

During the execution of the instruction, the contents of Register B are placed on the top half of the Address Bus, making it possible to extend the number of addressable I/O ports.

JP label — JUMP TO THE INSTRUCTION IDENTIFIED IN THE OPERAND



JP label
C3 ppqq

Load the contents of the Jump instruction object code second and third bytes into the Program Counter; this becomes the memory address for the next instruction to be executed. The previous Program Counter contents are lost.

In the following sequence:

```

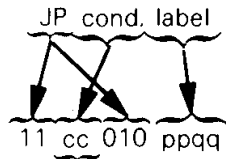
JP      NEXT
AND     7FH
-
-

```

NEXT CPL

The CPL instruction will be executed after the JP instruction. The AND instruction will never be executed, unless a Jump instruction somewhere else in the instruction sequence jumps to this instruction.

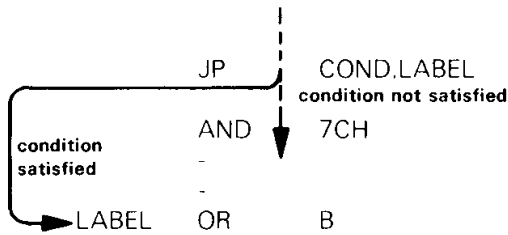
JP condition,label — JUMP TO ADDRESS IDENTIFIED IN THE OPERAND IF CONDITION IS SATISFIED



		<u>Condition</u>	<u>Relevant Flag</u>
000	NZ	Non-Zero	Z
001	Z	Zero	Z
010	NC	No Carry	C
011	C	Carry	C
100	PO	Parity Odd	P/O
101	PE	Parity Even	P/O
110	P	Sign Positive	S
111	M	Sign Negative	S

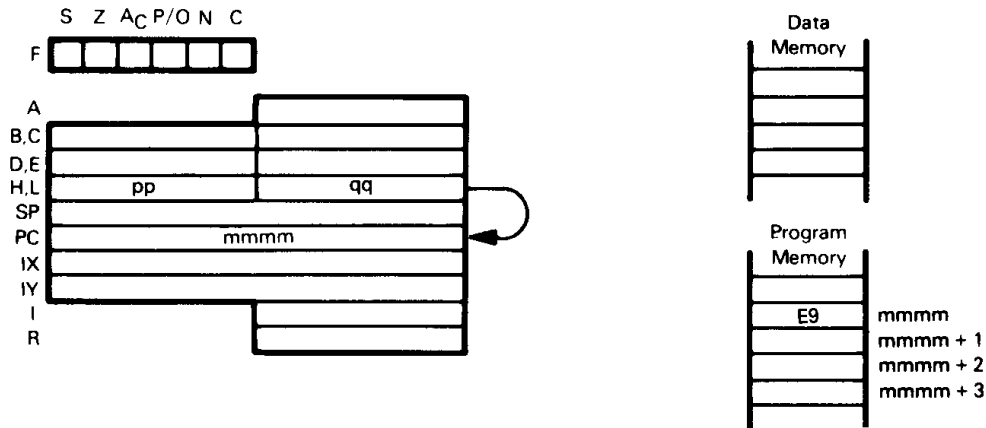
This instruction is identical to the JP instruction, except that the jump will be performed only if the condition is satisfied; otherwise, the instruction sequentially following the JP condition instruction will be executed.

Consider the instruction sequence



After the JP cond.label instruction has executed, if the condition is satisfied then the OR instruction will be executed. If the condition is not satisfied, the AND instruction, being the next sequential instruction, is executed.

**JP (HL) — JUMP TO ADDRESS SPECIFIED BY CONTENTS
 JP (IX) OF 16-BIT REGISTER
 JP (IY)**



The illustration shows execution of JP (HL):



The contents of the HL register pair are moved to the Program Counter; therefore, an implied addressing jump is performed.

The instruction sequence

```
LD    H,ADDR
JP    (HL)
```

has exactly the same net effect as the single instruction

```
JP    ADDR
```

Both specify that the instruction with label ADDR is to be executed next.

The JP (HL) instruction is useful when you want to increment a return address for a subroutine that has multiple returns.

Consider the following call to subroutine SUB:

```
CALL  SUB    ;CALL SUBROUTINE
JP    ERR    ;ERROR RETURN
                ;GOOD RETURN
```

Using RET to return from SUB would return execution of JP ERR; therefore, if SUB executes without detecting error conditions, return as follows:

```
POP   HL    ;POP RETURN ADDRESS TO HL
INC   HL    ;ADD 3 TO RETURN ADDRESS
INC   HL
INC   HL
JP    (HL)  ;RETURN
```



This instruction is identical to the JP (HL) instruction, except that it uses the IX register

instead of the HL register pair.

JP (IY)
FD E9

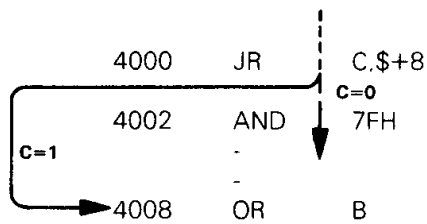
This instruction is identical to the JP (HL) instruction, except that it uses the IY register instead of the HL register pair.

JR C,disp — JUMP RELATIVE TO CONTENTS OF PROGRAM COUNTER IF CARRY IS SET

JR C, disp
38 dd-2

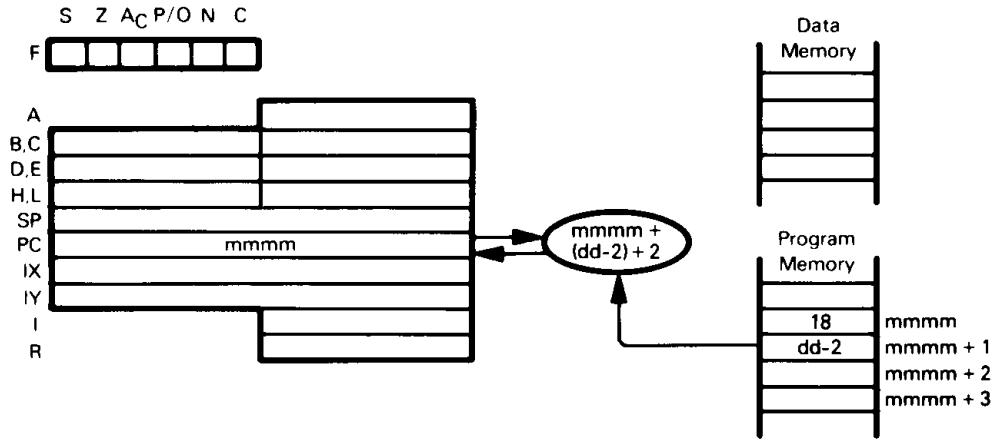
This instruction is identical to the JR disp instruction, except that the jump is only executed if the Carry status equals 1; otherwise, the next instruction is executed.

In the following instruction sequence:



After the JR C,\$+8 instruction, the OR instruction is executed if the Carry status equals 1. The AND instruction is executed if the Carry status equals 0.

JR disp — JUMP RELATIVE TO PRESENT CONTENTS OF PROGRAM COUNTER



JR disp

18 dd-2

Add the contents of the JR instruction object code second byte, the contents of the Program Counter, and 2. Load the sum into the Program Counter. The jump is measured from the address of the instruction operation code, and has a range of -126 to +129 bytes. The Assembler automatically adjusts for the twice-incremented PC.

The following assembly language statement is used to jump four steps forward from address 4000_{16} .

JR \$+4

Result of this instruction is shown below:

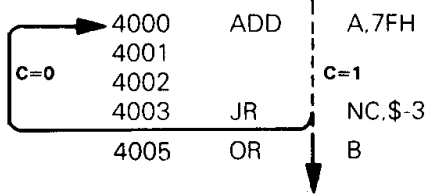
<u>Location</u>	<u>Instruction</u>
4000	18
4001	02
4002	-
4003	-
4004	- ← new PC value

JR NC,disp — JUMP RELATIVE TO CONTENTS OF PROGRAM COUNTER IF CARRY FLAG IS RESET

JR NC,disp
30 dd-2

This instruction is identical to the JR disp instruction, except that the jump is only executed if the Carry status equals 0; otherwise, the next instruction is executed.

In the following instruction sequence:



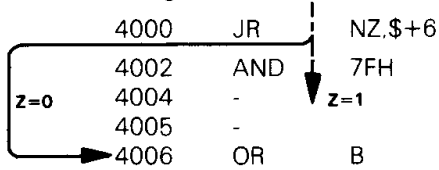
After the JR NC,\$-3 instruction, the OR instruction is executed if the Carry status equals 1. The ADD instruction is executed if the Carry status equals 0.

JR NZ,disp — JUMP RELATIVE TO CONTENTS OF PROGRAM COUNTER IF ZERO FLAG IS RESET

JR NZ,disp
20 dd-2

This instruction is identical to the JR disp instruction, except that the jump is only executed if the Zero status equals 0; otherwise, the next instruction is executed.

In the following instruction sequence:



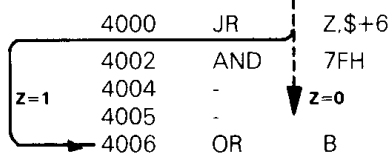
After the JR NZ,\$+6 instruction, the OR instruction is executed if the Zero status equals 0. The AND instruction is executed if the Zero status equals 1.

JR Z,disp — JUMP RELATIVE TO CONTENTS OF PROGRAM COUNTER IF ZERO FLAG IS SET

JR Z,disp
28 dd-2

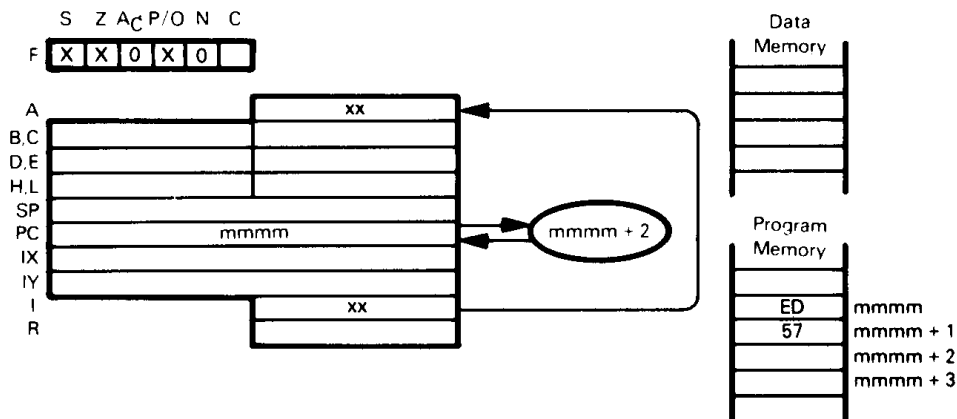
This instruction is identical to the JR disp instruction, except that the jump is only executed if the Zero status equals 1; otherwise, the next instruction is executed.

In the following instruction sequence:



After the JR Z,\$+6 instruction, the OR instruction is executed if the Zero status equals 1. The AND instruction is executed if the Zero status equals 0.

LD A,I — MOVE CONTENTS OF INTERRUPT VECTOR OR LD A,R REFRESH REGISTER TO ACCUMULATOR



The illustration shows execution of LD A,I:

LD A,I
ED 57

Move the contents of the Interrupt Vector register to the Accumulator, and reflect interrupt enable status in Parity/Overflow flag.

Suppose the Interrupt Vector register contains 7F₁₆, and interrupts are disabled. After execution of

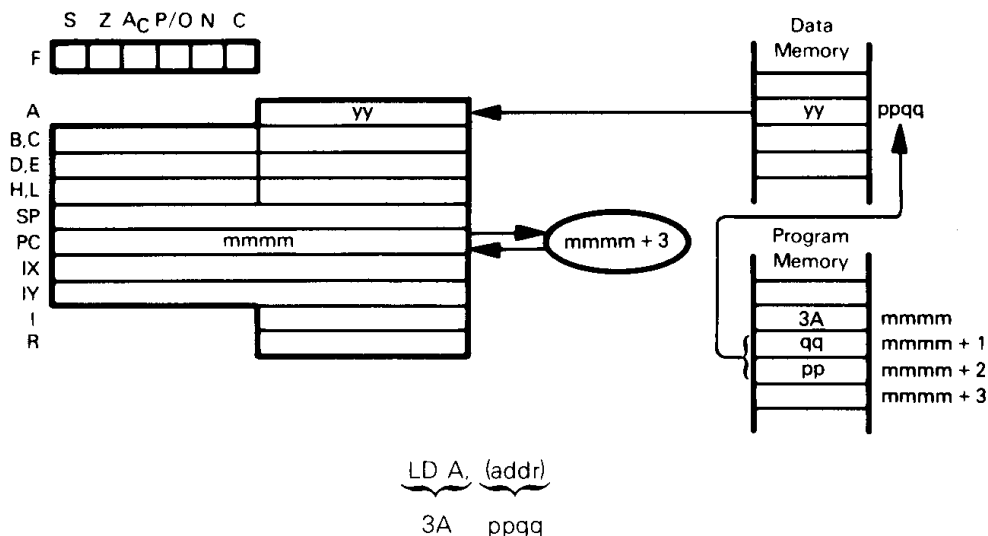
LD A,I

Register A will contain 7F₁₆, and P/O will be 0.

LD A,R
ED 5F

Move the contents of the Refresh register to the Accumulator. The value of the interrupt flip-flop will appear in the Parity/Overflow flag.

LD A,(addr) — LOAD ACCUMULATOR FROM MEMORY USING DIRECT ADDRESSING



Load the contents of the memory byte (addressed directly by the second and third bytes of the LD A,(addr) instruction object code) into the Accumulator. Suppose memory byte $084A_{16}$ contains 20_{16} . After the instruction

```

label    EQU    084AH
-
-
LD      A,(label)

```

has executed, the Accumulator will contain 20_{16} .

Remember that EQU is an assembler directive rather than an instruction; it tells the Assembler to use the 16-bit value $084A_{16}$ wherever the label appears.

The instruction

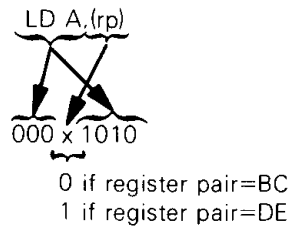
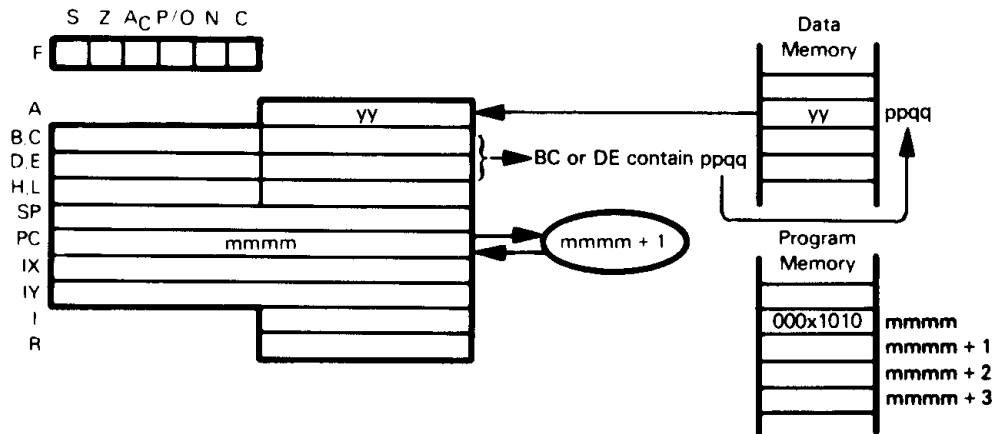
```
LD      A,(label)
```

is equivalent to the two instructions

```
LD      HL,label
LD      A,(HL)
```

When you are loading a single value from memory, the LD A,(label) instruction is preferred; it uses one instruction and three object program bytes to do what the LD HL,label, LD A,(HL) combination does in two instructions and four object program bytes. Also, the LD HL,label, LD A,(HL) combination uses the H and L registers, which LD A,(label) does not.

LD A,(rp) — LOAD ACCUMULATOR FROM MEMORY LOCATION ADDRESSED BY REGISTER PAIR



Load the contents of the memory byte (addressed by the BC or DE register pair) into the Accumulator.

Suppose the B register contains 08_{16} , the C register contains $4A_{16}$, and memory byte $084A_{16}$ contains $3A_{16}$. After the instruction

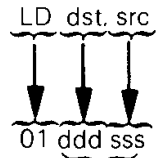
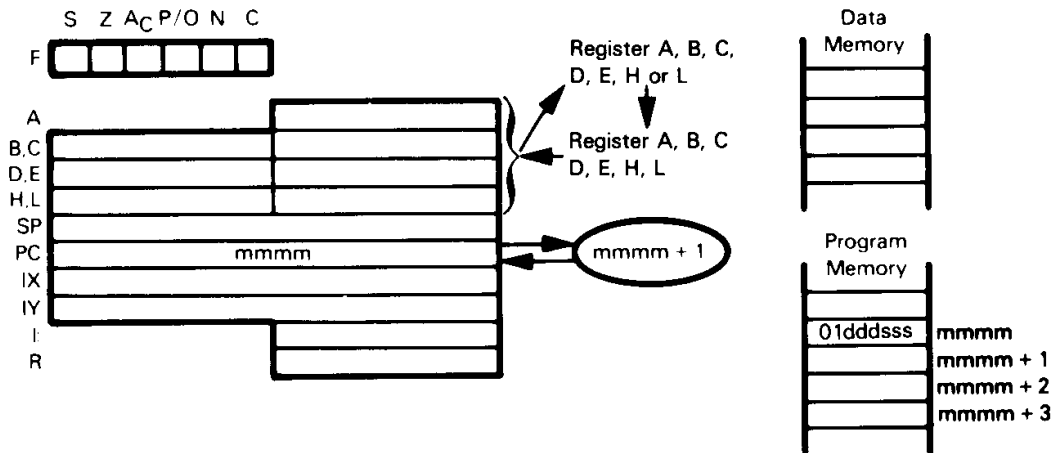
LD A,(BC)

has executed, the Accumulator will contain $3A_{16}$.

Normally, the LD A,(rp) and LD rp,data will be used together, since the LD rp,data instruction loads a 16-bit address into the BC or DE registers as follows:

```
LD    BC,084AH
LD    A,(BC)
```

LD dst,src — MOVE CONTENTS OF SOURCE REGISTER TO DESTINATION REGISTER



- 000 for dst or src=B
- 001 for dst or src=C
- 010 for dst or src=D
- 011 for dst or src=E
- 100 for dst or src=H
- 101 for dst or src=L
- 111 for dst or src=A

The contents of any designated register are loaded into any other register.

For example:

LD A,B

loads the contents of Register B into Register A.

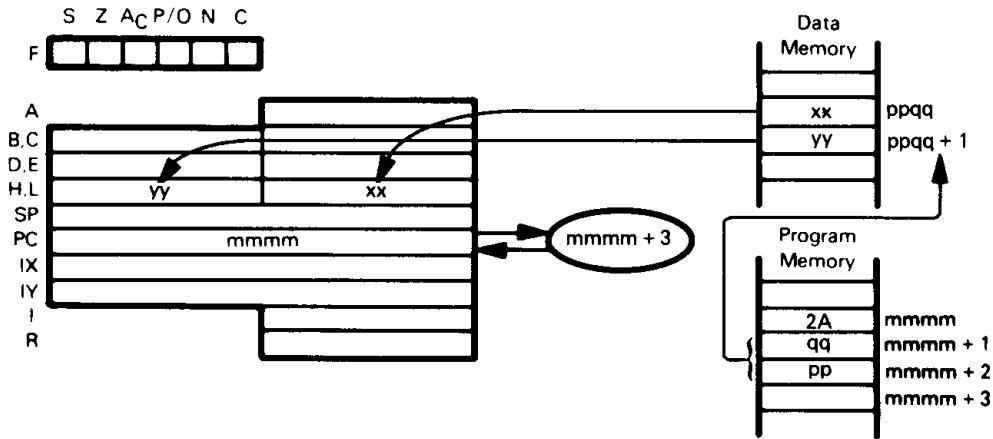
LD L,D

loads the contents of Register D into Register L.

LD C,C

does nothing, since the C register has been specified as both the source and the destination.

**LD HL,(addr) — LOAD REGISTER PAIR OR INDEX REGISTER
 LD rp,(addr) FROM MEMORY USING DIRECT ADDRESSING
 LD IX,(addr)
 LD IY,(addr)**



The illustration shows execution of LD HL(ppqq):

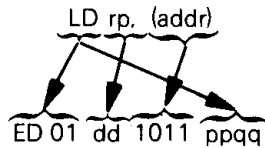
LD HL,addr
 2A ppqq

Load the HL register pair from directly addressed memory location.

Suppose memory location 4004_{16} contains AD_{16} and memory location 4005_{16} contains 12_{16} . After the instruction

LD HL,(4004H)

has executed, the HL register pair will contain $12AD_{16}$.



- 00 for rp is register pair BC
- 01 for rp is register pair DE
- 10 for rp is register pair HL
- 11 for rp is Stack Pointer

Load register pair from directly addressed memory.

Suppose memory location $49FF_{16}$ contains BE_{16} and memory location $4A00_{16}$ contains 33_{16} . After the instruction

LD DE,(49FFH)

has executed, the DE register pair will contain $33BE_{16}$.

LD IX,(addr)
 DD 2A ppqq

Load IX register from directly addressed memory.

Suppose memory location $D111_{16}$ contains FF_{16} and memory location $D112_{16}$ contains 56_{16} . After the instruction

LD IX,(D111H)

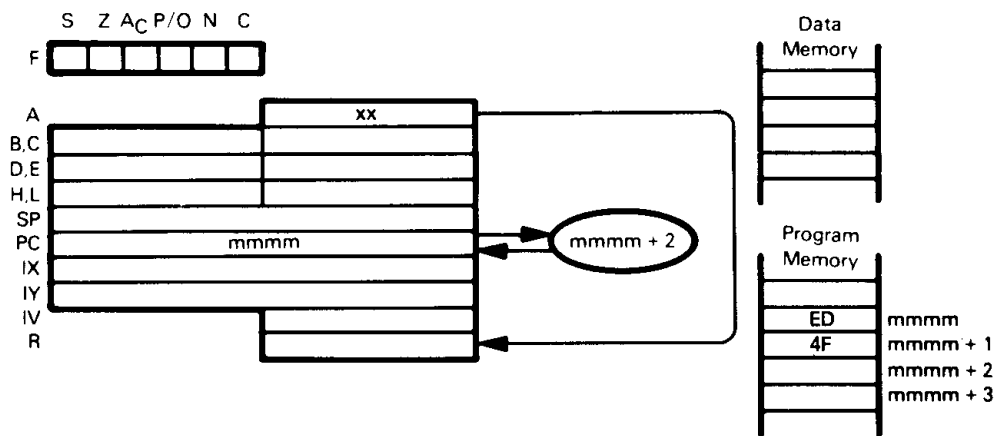
has executed, the IX register will contain $56FF_{16}$.

LD IY,(addr)
FD 2A ppqq

Load IY register from directly addressed memory.

Affects IY register instead of IX. Otherwise identical to LD IX(addr).

LD I,A — LOAD INTERRUPT VECTOR OR REFRESH LD R,A REGISTER FROM ACCUMULATOR



The illustration shows execution of LD R,A:

LD R,A
ED 4F

Load Refresh register from Accumulator.

Suppose the Accumulator contains $7F_{16}$. After the instruction

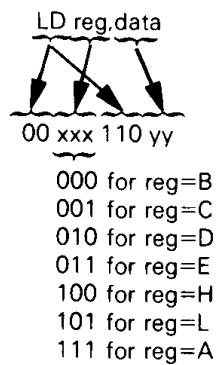
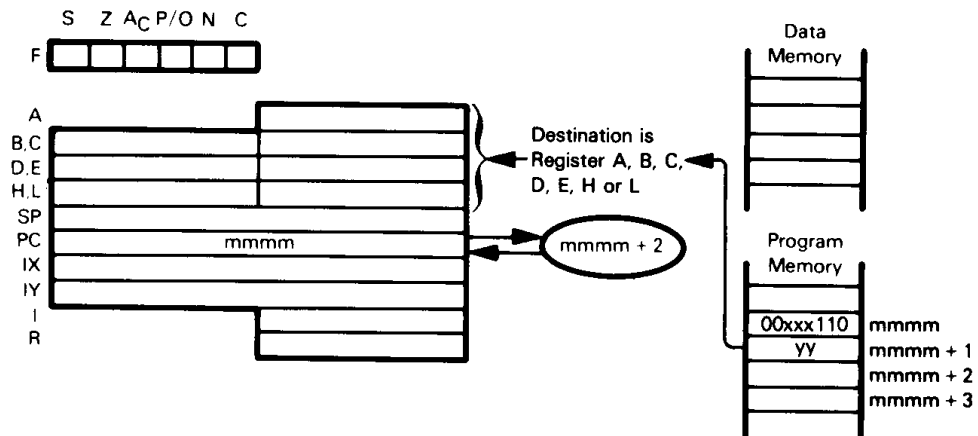
LD R,A

has executed, the Refresh register will contain $7F_{16}$.

LD I,A
ED 47

Load Interrupt Vector register from Accumulator.

LD reg,data — LOAD IMMEDIATE INTO REGISTER



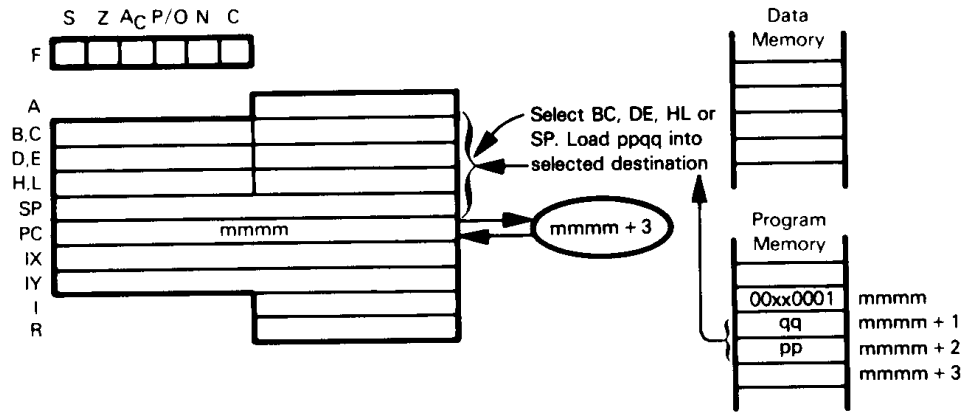
Load the contents of the second object code byte into one of the registers.

When the instruction

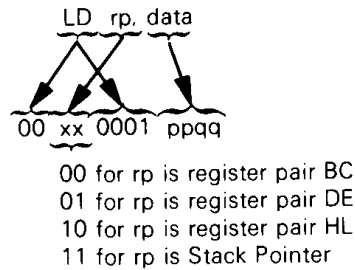
LD A,2AH

has executed, 2A₁₆ is loaded into the Accumulator.

LD rp,data — LOAD 16 BITS OF DATA IMMEDIATE INTO REGISTER
LD IX,data
LD IY,data



The illustration shows execution of LD rp,data:



Load the contents of the second and third object code bytes into the selected register pair. After the instruction

```
LD SP,217AH
```

has executed, the Stack Pointer will contain 217A₁₆.

```
LD IX, data  
DD 21 ppqq
```

Load the contents of the second and third object code bytes into the Index register IX.

```
LD IY, data  
FD 21 ppqq
```

Load the contents of the second and third object code bytes into the Index Register IY. Notice that the LD rp,data instruction is equivalent to two LD reg,data instructions.

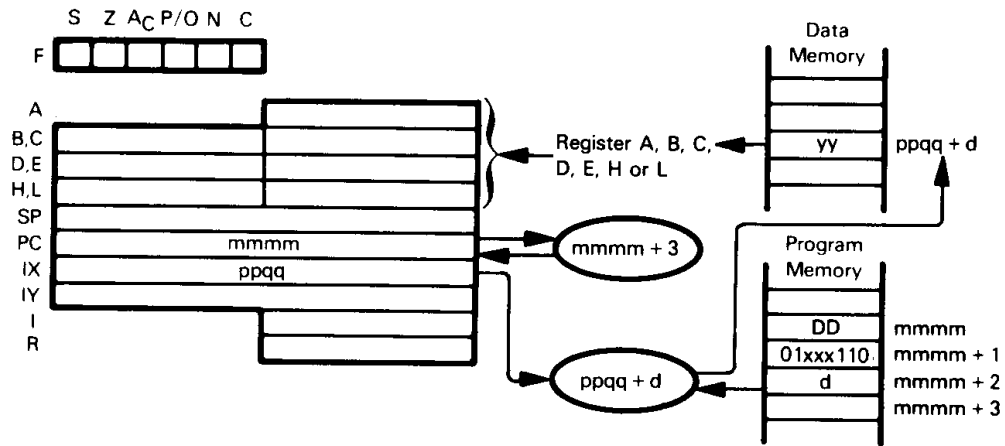
For example:

```
LD HL,032AH
```

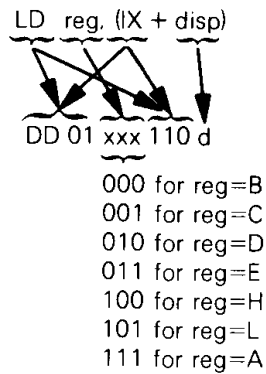
is equivalent to

```
LD H,03H  
LD L,2AH
```

LD reg,(HL) — LOAD REGISTER FROM MEMORY
LD reg,(IX+disp)
LD reg,(IY+disp)



The illustration shows execution of LD reg,(IX+disp):

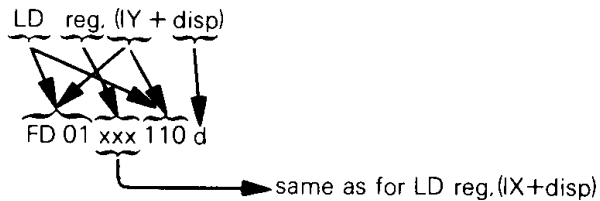


Load specified register from memory location (specified by the sum of the contents of the IX register and the displacement digit d).

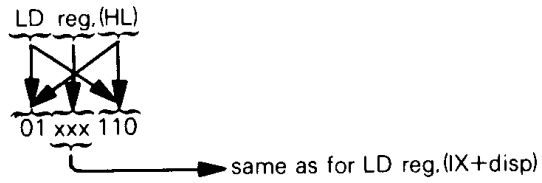
Suppose $ppqq=4004_{16}$ and memory location 4010_{16} contains FF_{16} . After the instruction

LD B(IX+0CH)

has executed, Register B will contain FF_{16} .

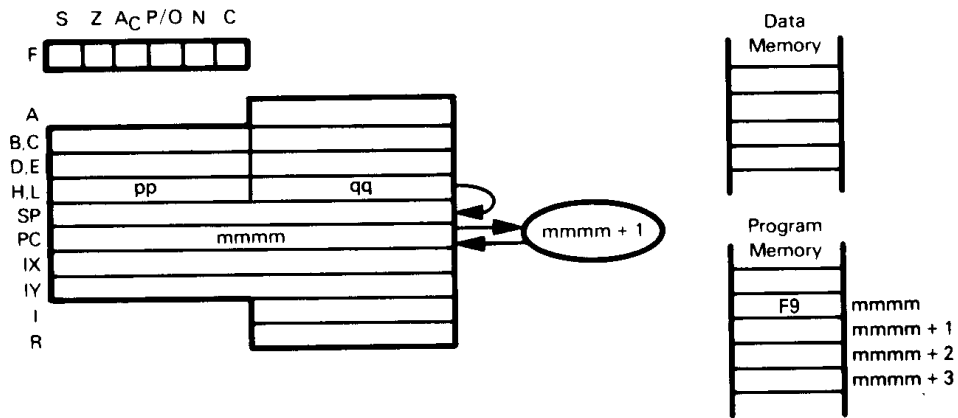


This instruction is identical to LD reg,(IX+disp), except that it uses the IY register instead of the IX register.



Load specified register from memory location (specified by the contents of the HL register pair).

**LD SP,HL — MOVE CONTENTS OF HL OR INDEX REGISTER
LD SP,IX TO STACK POINTER
LD SP,IY**



The illustration shows execution of LD SP,HL:

LD SP,HL
F9

Load contents of HL into Stack Pointer.

Suppose pp=0816 and qq=3F16. After the instruction

LD SP,HL

has executed, the Stack Pointer will contain 083F16.

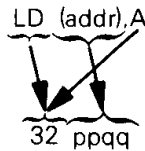
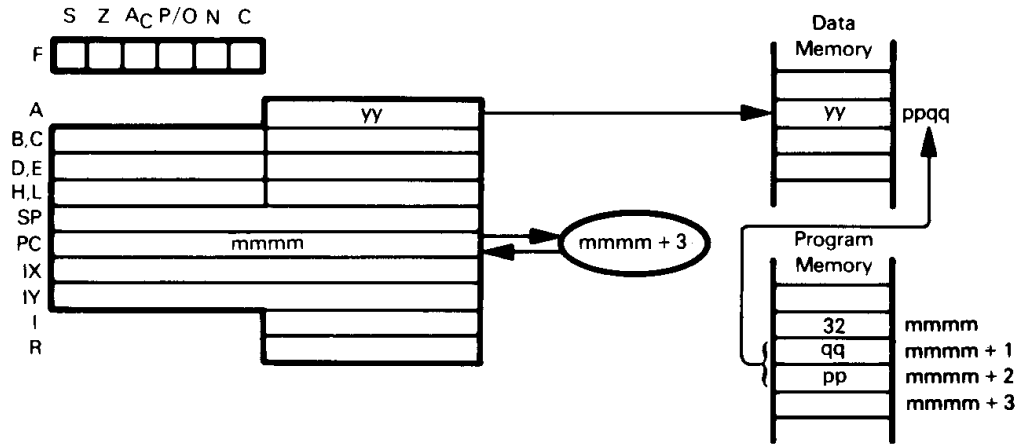
LD SP,IX
DD F9

Load contents of Index Register IX into Stack Pointer.

LD SP,IY
FD F9

Load contents of Index Register IY into Stack Pointer.

LD (addr),A — STORE ACCUMULATOR IN MEMORY USING DIRECT ADDRESSING



Store the Accumulator contents in the memory byte addressed directly by the second and third bytes of the LD (addr),A instruction object code.

Suppose the Accumulator contains $3A_{16}$. After the instruction

```
label EQU 084AH
-
-
LD (label),A
```

has executed, memory byte $084A_{16}$ will contain $3A_{16}$.

Remember that EQU is an assembler directive rather than an instruction; it tells the Assembler to use the 16-bit value $084A_{16}$ whenever the word "label" appears.

The instruction

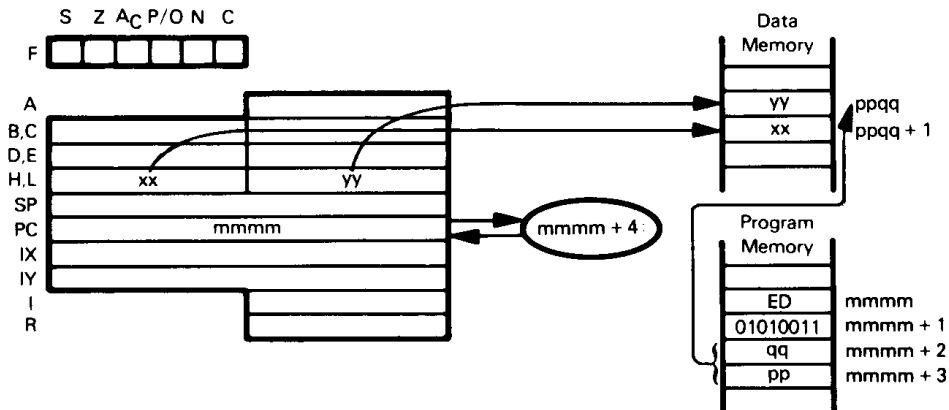
```
LD (addr),A
```

is equivalent to the two instructions

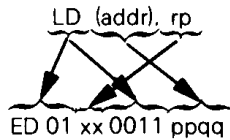
```
LD H,label
LD (HL),A
```

When you are storing a single data value in memory, the LD (label),A instruction is preferred because it uses one instruction and three object program bytes to do what the LD H(label), LD (HL),A combination does in two instructions and four object program bytes. Also, the LD H(label), LD (HL),A combination uses the H and L registers, while the LD (label),A instruction does not.

**LD (addr),HL — STORE REGISTER PAIR OR INDEX
 LD (addr),rp REGISTER IN MEMORY USING DIRECT
 LD (addr),xy ADDRESSING**



The illustration shows execution of LD (ppqq),DE:



- 00 for rp is register pair BC
- 01 for rp is register pair DE
- 10 for rp is register pair HL
- 11 for rp is Stack Pointer

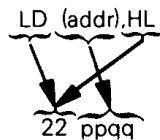
Store the contents of the specified register pair in memory. The third and fourth object code bytes give the address of the memory location where the low-order byte is to be written. The high-order byte is written into the next sequential memory location.

Suppose the BC register pair contains $3C2A_{16}$. After the instruction

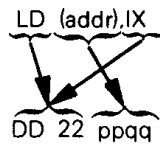
```
label EQU 084AH
-
-
-
LD (label),BC
```

has executed, memory byte $084A_{16}$ will contain $2A_{16}$. Memory byte $084B_{16}$ will contain $3C_{16}$.

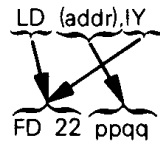
Remember that EQU is an assembler directive rather than an instruction; it tells the Assembler to use the 16-bit value $084A_{16}$ whenever the word "label" appears.



This is a three-byte version of LD (addr),rp which directly specifies HL as the source register pair.

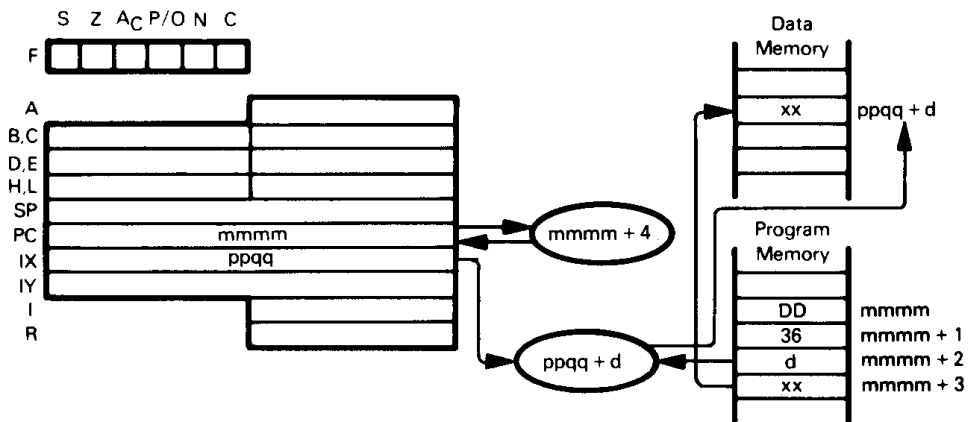


Store the contents of Index register IX in memory. The third and fourth object code bytes give the address of the memory location where the low-order byte is to be written. The high-order byte is written into the next sequential memory location.



This instruction is identical to the LD (addr), IX instruction, except that it uses the IY register instead of the IX register.

LD (HL),data — LOAD IMMEDIATE INTO MEMORY
LD (IX+disp),data
LD (IY+disp),data



The illustration shows execution of LD (IX+d),xx:

```
LD (IX+disp).data
DD 36 d xx
```

Load Immediate into the Memory location designated by base relative addressing.

Suppose ppqq=5400₁₆. After the instruction

```
LD (IX+9),FAH
```

has executed, memory location 5409₁₆ will contain FA₁₆.

```
LD (IY+disp).data
FD 36 d xx
```

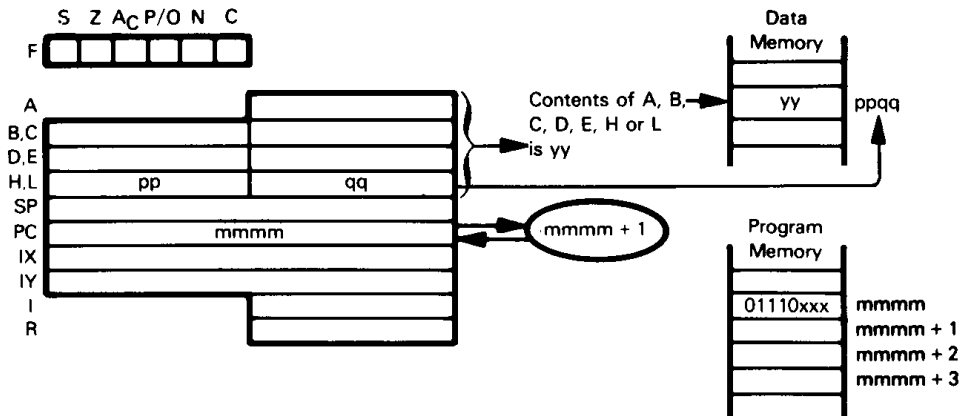
This instruction is identical to LD (IX+disp),data, but uses the IY register instead of the IX register.

```
LD (HL).data
36 xx
```

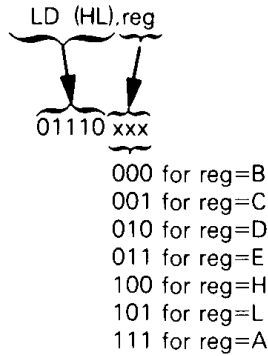
Load Immediate into the Memory location (specified by the contents of the HL register pair).

The Load Immediate into Memory instructions are used much less than the Load Immediate into Register instructions.

LD (HL),reg — LOAD MEMORY FROM REGISTER
LD (IX+disp),reg
LD (IY+disp),reg



The illustration shows execution of LD (HL),reg:

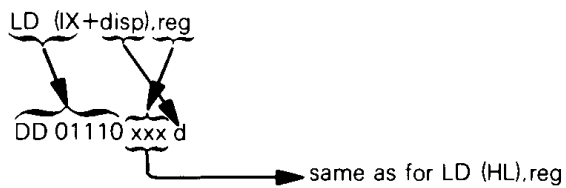


Load memory location (specified by the contents of the HL register pair) from specified register.

Suppose ppq=4500₁₆ and Register C contains F9₁₆. After the instruction

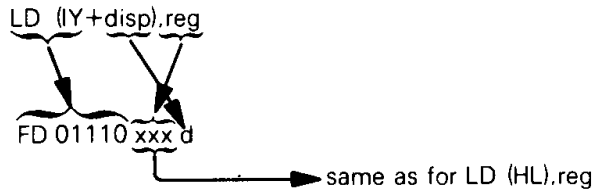
LD (HL),C

has executed, memory location 4500₁₆ will contain F9₁₆.



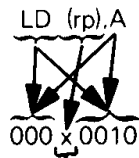
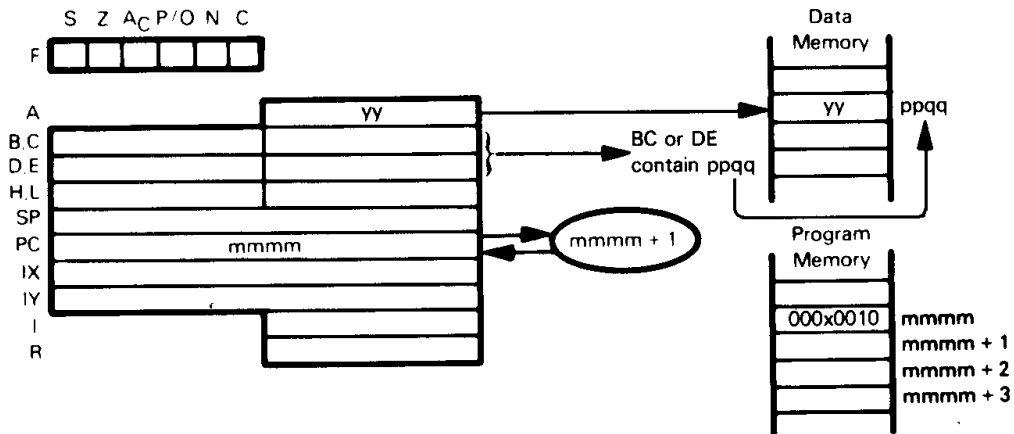
Load memory location (specified by the sum of the contents of the IX register and the

displacement value d) from specified register.



This instruction is identical to LD (IX+disp),reg, except that it uses the IY register instead of the IX register.

LD (rp),A — LOAD ACCUMULATOR INTO THE MEMORY LOCATION ADDRESSED BY REGISTER PAIR



0 if register pair=BC
1 if register pair=DE

Store the Accumulator in the memory byte addressed by the BC or DE register pair.

Suppose the BC register pair contains $084A_{16}$ and the Accumulator contains $3A_{16}$. After the instruction

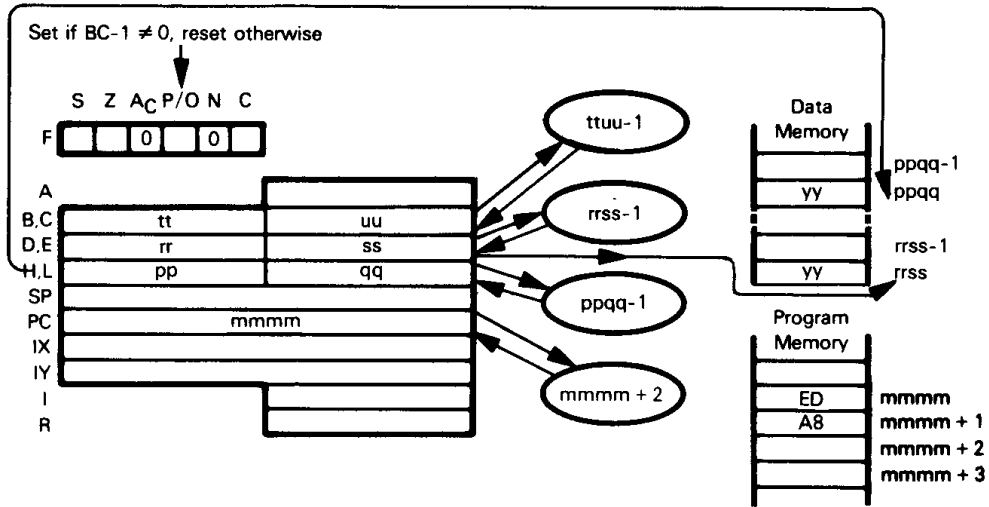
LD (BC),A

has executed, memory byte $084A_{16}$ will contain $3A_{16}$.

The LD (rp),A and LD rp,data will normally be used together, since the LD rp,data instruction loads a 16-bit address into the BC or DE registers as follows:

LD BC,084AH
LD (BC),A

LDD — TRANSFER DATA BETWEEN MEMORY LOCATIONS, DECREMENT DESTINATION AND SOURCE ADDRESSES



Transfer a byte of data from memory location addressed by the HL register pair to memory location addressed by the DE register pair. Decrement contents of register pairs BC, DE, and HL.

Suppose register pair BC contains $004F_{16}$. DE contains 4545_{16} . HL contains 2012_{16} . and memory location 2012_{16} contains 18_{16} . After the instruction

LDD

has executed, memory location 4545_{16} will contain 18_{16} , register pair BC will contain $004E_{16}$. DE will contain 4544_{16} , and HL will contain 2011_{16} .

LDDR — TRANSFER DATA BETWEEN MEMORY LOCATIONS UNTIL BYTE COUNTER IS ZERO. DECREMENT DESTINATION AND SOURCE ADDRESSES

LDDR
 ED B8

This instruction is identical to LDD, except that it is repeated until the BC register pair contains zero. After each data transfer, interrupts will be recognized and two refresh cycles will be executed.

Suppose we have the following contents in memory and register pairs:

<u>Register/Contents</u>	<u>Location/Contents</u>
HL 2012 ₁₆	2012 ₁₆ 18 ₁₆
DE 4545 ₁₆	2011 ₁₆ AA ₁₆
BC 0003 ₁₆	2010 ₁₆ 25 ₁₆

After execution of

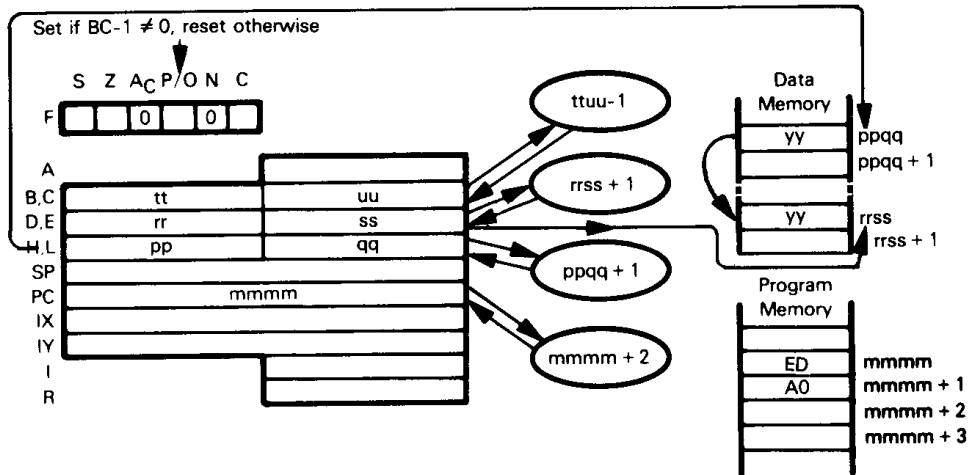
LDDR

register pairs and memory locations will have the following contents:

<u>Register/Contents</u>	<u>Location/Contents</u>	<u>Location/Contents</u>
HL 2009 ₁₆	2012 ₁₆ 18 ₁₆	4545 ₁₆ 18 ₁₆
DE 4542 ₁₆	2011 ₁₆ AA ₁₆	4544 ₁₆ AA ₁₆
BC 0000 ₁₆	2010 ₁₆ 25 ₁₆	4543 ₁₆ 25 ₁₆

This instruction is extremely useful for transferring blocks of data from one area of memory to another.

LDI — TRANSFER DATA BETWEEN MEMORY LOCATIONS, INCREMENT DESTINATION AND SOURCE ADDRESSES



LDI
ED A0

Transfer a byte of data from memory location addressed by the HL register pair to memory location addressed by the DE register pair. Increment contents of register pairs HL and DE. Decrement contents of the BC register pair.

Suppose register pair BC contains $004F_{16}$, DE contains 4545_{16} , HL contains 2012_{16} , and memory location 2012_{16} contains 18_{16} . After the instruction

LDI

has executed, memory location 4545_{16} will contain 18_{16} , register pair BC will contain $004E_{16}$, DE will contain 4546_{16} , and HL will contain 2013_{16} .

LDIR — TRANSFER DATA BETWEEN MEMORY LOCATIONS UNTIL BYTE COUNTER IS ZERO. INCREMENT DESTINATION AND SOURCE ADDRESSES

LDIR
ED B0

This instruction is identical to LDI, except that it is repeated until the BC register pair contains zero. After each data transfer, interrupts will be recognized and two refresh cycles will be executed.

Suppose we have the following contents in memory and register pairs:

Register/Contents	Location/Contents
HL 2012 ₁₆	2012 ₁₆ 18 ₁₆
DE 4545 ₁₆	2013 ₁₆ CD ₁₆
BC 0003 ₁₆	2014 ₁₆ F0 ₁₆

After execution of

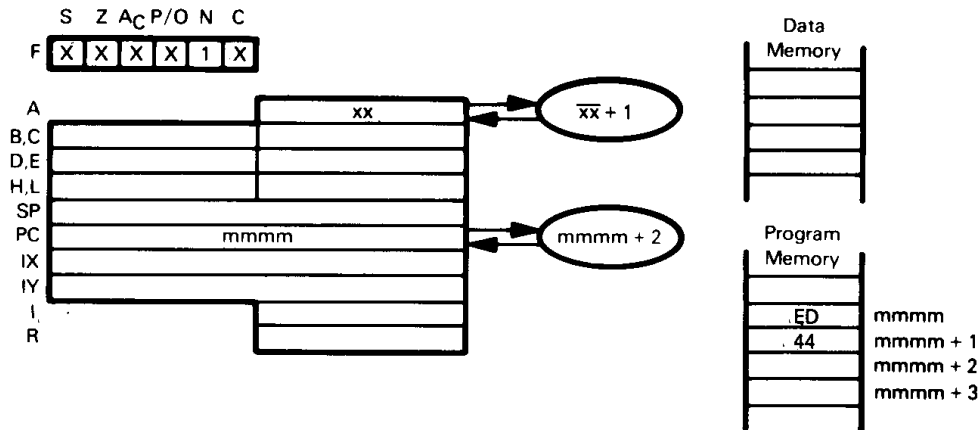
LDIR

register pairs and memory will have the following contents:

Register/Contents	Location/Contents	Location/Contents
HL 2015 ₁₆	2012 ₁₆ 18 ₁₆	4545 ₁₆ 18 ₁₆
DE 4548 ₁₆	2013 ₁₆ CD ₁₆	4546 ₁₆ CD ₁₆
BC 0000 ₁₆	2014 ₁₆ F0 ₁₆	4547 ₁₆ F0 ₁₆

This instruction is extremely useful for transferring blocks of data from one area of memory to another.

NEG — NEGATE CONTENTS OF ACCUMULATOR



Negate contents of Accumulator. This is the same as subtracting contents of the Accumulator from zero. The result is the two's complement. 80H will be left unchanged.

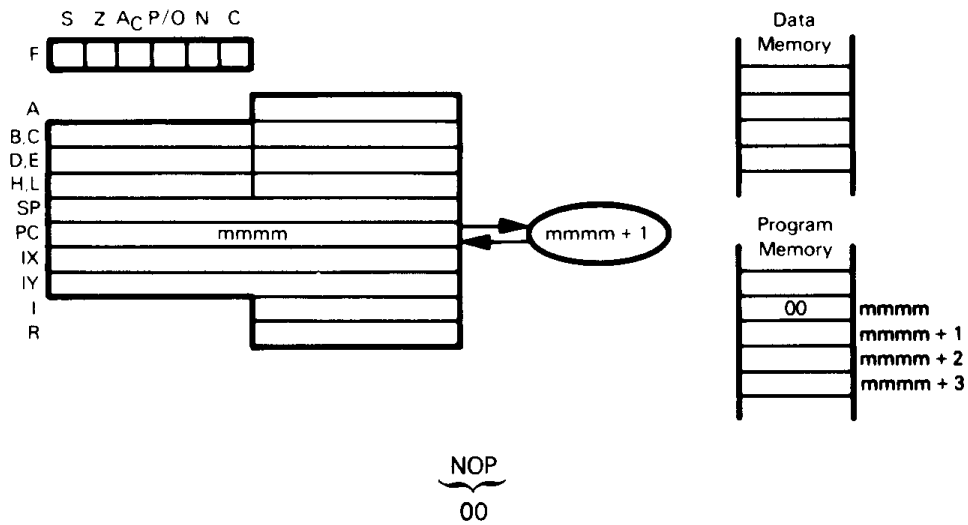
Suppose $xx=5A_{16}$. After the instruction

NEG

has executed, the Accumulator will contain $A6_{16}$.

$$\begin{aligned}
 5A &= 0101\ 1010 \\
 \text{Two's complement} &= 1010\ 0110
 \end{aligned}$$

NOP — NO OPERATION

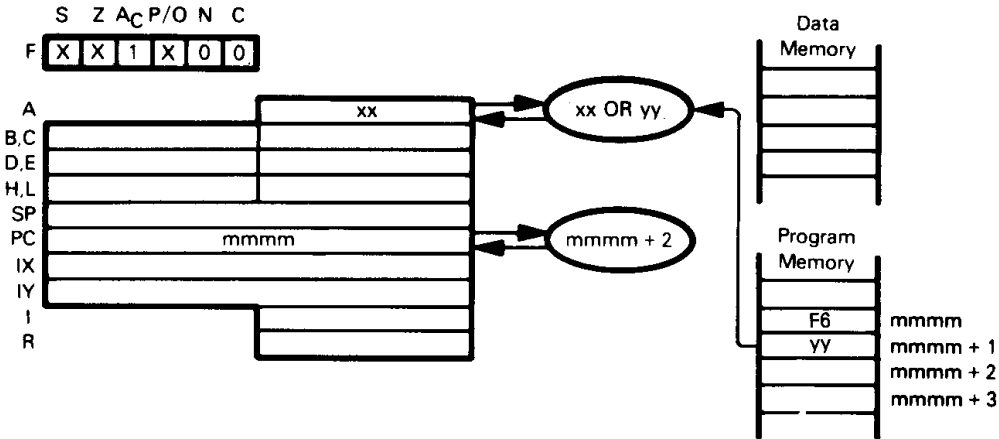


This is a one-byte instruction which performs no operation, except that the Program Counter is incremented and memory refresh continues. This instruction is present for several reasons:

- 1) A program error that fetches an object code from non-existent memory will fetch 00. It is a good idea to ensure that the most common program error will do nothing.
- 2) The NOP instruction allows you to give a label to an object program byte:
HERE NOP
- 3) To fine-tune delay times. Each NOP instruction adds four clock cycles to a delay.

NOP is not a very useful or frequently used instruction.

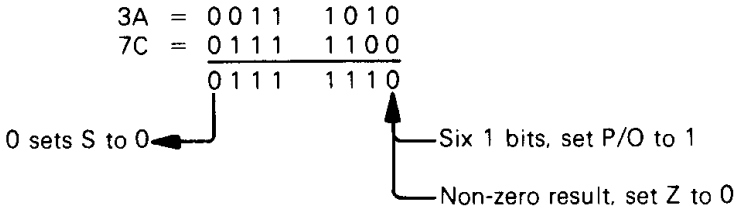
OR data — OR IMMEDIATE WITH ACCUMULATOR



OR the Accumulator with the contents of the second instruction object code byte.
 Suppose $xx=3A_{16}$. After the instruction

OR 7CH

has executed, the Accumulator will contain $7E_{16}$.

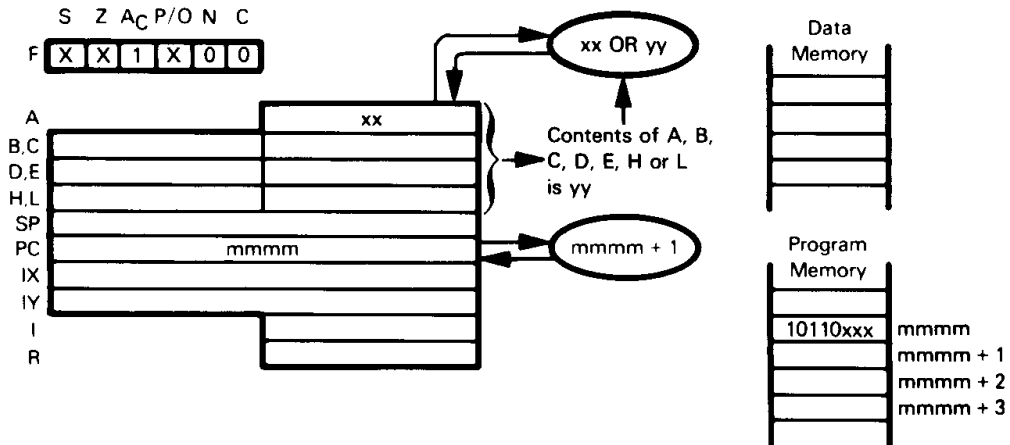


This is a routine logical instruction; it is often used to turn bits "on". For example, the instruction

OR 80H

will unconditionally set the high-order Accumulator bit to 1.

OR reg — OR REGISTER WITH ACCUMULATOR



$\overbrace{10110}^{\text{OR}}$ $\overbrace{xxx}^{\text{reg}}$
 000 for reg=B
 001 for reg=C
 010 for reg=D
 011 for reg=E
 100 for reg=H
 101 for reg=L
 111 for reg=A

Logically OR the contents of the Accumulator with the contents of Register A, B, C, D, E, H or L. Store the result in the Accumulator.

Suppose $xx=E3_{16}$ and Register E contains $A8_{16}$. After the instruction

OR E

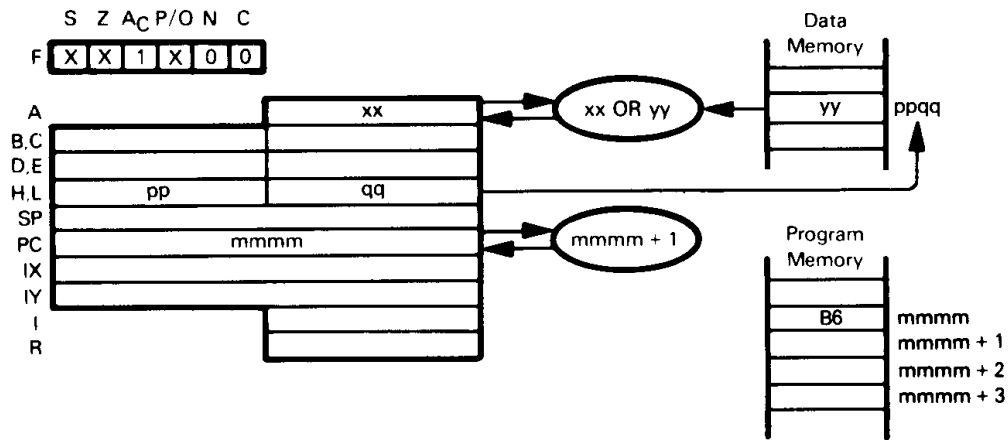
has executed, the Accumulator will contain EB_{16} .

E3	=	1 1 1 0	0 0 1 1
A8	=	1 0 1 0	1 0 0 0

		1 1 1 0	1 0 1 1

1 sets S to 1 ←
 Six 1 bits, set P/O to 1
 Non-zero result, set Z to 0

OR (HL) — OR MEMORY WITH ACCUMULATOR
OR (IX+disp)
OR (IY+disp)



The illustration shows execution of OR (HL):

OR (HL)
 ───────────
 B6

OR contents of memory location (specified by the contents of the HL register pair) with the Accumulator.

Suppose $xx = E3_{16}$, $ppqq = 4000_{16}$, and memory location 4000_{16} contains $A8_{16}$. After the instruction

OR (HL)

has executed, the Accumulator will contain EB_{16} .

E3 =	1 1 1 0	0 0 1 1
A8 =	1 0 1 0	1 0 0 0
	1 1 1 0	1 0 1 1

1 sets S to 1

Six 1 bits, set P/O to 1

Non-zero result, set Z to 0

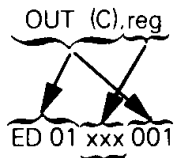
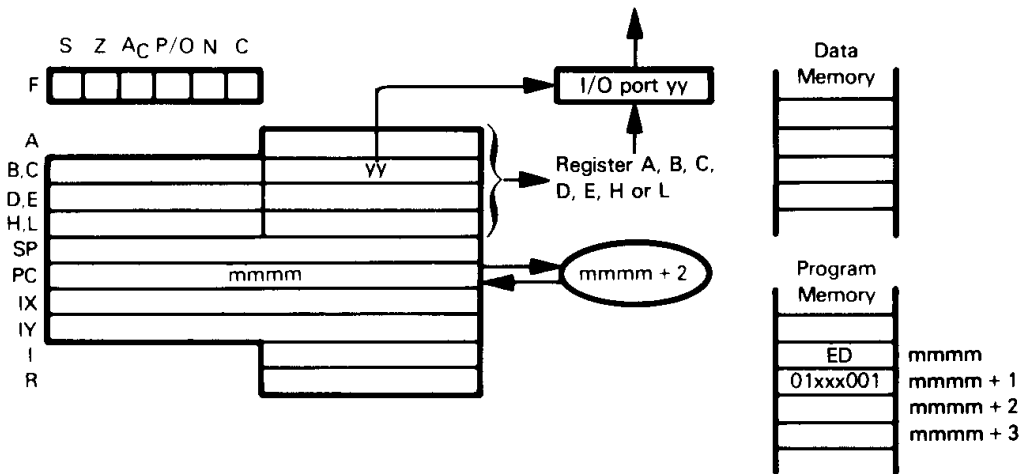
OR (IX+disp)
 ───────────
 DD B6 d

OR contents of memory location (specified by the sum of the contents of the IX register and the displacement value d) with the Accumulator.

OR (IY+disp)
 ───────────
 FD B6 d

This instruction is identical to OR (IX+disp), except that it uses the IY register instead of the IX register.

OUT (C),reg — OUTPUT FROM REGISTER

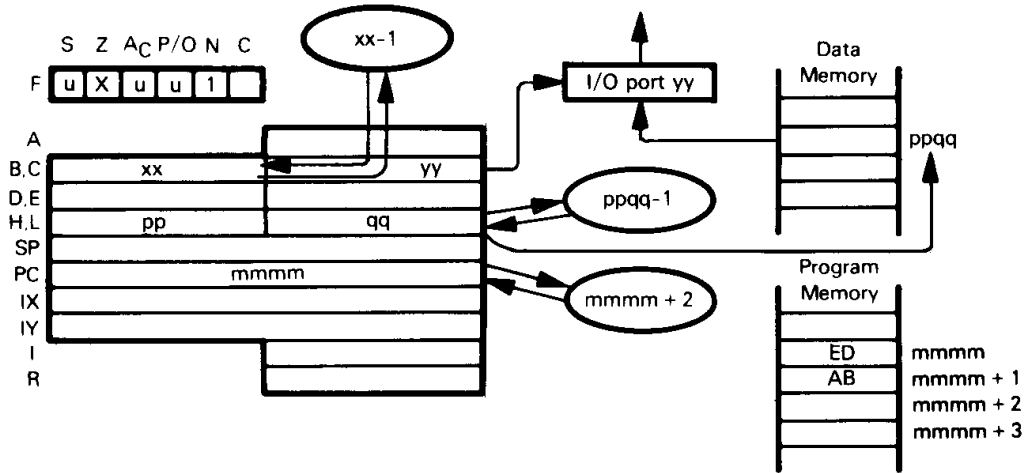


- 000 for reg=B
- 001 for reg=C
- 010 for reg=D
- 011 for reg=E
- 100 for reg=H
- 101 for reg=L
- 111 for reg=A

Suppose `yy=1F16` and the contents of H are `AA16`. After the execution of `OUT (C),H`

`AA16` will be in the buffer of I/O port `1F16`.

OUTD — OUTPUT FROM MEMORY. DECREMENT ADDRESS



OUTD
ED AB

Output from memory location specified by HL to I/O port addressed by Register C. Registers B and HL are decremented.

Suppose $xx=0A_{16}$, $yy=FF_{16}$, $ppqq=5000_{16}$, and memory location 5000_{16} contains 77_{16} . After the instruction

OUTD

has executed, 77_{16} will be held in the buffer of I/O port FF_{16} . The B register will contain 09_{16} , and the HL register pair $4FFF_{16}$.

OTDR — OUTPUT FROM MEMORY. DECREMENT ADDRESS, CONTINUE UNTIL REGISTER B=0

OTDR
ED BB

OTDR is identical to OUTD, but is repeated until Register B contains 0.

Suppose Register B contains 03_{16} , Register C contains FF_{16} , and HL contains 5000_{16} . Memory locations $4FFE_{16}$ through 5000_{16} contain:

Location/Contents	
$4FFE_{16}$	CA_{16}
$4FFF_{16}$	$1B_{16}$
5000_{16}	$F1_{16}$

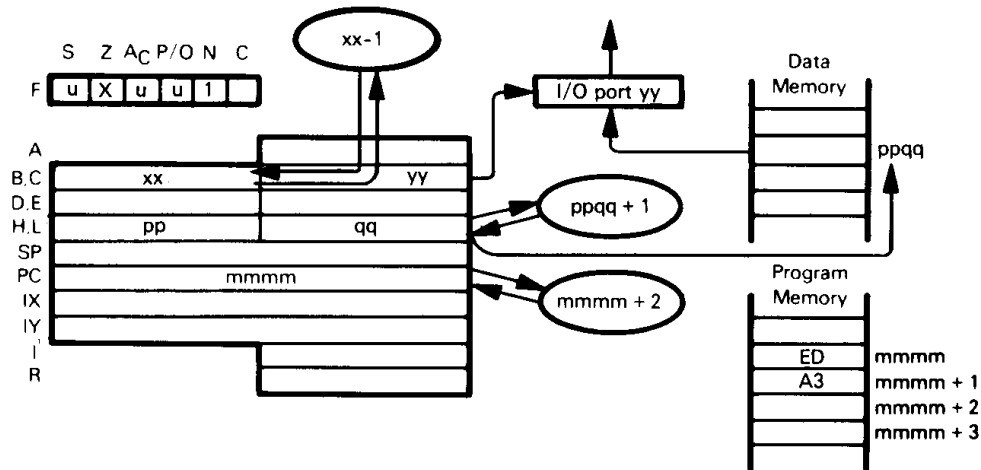
After execution of

OTDR

register pair HL will contain $4FFD_{16}$, Register B will contain zero, and the sequence $F1_{16}$, $1B_{16}$, CA_{16} will have been written to I/O port FF_{16} .

This instruction is very useful for transferring blocks of data from memory to output devices.

OUTI — OUTPUT FROM MEMORY. INCREMENT ADDRESS



OUTI
ED A3

Output from memory location specified by HL to I/O port addressed by Register C. Register B is decremented and the HL register pair is incremented.

Suppose $xx=0A_{16}$, $yy=FF_{16}$, $ppqq=5000_{16}$, and memory location 5000_{16} contains 77_{16} . After the instruction

OUTI

has executed, 77_{16} will be held in the buffer of I/O port FF_{16} . The B register will contain 09_{16} and the HL register pair will contain 5001_{16} .

OTIR — OUTPUT FROM MEMORY. INCREMENT ADDRESS, CONTINUE UNTIL REGISTER B=0

OTIR
ED B3

OTIR is identical to OUTI, except that it is repeated until Register B contains 0.

Suppose Register B contains 04_{16} , Register C contains FF_{16} , and HL contains 5000_{16} . Memory locations 5000_{16} through 5003_{16} contain:

Location/Contents	
5000_{16}	CA_{16}
5001_{16}	$1B_{16}$
5002_{16}	$B1_{16}$
5003_{16}	AD_{16}

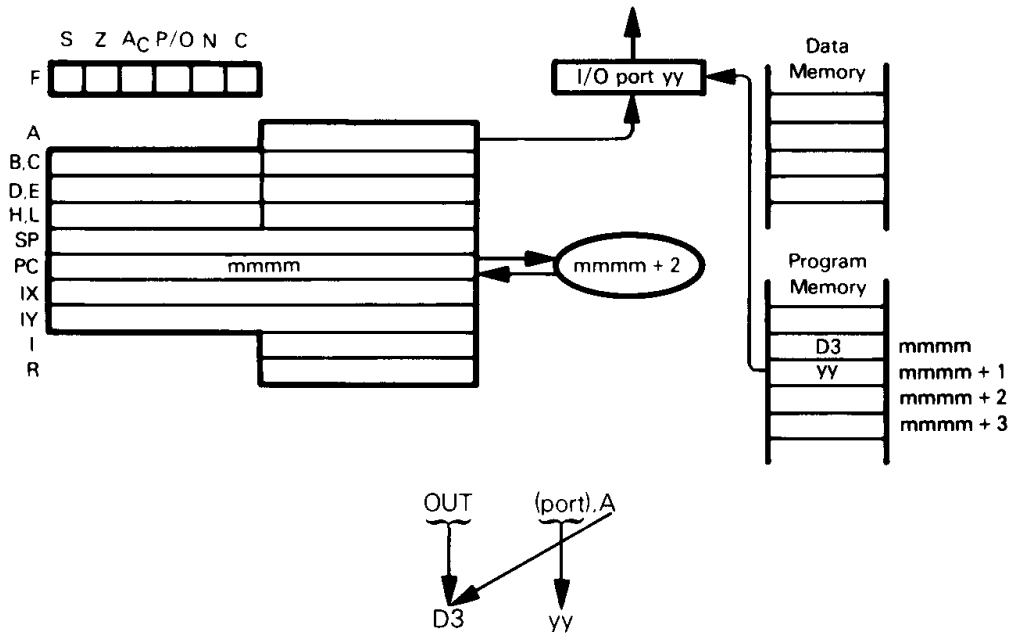
After execution of

OTIR

register pair HL will contain 5004_{16} , Register B will contain zero and the sequence CA_{16} , $1B_{16}$, $B1_{16}$ and AD_{16} will have been written to I/O port FF_{16} .

This instruction is very useful for transferring blocks of data from memory to an output device.

OUT (port),A — OUTPUT FROM ACCUMULATOR



Output the contents of the Accumulator to the I/O port identified by the second OUT instruction object code byte.

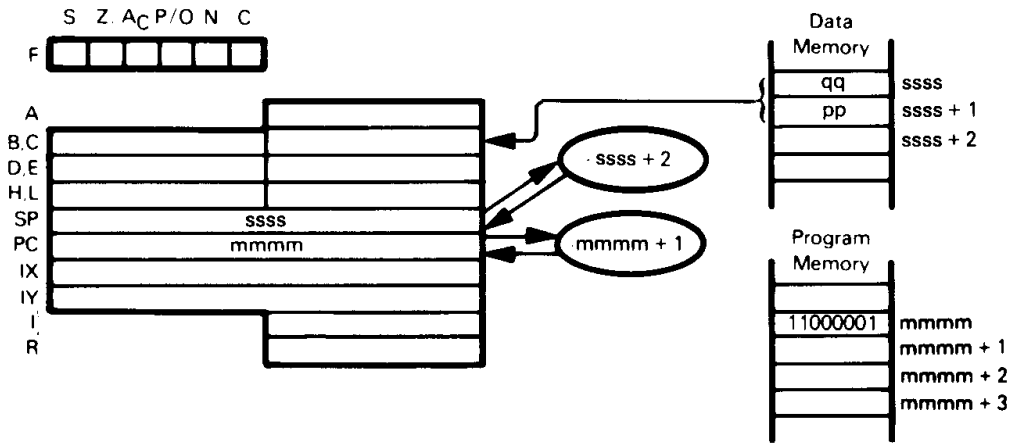
Suppose 36_{16} is held in the Accumulator. After the instruction

`OUT (1AH),A`

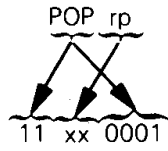
has executed, 36_{16} will be in the buffer of I/O port $1A_{16}$.

The OUT instruction does not affect any statuses. Use of the OUT instruction is very hardware-dependent. Valid I/O port addresses are determined by the way in which I/O logic has been implemented. It is also possible to design a microcomputer system that accesses external logic using memory reference instructions with specific memory addresses. OUT instructions are frequently used in special ways to control microcomputer logic external to the CPU.

POP rp — READ FROM THE TOP OF THE STACK
POP IX
POP IY



The illustration shows execution of POP BC:



- 00 for rp is register pair BC
- 01 for rp is register pair DE
- 10 for rp is register pair HL
- 11 for rp is register pair A and F

POP the two top stack bytes into the designated register pair.

Suppose $qq=01_{16}$ and $pp=2A_{16}$. Execution of

POP HL

loads 01_{16} into the L register and $2A_{16}$ into the H register. Execution of the instruction

POP AF

loads 01 into the status flags and $2A_{16}$ into the Accumulator. Thus, the Carry status will be set to 1 and other statuses will be cleared.

POP IX
 DD E1

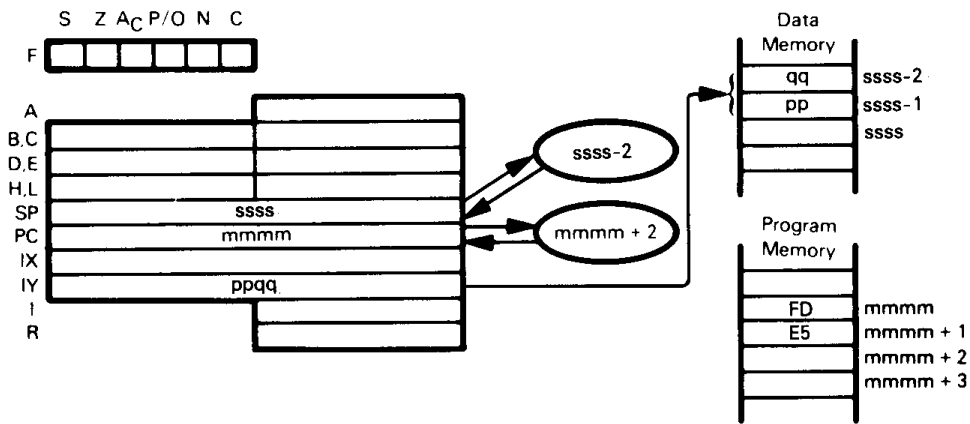
POP the two top stack bytes into the IX register.

POP IY
 FD E1

POP the two top stack bytes into the IY register.

The POP instruction is most frequently used to restore register and status contents which have been saved on the stack; for example, while servicing an interrupt.

PUSH rp — WRITE TO THE TOP OF THE STACK
PUSH IX
PUSH IY



The illustration shows execution of PUSH IY:

PUSH IY
FD E5

PUSH the contents of the IY register onto the top of the stack.

Suppose the IY register contains $45FF_{16}$. Execution of the instruction

PUSH IY

loads 45_{16} , then FF_{16} onto the top of the stack.

PUSH IX
DD E5

PUSH the contents of the IX register onto the top of the stack.



- 00 for rp is register pair BC
- 01 for rp is register pair DE
- 10 for rp is register pair HL
- 11 for rp is register pair A and F

PUSH contents of designated register pair onto the top of the stack.

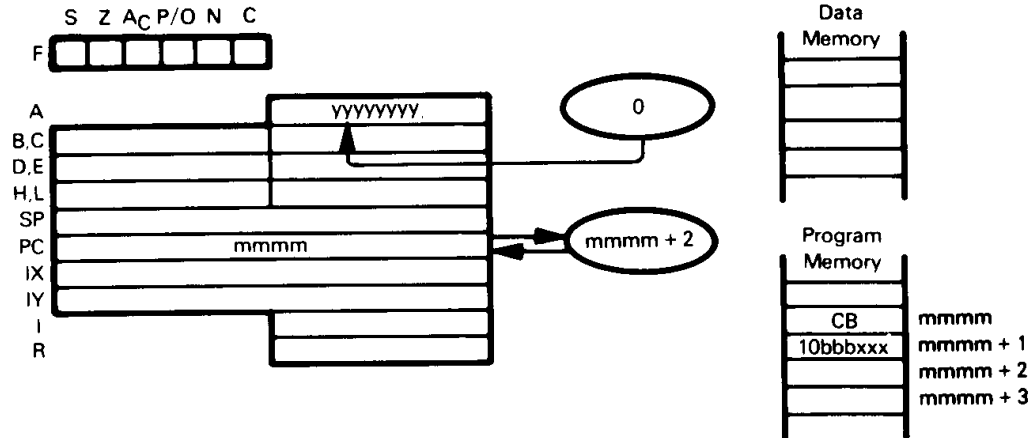
Execution of the instruction

PUSH AF

loads the Accumulator and then the status flags onto the top of the stack.

The PUSH instruction is most frequently used to save register and status contents; for example, before servicing an interrupt.

RES b,reg — RESET INDICATED REGISTER BIT



RES	b.reg		Register	
CB	10	bbb	xxx	
Bit	bbb	xxx		
0	000	000	B	
1	001	001	C	
2	010	010	D	
3	011	011	E	
4	100	100	H	
5	101	101	L	
6	110	111	A	
7	111			

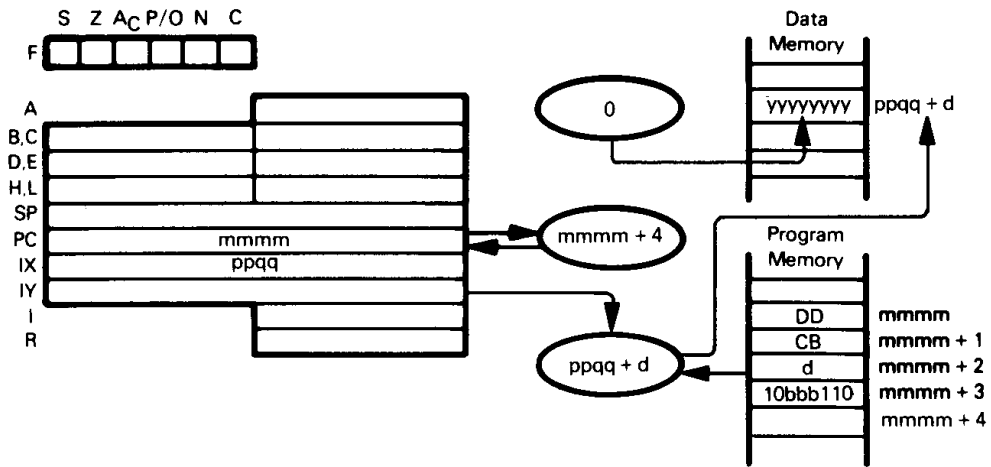
Reset indicated bit within specified register.

After the instruction

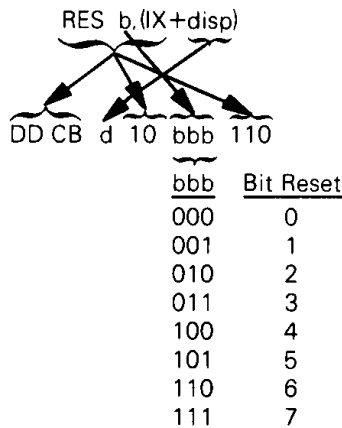
RES 6,H

has executed, bit 6 in Register H will be reset. (Bit 0 is the least significant bit.)

RES b,(HL) — RESET BIT b OF INDICATED MEMORY POSITION
RES b,(IX+disp)
RES b,(IY+disp)



The illustration shows execution of SET b,(IX+disp). Bit 0 is execution of SET b,(IX+disp). Bit 0 is the least significant bit.

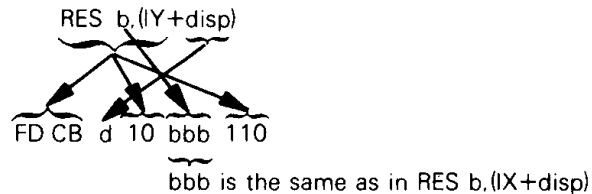


Reset indicated bit within memory location indicated by the sum of Index Register IX and d.

Suppose IX contains 4110_{16} . After the instruction

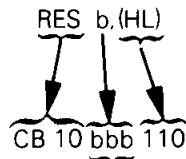
RES 0,(IX+7)

has executed, bit 0 in memory location 4117_{16} will be 0.



This instruction is identical to RES b,(IX+disp), except that it uses the IY register instead

of the IX register.



bbb is the same as in RES b, (IX+disp)

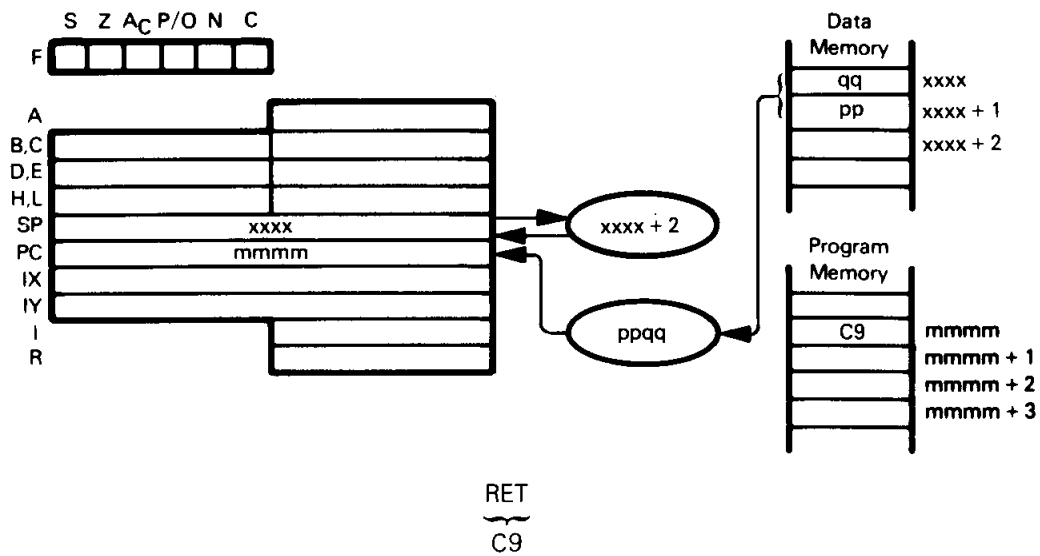
Reset indicated bit within memory location indicated by HL.

Suppose HL contains 4444_{16} . After execution of

RES 7, (HL)

bit 7 in memory location 4444_{16} will be 0.

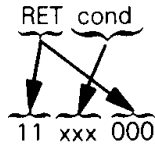
RET — RETURN FROM SUBROUTINE



Move the contents of the top two stack bytes to the Program Counter; these two bytes provide the address of the next instruction to be executed. Previous Program Counter contents are lost. Increment the Stack Pointer by 2, to address the new top of stack.

Every subroutine must contain at least one Return (or conditional Return) instruction; this is the last instruction executed within the subroutine, and causes execution to return to the calling program.

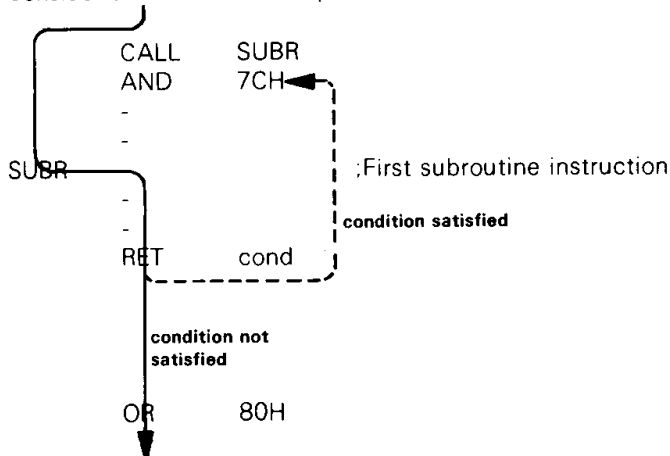
RET cond — RETURN FROM SUBROUTINE IF CONDITION IS SATISFIED



		Condition	Relevant Flag
000	NZ	Non-Zero	Z
001	Z	Zero	Z
010	NC	Non-Carry	C
011	C	Carry	C
100	PO	Parity Odd	P/O
101	PE	Parity Even	P/O
110	P	Sign Positive	S
111	M	Sign Negative	S

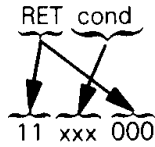
This instruction is identical to the RET instruction, except that the return is not executed unless the condition is satisfied; otherwise, the instruction sequentially following the RET cond instruction will be executed.

Consider the instruction sequence:



After the RET cond is executed, if the condition is satisfied then execution returns to the AND instruction which follows the CALL. If the condition is not satisfied, the OR instruction, being the next sequential instruction, is executed.

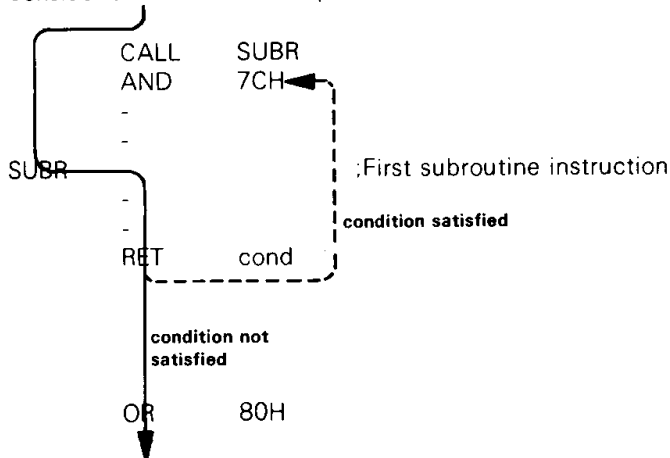
RET cond — RETURN FROM SUBROUTINE IF CONDITION IS SATISFIED



		Condition	Relevant Flag
000	NZ	Non-Zero	Z
001	Z	Zero	Z
010	NC	Non-Carry	C
011	C	Carry	C
100	PO	Parity Odd	P/O
101	PE	Parity Even	P/O
110	P	Sign Positive	S
111	M	Sign Negative	S

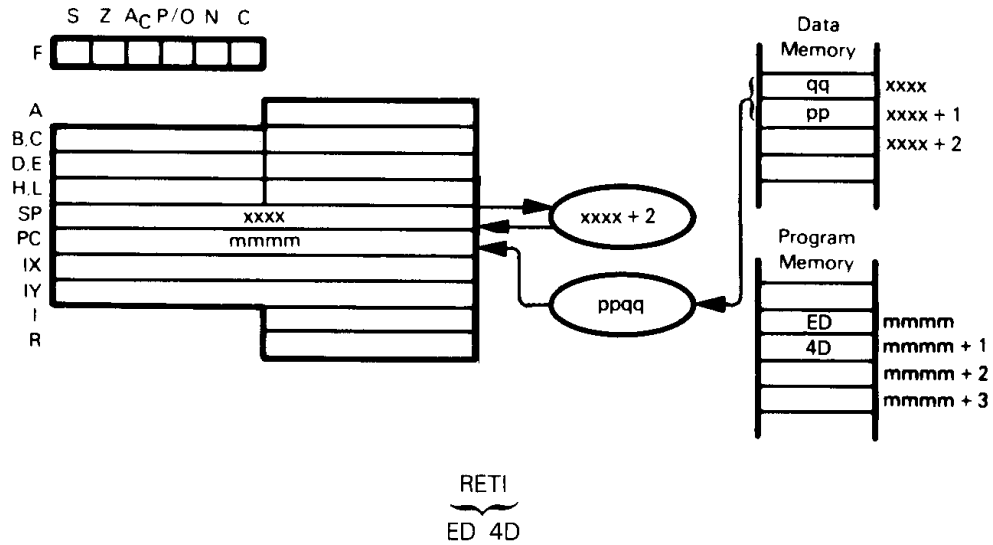
This instruction is identical to the RET instruction, except that the return is not executed unless the condition is satisfied; otherwise, the instruction sequentially following the RET cond instruction will be executed.

Consider the instruction sequence:



After the RET cond is executed, if the condition is satisfied then execution returns to the AND instruction which follows the CALL. If the condition is not satisfied, the OR instruction, being the next sequential instruction, is executed.

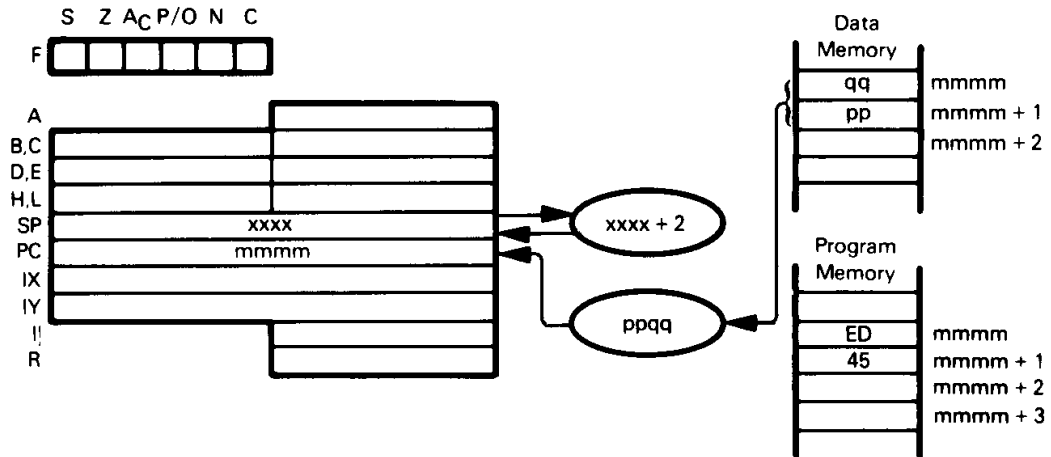
RETI — RETURN FROM INTERRUPT



Move the contents of the top two stack bytes to the Program Counter; these two bytes provide the address of the next instruction to be executed. Previous Program Counter contents are lost. Increment the Stack Pointer by 2, and address the new top of stack.

This instruction is used at the end of an interrupt service routine, and, in addition to returning control to the interrupted program, it is used to signal an I/O device that the interrupt routine has been completed. The I/O device must provide the logic necessary to sense the instruction operation code: refer to An Introduction to Microcomputers: Volume 2 for a description of how the RETI instruction operates with the Z80 family of devices.

RETN — RETURN FROM NON-MASKABLE INTERRUPT

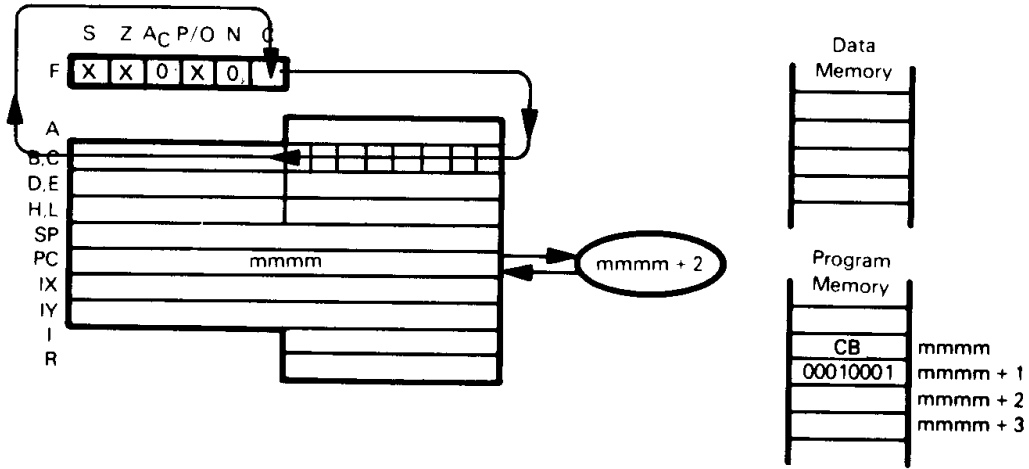


RETN
 ED 45

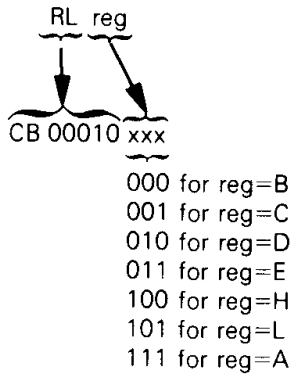
Move the contents of the top two stack bytes to the Program Counter; these two bytes provide the address of the next instruction to be executed. Previous Program Counter contents are lost. Increment the Stack Pointer by 2 to address the new top of stack. Restore the interrupt enable logic to the state it had prior to the occurrence of the non-maskable interrupt.

This instruction is used at the end of a service routine for a non-maskable interrupt, and causes execution to return to the program that was interrupted.

RL reg — ROTATE CONTENTS OF REGISTER LEFT THROUGH CARRY



The illustration shows execution of RL C:

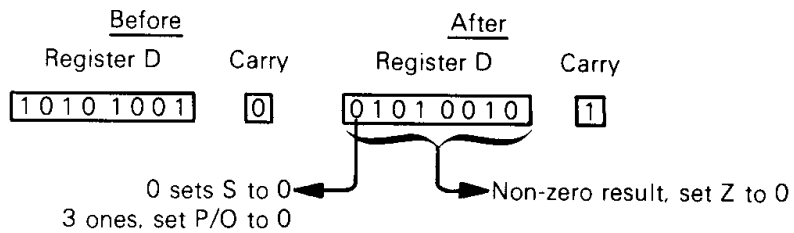


Rotate contents of specified register left one bit through Carry.

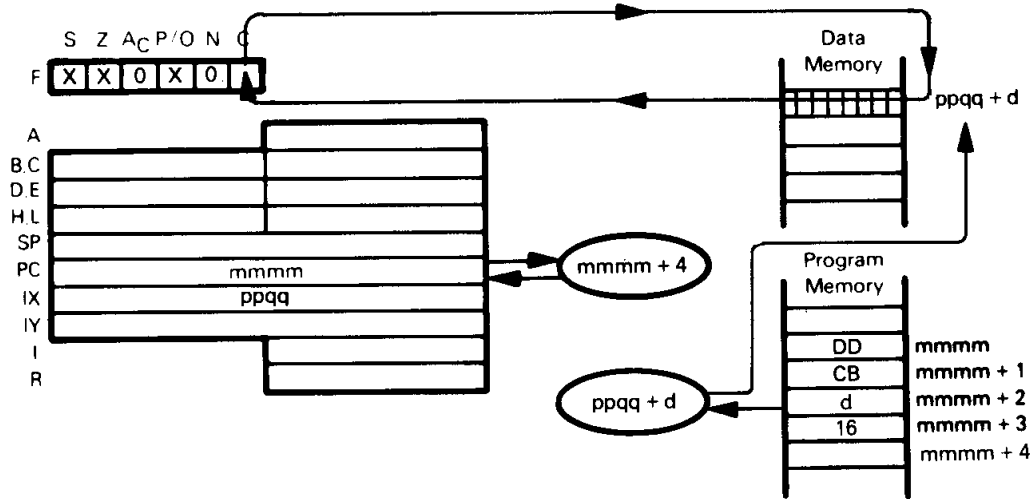
Suppose D contains $A9_{16}$ and Carry=0. After the instruction

RL D

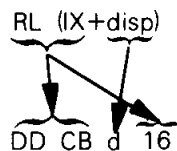
has executed, D will contain 52_{16} and Carry will be 1:



RL (HL) — ROTATE CONTENTS OF MEMORY LOCATION
RL (IX+disp) LEFT THROUGH CARRY
RL (IY+disp)



The illustration shows execution of RL (IX+disp):

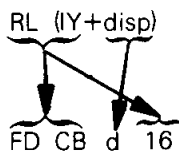
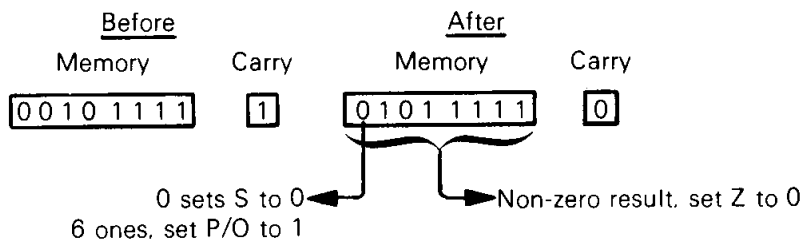


Rotate contents of memory location (specified by the sum of the contents of Index Register IX and displacement integer d) left one bit through Carry.

Suppose the IX register contains 4000_{16} , memory location 4007_{16} contains $2F_{16}$, and Carry is set to 1. After execution of the instruction

RL (IX+7)

memory location 4007_{16} will contain $5F_{16}$, and Carry is 0:

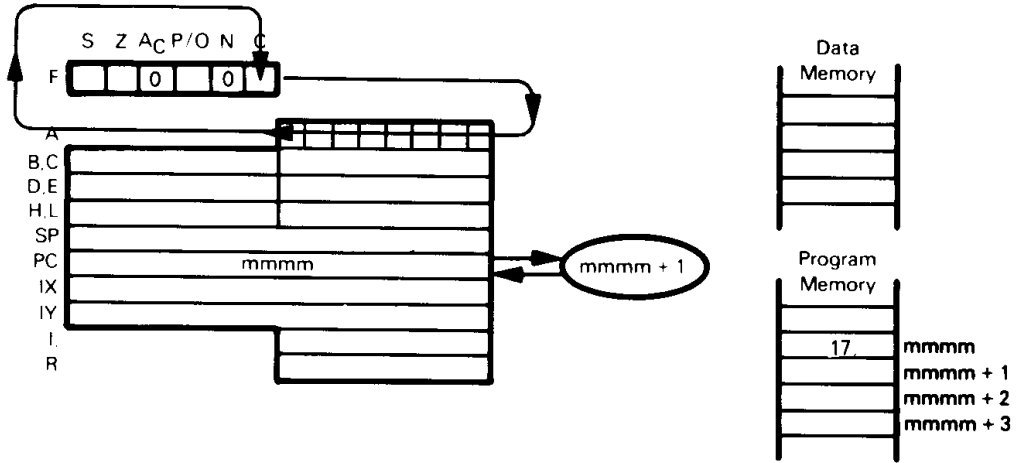


This instruction is identical to RL (IX+disp), but uses the IY register instead of the IX register.

RL (HL)
 ~~~~~  
 CB 16

Rotate contents of memory location (specified by the contents of the HL register pair) left one bit through Carry.

**RLA — ROTATE ACCUMULATOR LEFT THROUGH CARRY**



RLA  
 ~~~~~  
 17

Rotate Accumulator contents left one bit through Carry status.

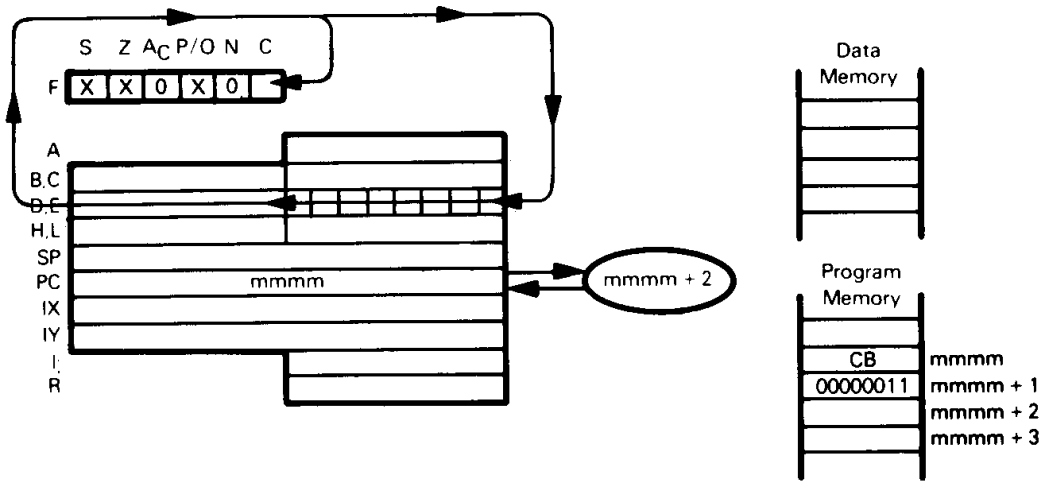
Suppose the Accumulator contains $2A_{16}$ and the Carry status is set to 1. After the instruction

RLA

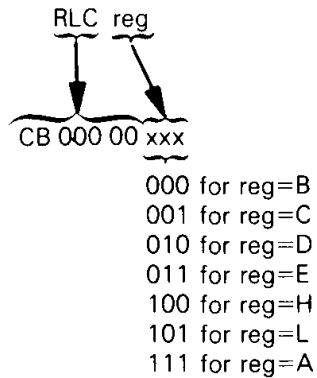
has executed, the Accumulator will contain $F5_{16}$ and the Carry status will be reset to 0:

<u>Before</u>		<u>After</u>	
Accumulator	Carry	Accumulator	Carry
01111010	1	11110101	0

RLC reg — ROTATE CONTENTS OF REGISTER LEFT CIRCULAR



The illustration shows execution of RLC E:

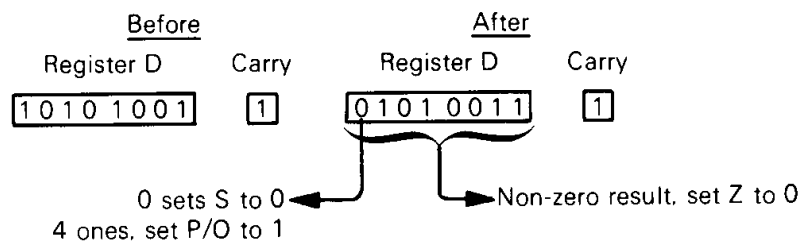


Rotate contents of specified register left one bit, copying bit 7 into Carry.

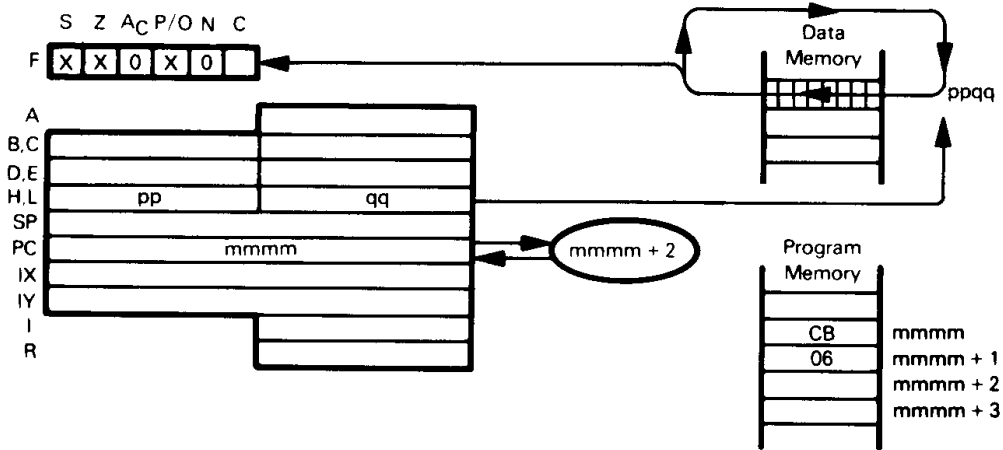
Suppose Register D contains $A9_{16}$ and Carry is 1. After execution of

RLC D

Register D will contain 53_{16} and Carry will be 1:



RLC (HL) — ROTATE CONTENTS OF MEMORY LOCATION
RLC (IX+disp) LEFT CIRCULAR
RLC (IY+disp)



The illustration shows execution of RLC (HL):

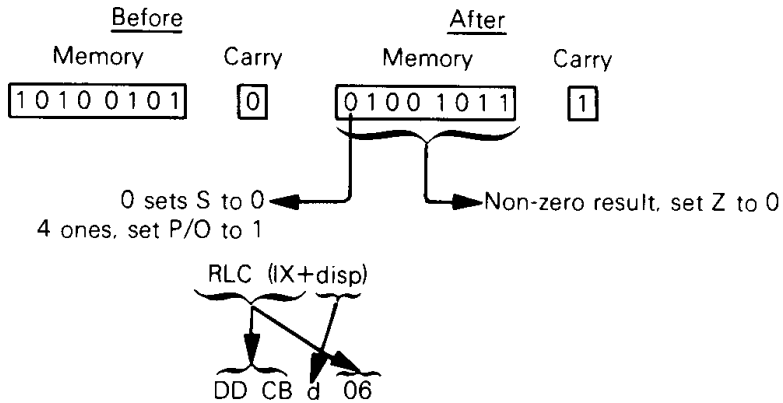
RLC (HL)
 ───────────
 CB 06

Rotate contents of memory location (specified by the contents of the HL register pair) left one bit, copying bit 7 into Carry.

Suppose register pair HL contains 54FF₁₆. Memory location 54FF₁₆ contains A5₁₆, and Carry is 0. After execution of

RLC (HL)

memory location 54FF₁₆ will contain 4B₁₆, and Carry will be 1:

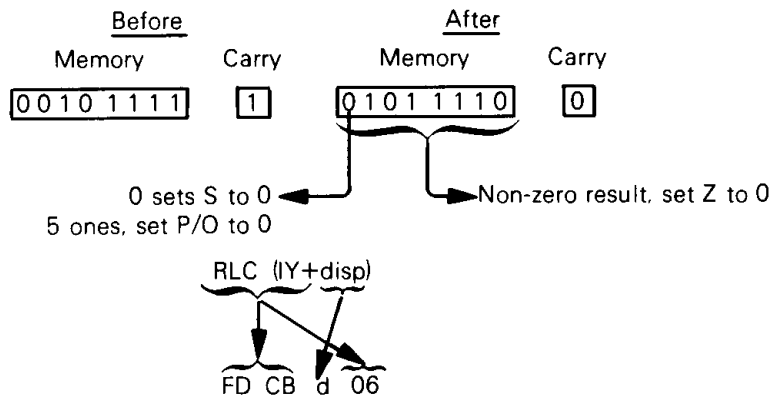


Rotate memory location (specified by the sum of the contents of Index register IX and displacement integer d) left one bit, copying bit 7 into Carry.

Suppose the IX register contains 4000₁₆. Carry is 1, and memory location 4007₁₆ contains 2F₁₆. After the instruction

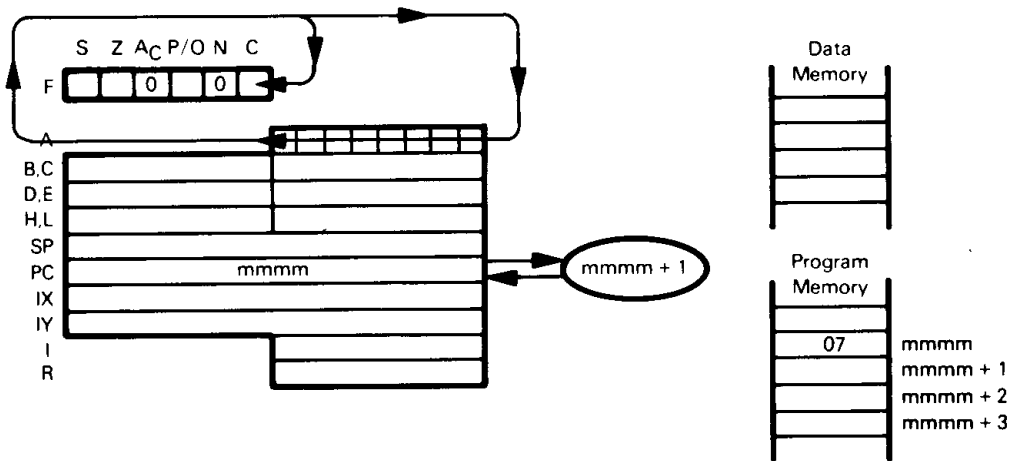
RLC (IX+7)

has executed, memory location 4007_{16} will contain $5E_{16}$, and Carry will be 0:



This instruction is identical to RLC (IX+disp), but uses the IY register instead of the IX register.

RLCA — ROTATE ACCUMULATOR LEFT CIRCULAR

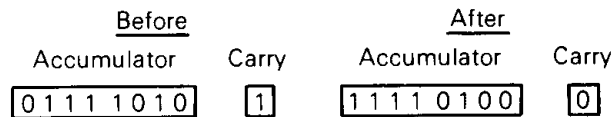


Rotate Accumulator contents left one bit, copying bit 7 into Carry.

Suppose the Accumulator contains $7A_{16}$ and the Carry status is set to 1. After the instruction

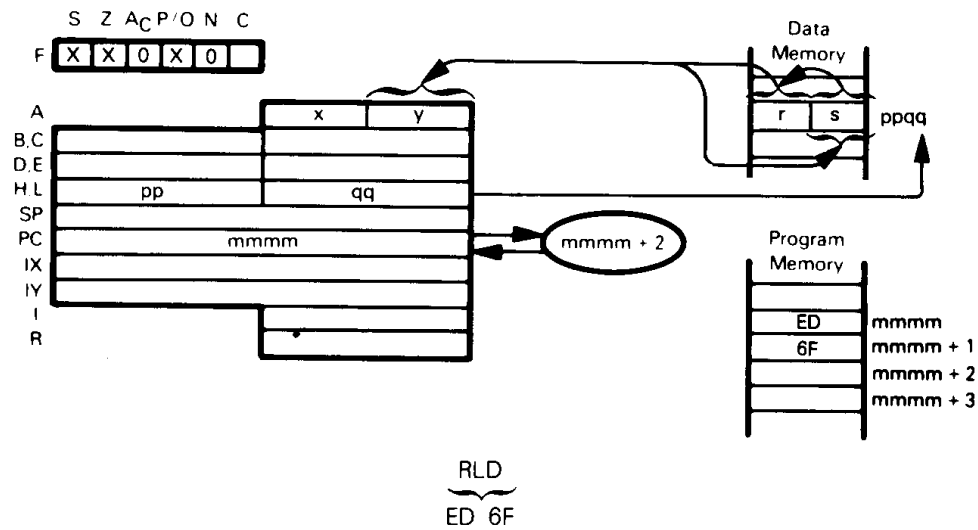
RLCA

has executed, the Accumulator will contain $F4_{16}$ and the Carry status will be reset to 0:



RLCA should be used as a logical instruction.

RLD — ROTATE ONE BCD DIGIT LEFT BETWEEN THE ACCUMULATOR AND MEMORY LOCATION

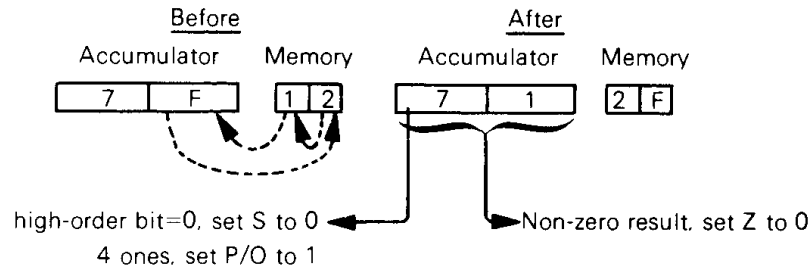


The four low-order bits of a memory location (specified by the contents of register pair HL) are copied into the four high-order bits of the same memory location. The previous contents of the four high-order bits of that memory location are copied into the four low-order bits of the Accumulator. The previous four low-order bits of the Accumulator are copied into the four low-order bits of the specified memory location.

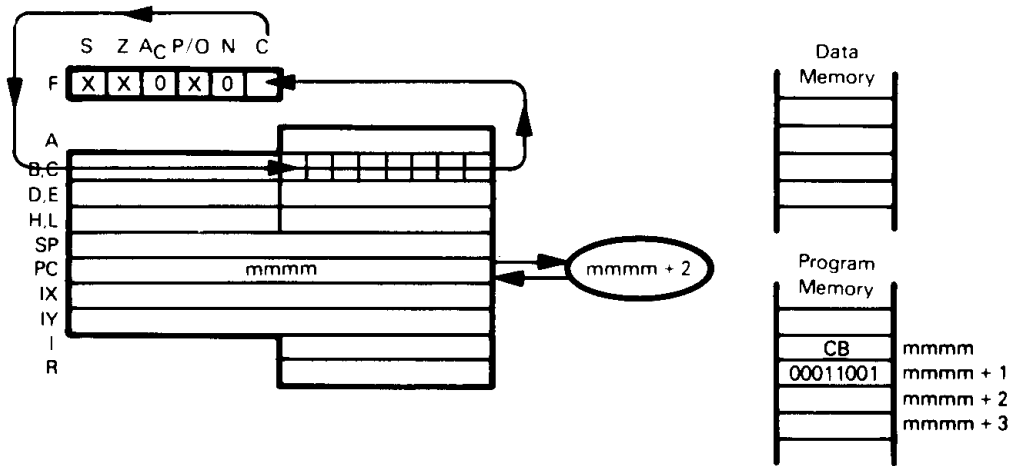
Suppose the Accumulator contains $7F_{16}$, HL register pair contains 4000_{16} , and memory location 4000_{16} contains 12_{16} . After execution of the instruction

RLD

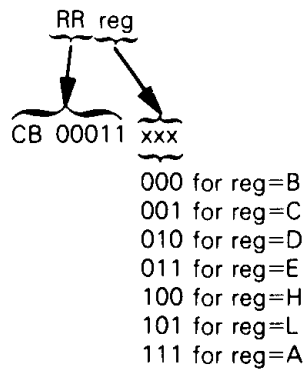
the Accumulator will contain 71_{16} and memory location 4000_{16} will contain $2F_{16}$:



RR reg — ROTATE CONTENTS OF REGISTER RIGHT THROUGH CARRY



The illustration shows execution of RR C:

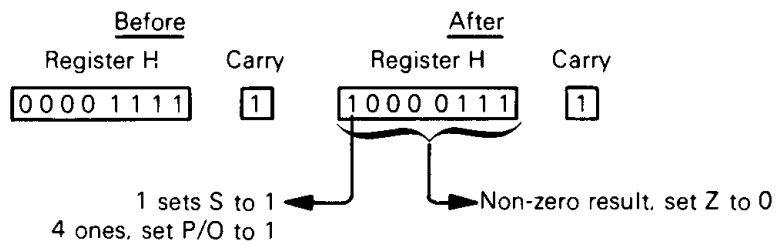


Rotate contents of specified register right one bit through Carry.

Suppose Register H contains $0F_{16}$ and Carry is set to 1. After the instruction

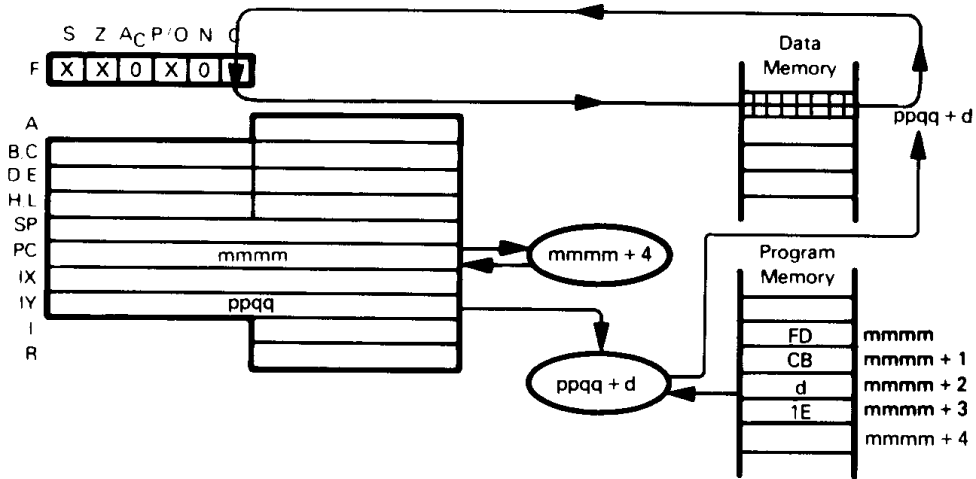
RR H

has executed, Register H will contain 87_{16} , and Carry will be 1:

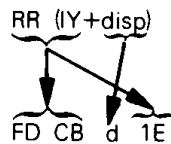


**RR (HL) — ROTATE CONTENTS OF MEMORY LOCATION
RIGHT THROUGH CARRY**

**RR (IX+disp)
RR (IY+disp)**



The illustration shows execution of RR (IY+disp):

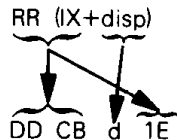
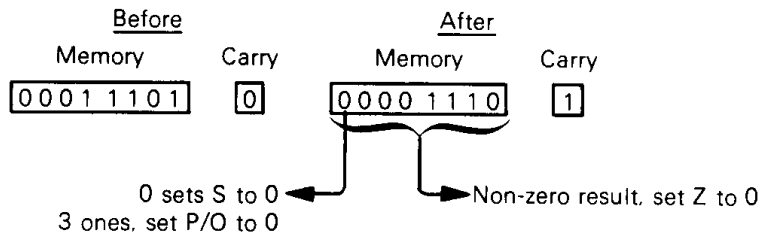


Rotate contents of memory location (specified by the sum of the contents of the IY register and the displacement value d) right one bit through Carry.

Suppose the IY register contains 4500_{16} , memory location $450F_{16}$ contains $1D_{16}$, and Carry is set to 0. After execution of the instruction

RR (IY+0FH)

memory location $450F_{16}$ will contain $0E_{16}$, and Carry will be 1:

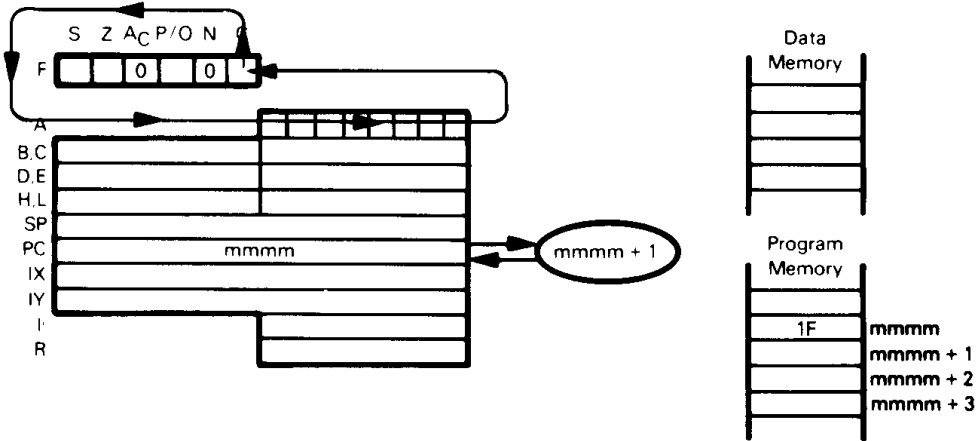


This instruction is identical to RR (IY+disp), but uses the IX register instead of the IY register.

RR (HL)
 ~~~~~  
 CB 1E

Rotate contents of memory location (specified by the contents of the HL register pair) right one bit through Carry.

**RRA — ROTATE ACCUMULATOR RIGHT THROUGH CARRY**



RRA  
 ~~~~~  
 1F

Rotate Accumulator contents right one bit through Carry status.

Suppose the Accumulator contains 7A₁₆ and the Carry status is set to 1. After the instruction

RRA

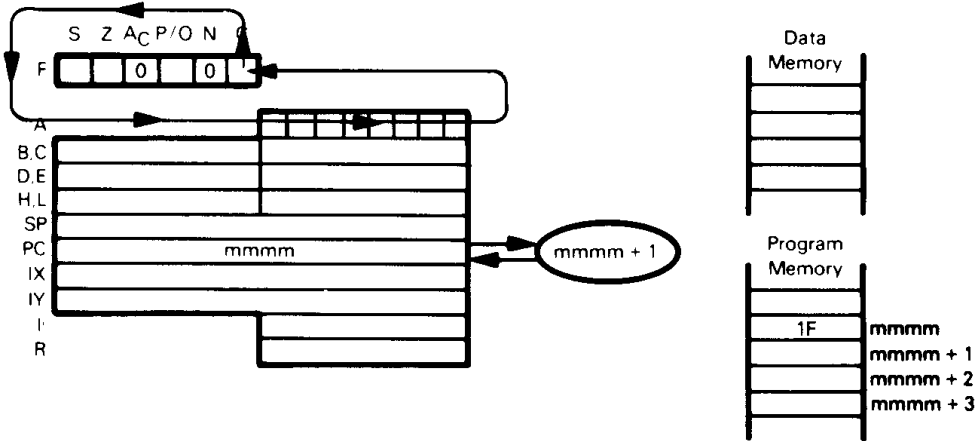
has executed, the Accumulator will contain BD₁₆ and the Carry status will be reset to 0:

<u>Before</u>		<u>After</u>	
Accumulator	Carry	Accumulator	Carry
0111 1010	1	1011 1101	0

RR (HL)
 ~~~~~  
 CB 1E

Rotate contents of memory location (specified by the contents of the HL register pair) right one bit through Carry.

**RRA — ROTATE ACCUMULATOR RIGHT THROUGH CARRY**



RRA  
 ~~~~~  
 1F

Rotate Accumulator contents right one bit through Carry status.

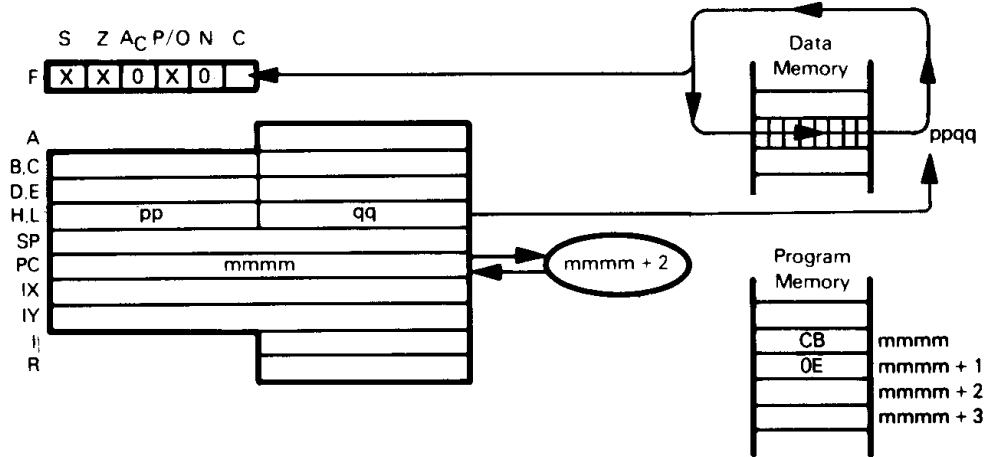
Suppose the Accumulator contains 7A₁₆ and the Carry status is set to 1. After the instruction

RRA

has executed, the Accumulator will contain BD₁₆ and the Carry status will be reset to 0:

<u>Before</u>		<u>After</u>	
Accumulator	Carry	Accumulator	Carry
0111 1010	1	1011 1101	0

RRC (HL) — ROTATE CONTENTS OF MEMORY LOCATION
RRC (IX+disp) RIGHT CIRCULAR
RRC (IY+disp)



The illustration shows execution of RRC (HL):

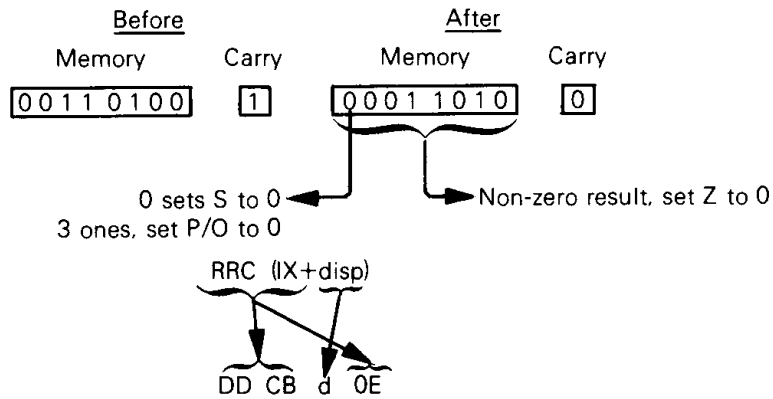
RRC (HL)
 CB OE

Rotate contents of memory location (specified by the contents of the HL register pair) right one bit circularly, copying bit 0 into the Carry status.

Suppose the HL register pair contains 4500_{16} , memory location 4500_{16} contains 34_{16} , and Carry is set to 1. After execution of

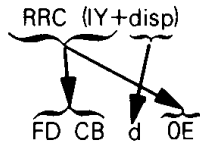
RRC (HL)

memory location 4500_{16} will contain $1A_{16}$, and Carry will be 0:



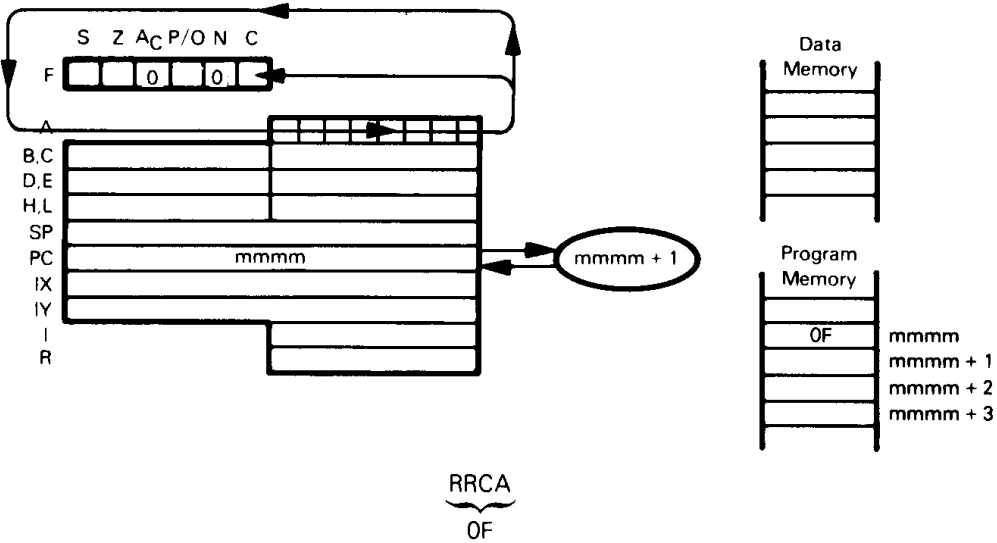
Rotate contents of memory location (specified by the sum of the contents of the IX

register and the displacement value d) right one bit circularly, copying bit 0 into the Carry status.



This instruction is identical to the RRC (IX+disp) instruction, but uses the IY register instead of the IX register.

RRCA — ROTATE ACCUMULATOR RIGHT CIRCULAR



Rotate Accumulator contents right one bit circularly, copying bit 0 into the Carry status. Suppose the Accumulator contains $7A_{16}$ and the Carry status is set to 1. After the instruction

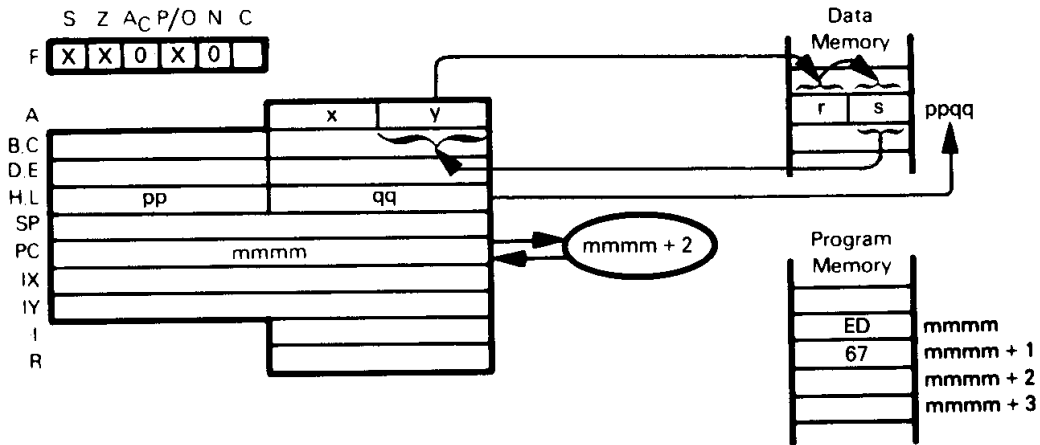
RRCA

has executed, the Accumulator will contain $3D_{16}$ and the Carry status will be reset to 0:

<u>Before</u>		<u>After</u>	
Accumulator	Carry	Accumulator	Carry
0111 1010	1	0011 1101	0

RRCA should be used as a logical instruction.

RRD — ROTATE ONE BCD DIGIT RIGHT BETWEEN THE ACCUMULATOR AND MEMORY LOCATION



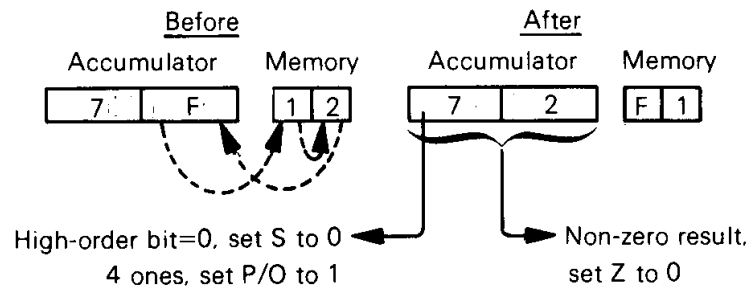
RRD
ED 67

The four high-order bits of a memory location (specified by the contents of register pair HL) are copied into the four low-order bits of the same memory location. The previous contents of the four low-order bits are copied into the four low-order bits of the Accumulator. The previous four low-order bits of the Accumulator are copied into the four high-order bits of the specified memory location.

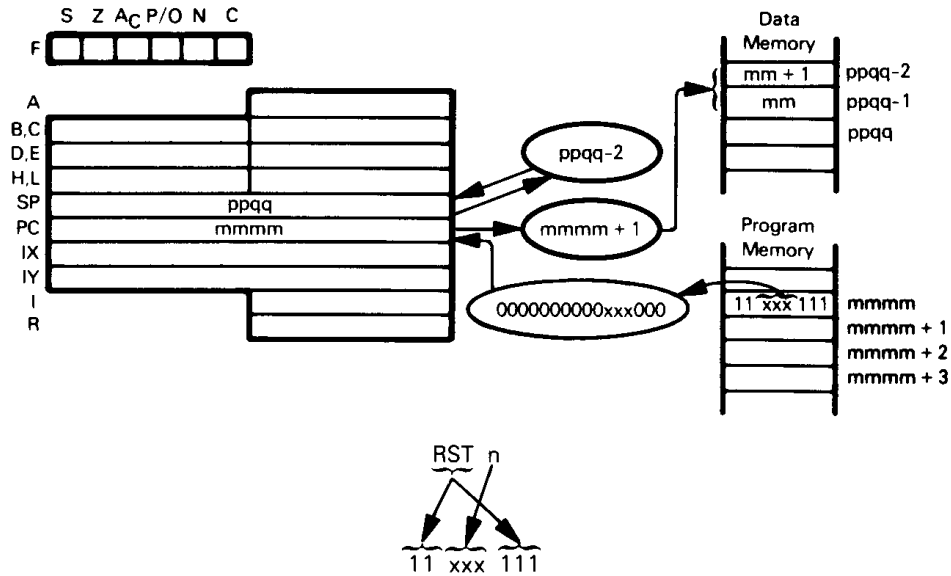
Suppose the Accumulator contains $7F_{16}$, HL register pair contains 4000_{16} , and memory location 4000_{16} contains 12_{16} . After execution of the instruction

RRD

the Accumulator will contain 72_{16} and memory location 4000_{16} will contain $F1_{16}$:



RST n — RESTART



Call the subroutine originated at the low memory address specified by n.

When the instruction

RST 18H

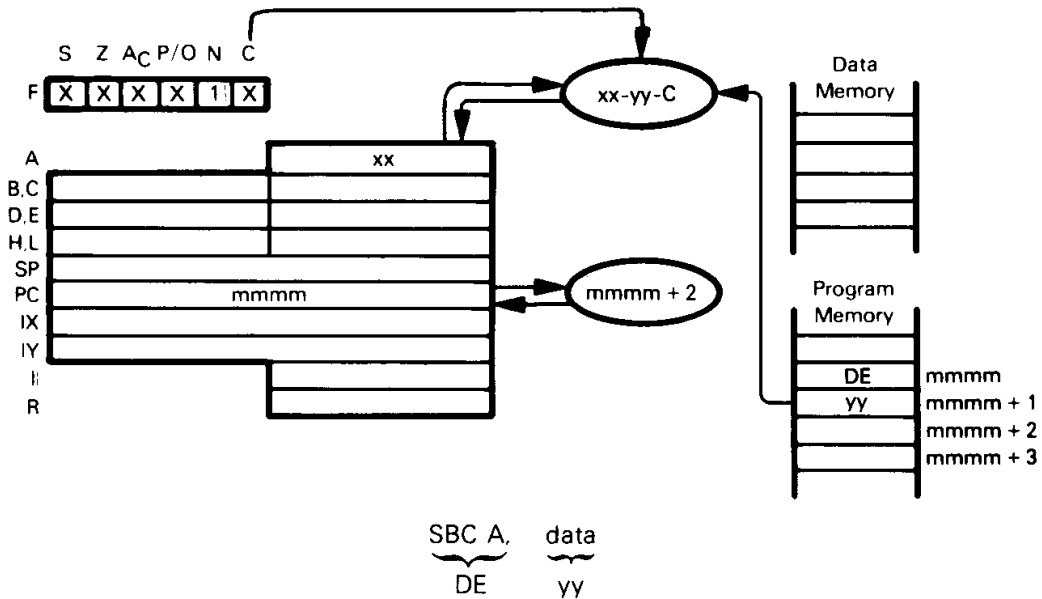
has executed, the subroutine originated at memory location 0018₁₆ is called. The previous Program Counter contents are pushed to the top of the stack.

Usually, the RST instruction is used in conjunction with interrupt processing, as described in Chapter 12.

If your application does not use all RST instruction codes to service interrupts, do not overlook the possibility of calling subroutines using RST instructions. Origin frequently used subroutines at appropriate RST addresses, and these subroutines can be called with a single-byte RST instruction instead of a three-byte CALL instruction.

**SUBROUTINE
CALL USING
RST**

SBC A,data — SUBTRACT IMMEDIATE DATA FROM ACCUMULATOR WITH BORROW



Subtract the contents of the second object code byte and the Carry status from the Accumulator.

Suppose $xx=3A_{16}$ and $\text{Carry}=1$. After the instruction

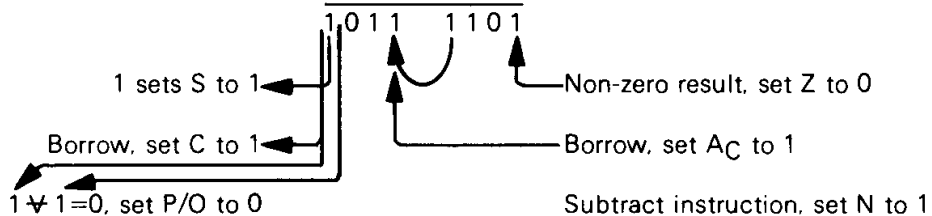
SBC A,7CH

has executed, the Accumulator will contain BD_{16} .

```

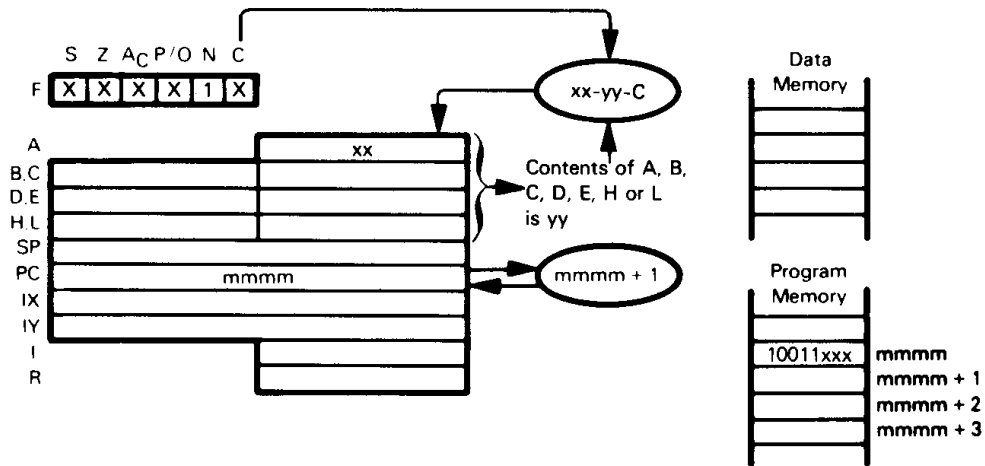
3A = 0011 1010
Twos comp of 7C = 1000 0100
Twos comp of Carry = 1111 1111

```



The Carry flag is set to 1 for a borrow and reset to 0 if there is no borrow.

SBC A,reg — SUBTRACT REGISTER WITH BORROW FROM ACCUMULATOR



SBC A, <u>reg</u>	
10011 <u>xxx</u>	
	000 for reg=B
	001 for reg=C
	010 for reg=D
	011 for reg=E
	100 for reg=H
	101 for reg=L
	111 for reg=A

Subtract the contents of the specified register and the Carry status from the Accumulator.

Suppose $xx = E3_{16}$. Register E contains $A0_{16}$, and Carry=1. After the instruction

SBC A,E

has executed, the Accumulator will contain 42_{16} .

E3 = 1 1 1 0 0 0 1 1	
Two's comp of A0 = 0 1 1 0 0 0 0 0	
Two's comp of 1 = 1 1 1 1 1 1 1 1	
0 1 0 0 0 0 1 0	

0 sets S to 0
Non-zero result, set Z to 0

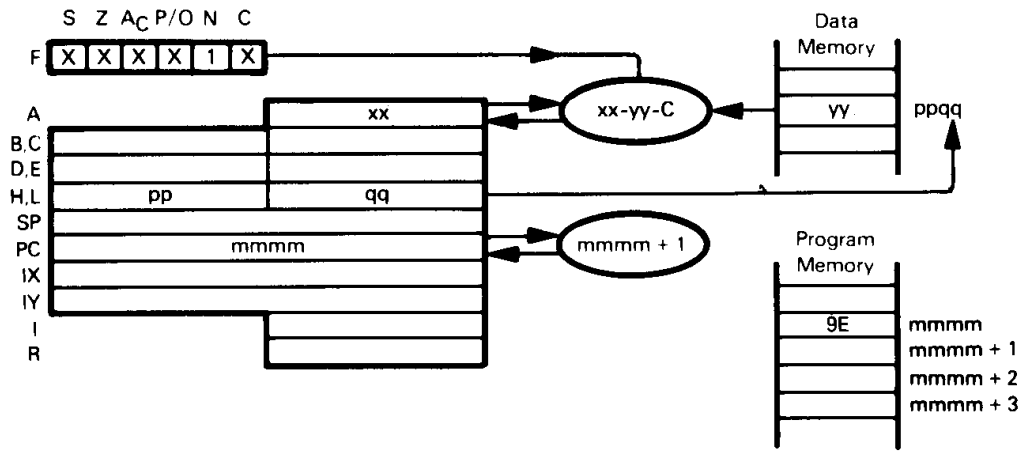
No borrow, set C to 0
No borrow, set A_C to 0

$1 \nabla 1 = 0$, set P/O to 0
Subtract instruction, set N to 1

The Carry flag is set to 1 for a borrow and reset to 0 if there is no borrow.

SBC A,(HL) —
SBC A,(IX+disp)
SBC A,(IY+disp)

SUBTRACT MEMORY AND CARRY FROM ACCUMULATOR



The illustration shows execution of SBC A,(HL):

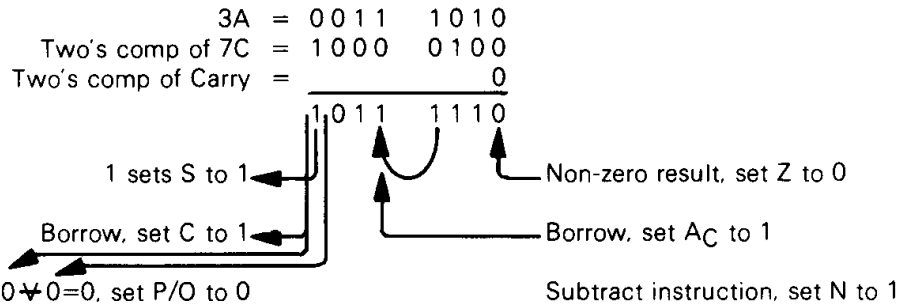
SBC A,(HL)
9E

Subtract the contents of memory location (specified by the contents of the HL register pair) and the Carry from the Accumulator.

Suppose Carry=0, ppqq=4000₁₆, xx=3A₁₆, and memory location 4000₁₆ contains 7C₁₆. After execution of the instruction

SBC A,(HL)

the Accumulator will contain BE₁₆.



The Carry flag is set to 1 for a borrow and reset to 0 if there is no borrow.

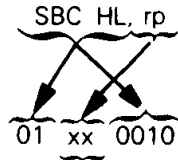
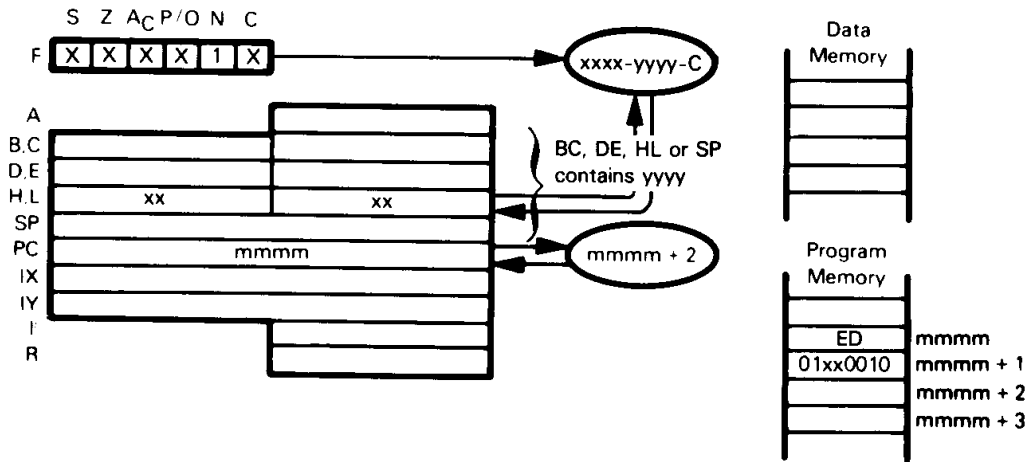
SBC A,(IX+disp)
DD 9E d

Subtract the contents of memory location (specified by the sum of the contents of the IX register and the displacement value d) and the Carry from the Accumulator.

SBC A,(IY+disp)
FD 9E d

This instruction is identical to the SBC A,(IX+disp) instruction, except that it uses the IY register instead of the IX register.

SBC HL, rp — SUBTRACT REGISTER PAIR WITH CARRY FROM H AND L



00 for rp is register pair BC
01 for rp is register pair DE
10 for rp is register pair HL
11 for rp is Stack Pointer

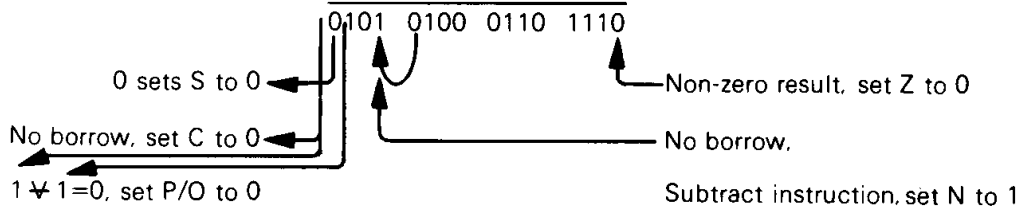
Subtract the contents of the designated register pair and the Carry status from the HL register pair.

Suppose HL contains $F4A2_{16}$, BC contains $A034_{16}$, and Carry=0. After the instruction

SBC HL,BC

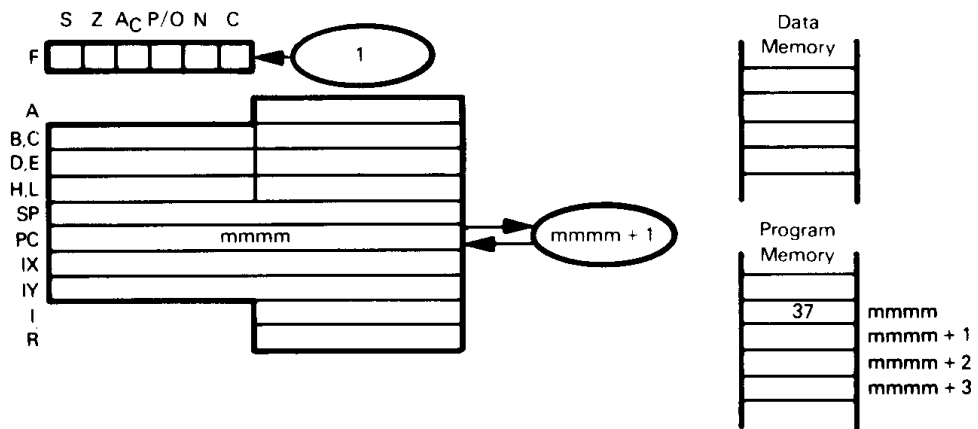
has executed, the HL register pair will contain $546E_{16}$:

Two's comp of $F4A2 = 1111\ 0100\ 1010\ 0010$
Two's comp of $A034 = 0101\ 1111\ 1100\ 1100$
Two's comp of Carry = 0



The Carry flag is set to 1 for a borrow and reset to 0 if there is no borrow.

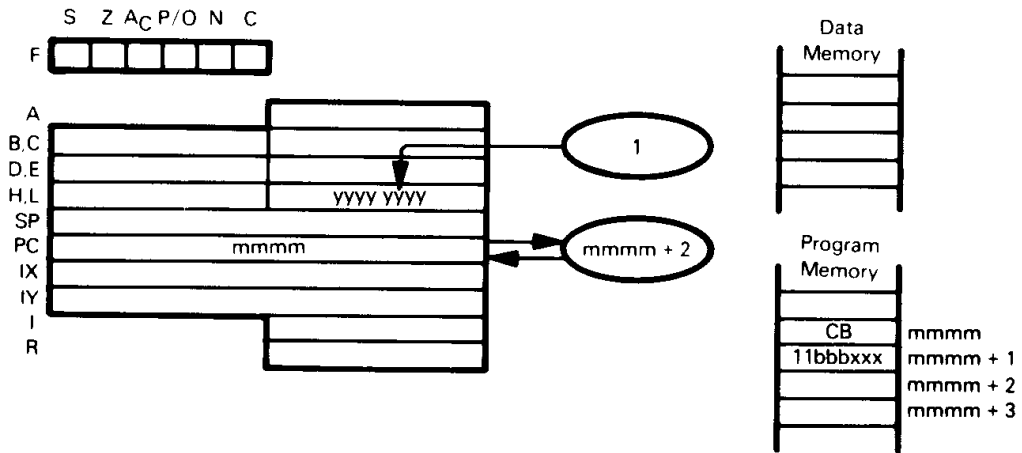
SCF — SET CARRY FLAG



SCF
37

When the SCF instruction is executed, the Carry status is set to 1 regardless of its previous value. No other statuses or register contents are affected.

SET b,reg — SET INDICATED REGISTER BIT



SET b,reg

CB 11bbb xxx
 ↓ ↓ ↓
 SET b,reg

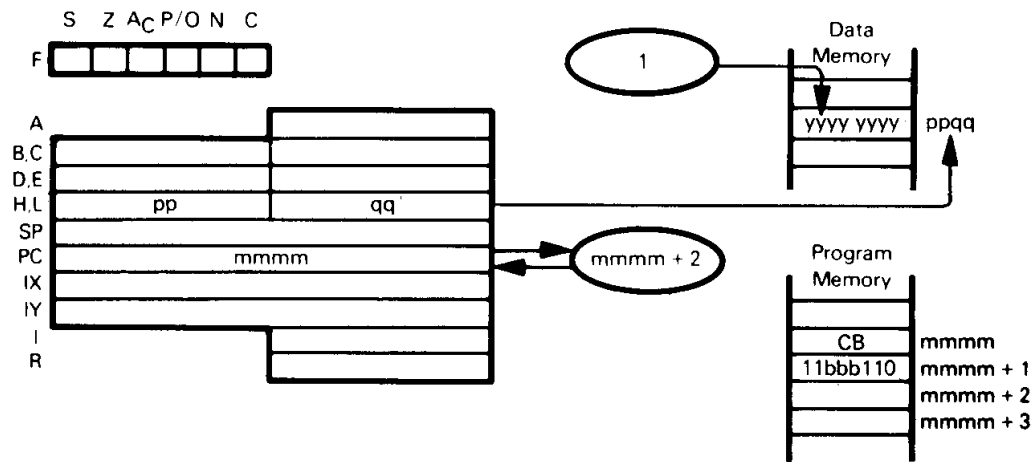
Bit	bbb	xxx	Register
0	000	000	B
1	001	001	C
2	010	010	D
3	011	011	E
4	100	100	H
5	101	101	L
6	110	111	A
7	111		

SET indicated bit within specified register. After the instruction

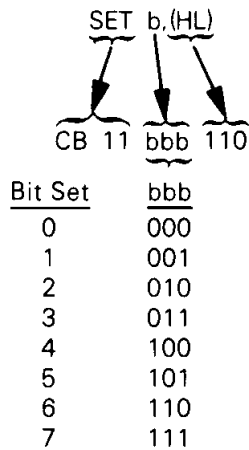
SET 2,L

has executed, bit 2 in Register L will be set. (Bit 0 is the least significant bit.)

SET b,(HL) — SET BIT b OF INDICATED MEMORY POSITION
SET b,(IX+disp)
SET b,(IY+disp)



The illustration shows execution of SET b,(HL). Bit 0 is the least significant bit.

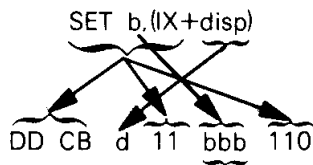


Set indicated bit within memory location indicated by HL.

Suppose HL contains 4000_{16} . After the instruction

SET 5,(HL)

has executed, bit 5 in memory position 4000_{16} will be 1.



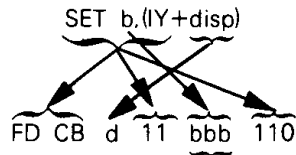
bbb is the same as in SET b,(HL)

Set indicated bit within memory location indicated by the sum of Index Register IX and displacement.

Suppose Index Register IX contains 4000_{16} . After execution of

SET 6,(IX+5H)

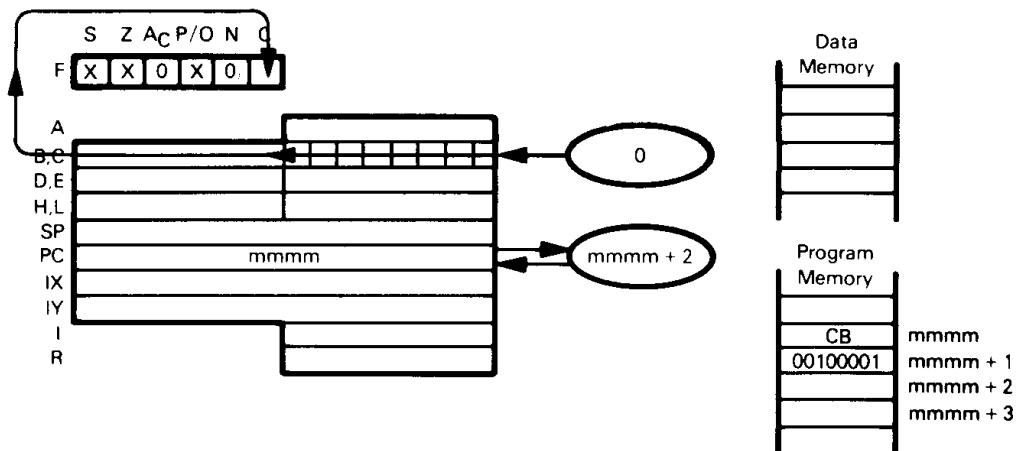
bit 6 in memory location 4005_{16} will be 1.



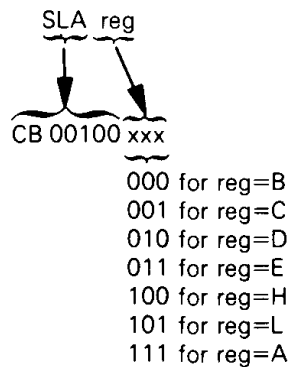
bbb is the same as in SET b.(HL)

This instruction is identical to SET b,(IX+disp), except that it uses the IY register instead of the IX register.

SLA reg — SHIFT CONTENTS OF REGISTER LEFT ARITHMETIC



The illustration shows execution of SLA C:

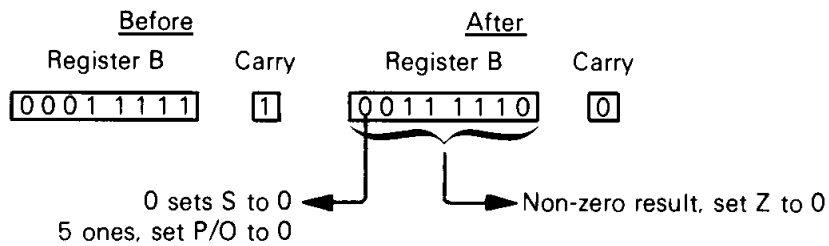


Shift contents of specified register left one bit, resetting the least significant bit to 0.

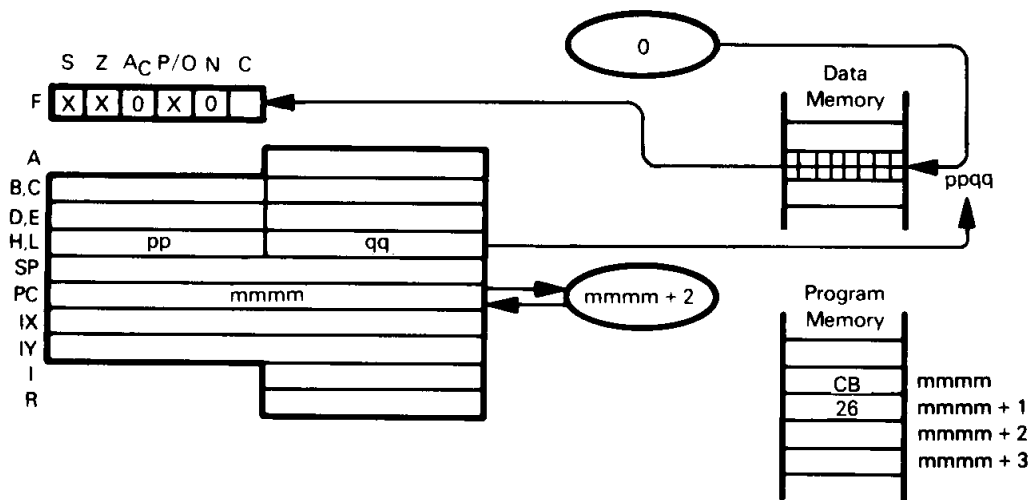
Suppose Register B contains $1F_{16}$, and Carry=1. After execution of

SLA B

Register B will contain $3E_{16}$ and Carry will be zero.



SLA (HL) — SHIFT CONTENTS OF MEMORY LOCATION
SLA (IX+disp) LEFT ARITHMETIC
SLA (IY+disp)



The illustration shows execution of SLA (HL):

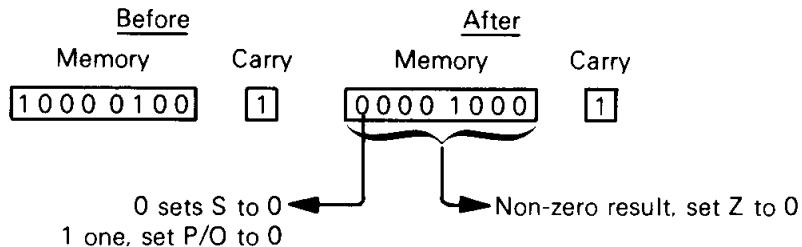
$\underbrace{\text{SLA (HL)}}_{\text{CB 26}}$

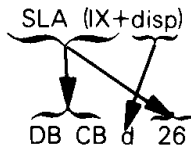
Shift contents of memory location (specified by the contents of the HL register pair) left one bit, resetting the least significant bit to 0.

Suppose the HL register pair contains 4500_{16} , memory location 4500_{16} contains 84_{16} , and Carry=0. After execution of

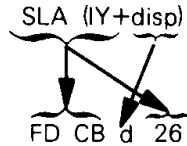
SLA (HL)

memory location 4500_{16} will contain 08_{16} , and Carry will be 1.



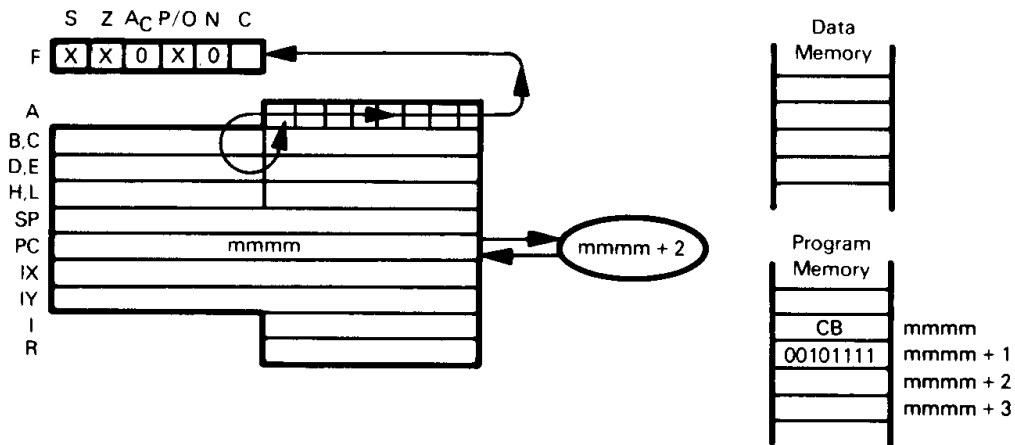


Shift contents of memory location (specified by the sum of the contents of the IX register and the displacement value d) left one bit arithmetically, resetting least significant bit to 0.

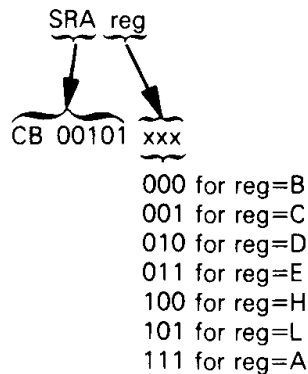


This instruction is identical to SLA (IX+disp), but uses the IY register instead of the IX register.

SRA reg — ARITHMETIC SHIFT RIGHT CONTENTS OF REGISTER



The illustration shows execution of SRA A:

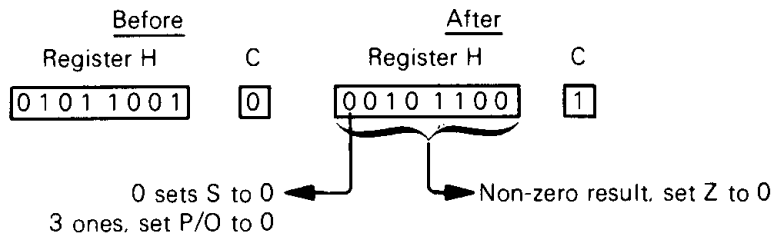


Shift specified register right one bit. Most significant bit is unchanged.

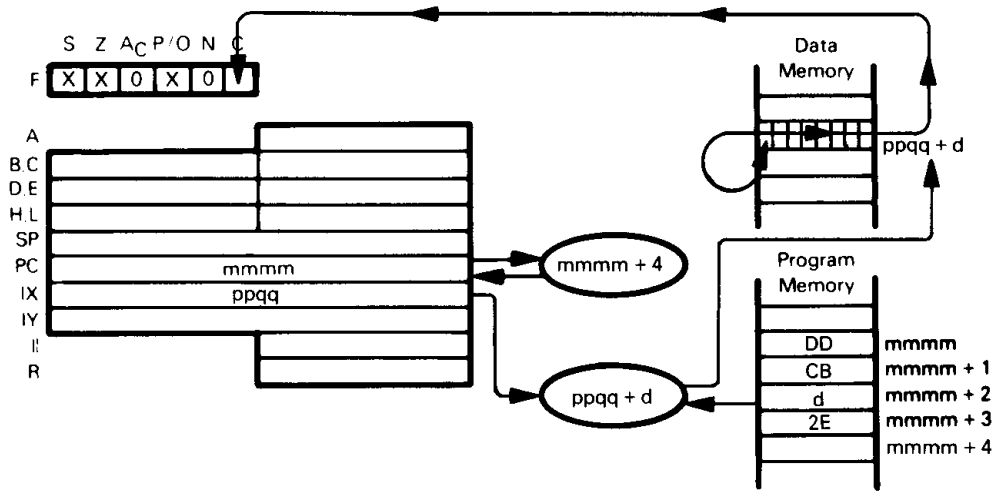
Suppose Register H contains 59_{16} , and Carry=0. After the instruction

SRA H

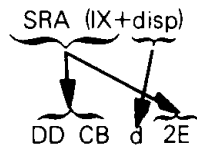
has executed, Register H will contain $2C_{16}$ and Carry will be 1.



SRA (HL) — ARITHMETIC SHIFT RIGHT CONTENTS OF
SRA (IX+disp) MEMORY POSITION
SRA (IY+disp)



The illustration shows execution of SRA (IX+disp):

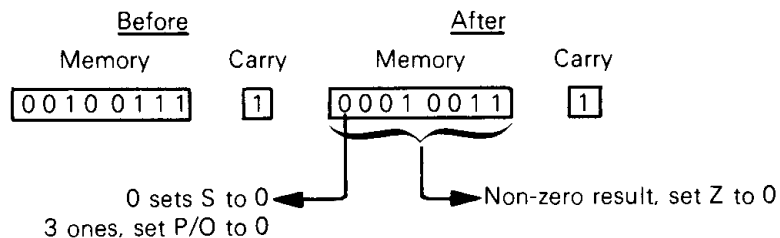


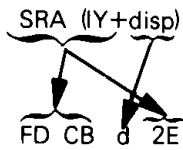
Shift contents of memory location (specified by the sum of the contents of Register IX and the displacement value d) right. Most significant bit is unchanged.

Suppose Register IX contains 3400_{16} , memory location $34AA_{16}$ contains 27_{16} , and Carry=1. After execution of

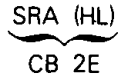
SRA (IX+0AAH)

memory location $34AA_{16}$ will contain 13_{16} , and Carry will be 1.



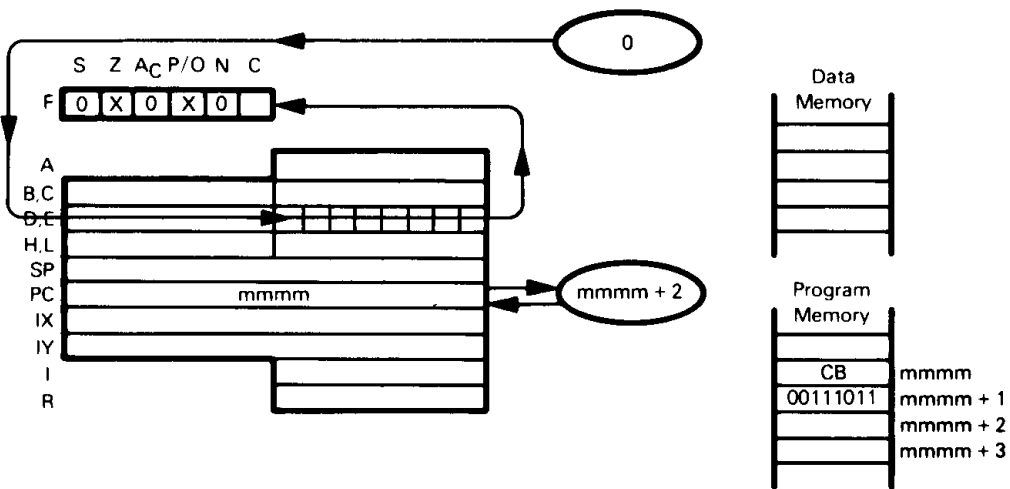


This instruction is identical to SRA (IX+disp), but uses the IY register instead of the IX register.

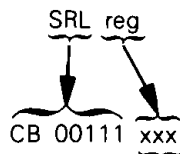


Shift contents of memory location (specified by the contents of the HL register pair) right one bit. Most significant bit is unchanged.

SRL reg — SHIFT CONTENTS OF REGISTER RIGHT LOGICAL



The illustration shows execution of SRL E:



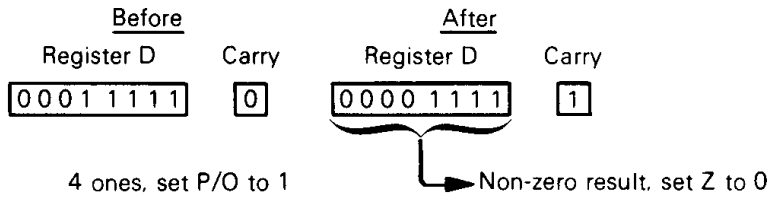
- 000 for reg=B
- 001 for reg=C
- 010 for reg=D
- 011 for reg=E
- 100 for reg=H
- 101 for reg=L
- 111 for reg=A

Shift contents of specified register right one bit. Most significant bit is reset to 0.

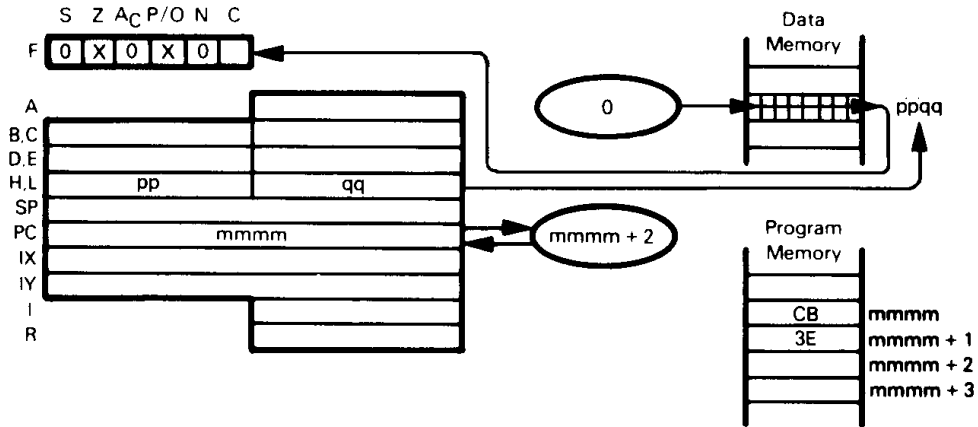
Suppose Register D contains 1F₁₆, and Carry=0. After execution of

SRL D

Register D will contain 0F₁₆, and Carry will be 1.



SRL (HL) — SHIFT CONTENTS OF MEMORY LOCATION RIGHT LOGICAL
SRL (IX+disp)
SRL (IY+disp)



The illustration shows execution of SRL (HL):

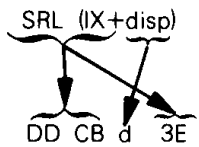
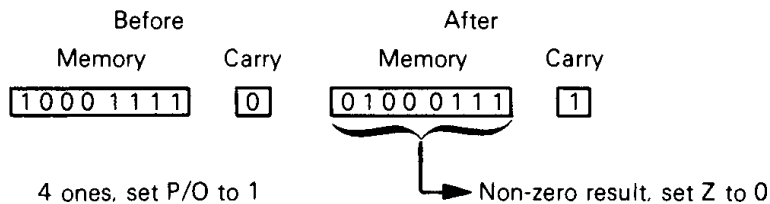
SRL (HL)
 └───┬───┘
 CB 3E

Shift contents of memory location (specified by the contents of the HL register pair) right one bit. Most significant bit is reset to 0.

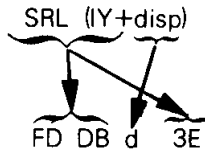
Suppose the HL register pair contains 2000_{16} , memory location 2000_{16} contains $8F_{16}$, and Carry=0. After execution of

SRL (HL)

memory location 2000_{16} will contain 47_{16} , and Carry will be 1.

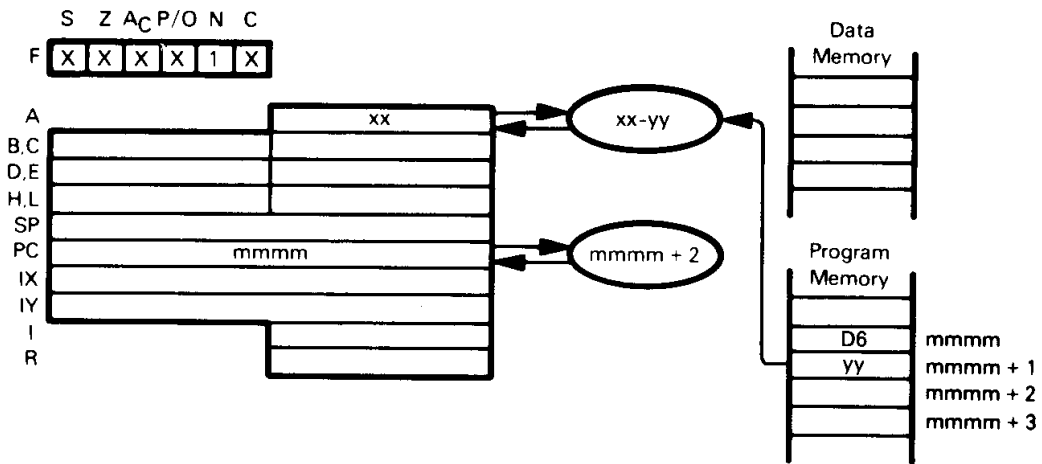


Shift contents of memory location (specified by the sum of the contents of the IX register and the displacement value d) right one bit. Most significant bit is reset to 0.



This instruction is identical to SRL (IX+disp), but uses the IY register instead of the IX register.

SUB data — SUBTRACT IMMEDIATE FROM ACCUMULATOR



SUB data
 D6 yy

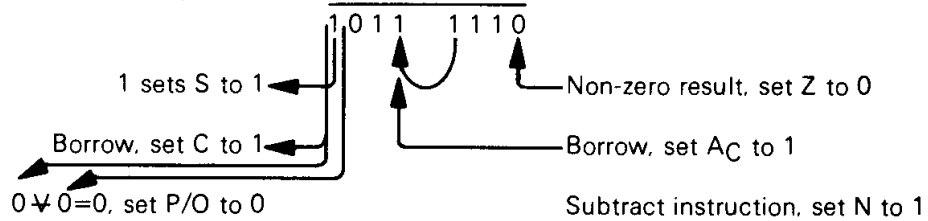
Subtract the contents of the second object code byte from the Accumulator.

Suppose $xx=3A_{16}$. After the instruction

SUB 7CH

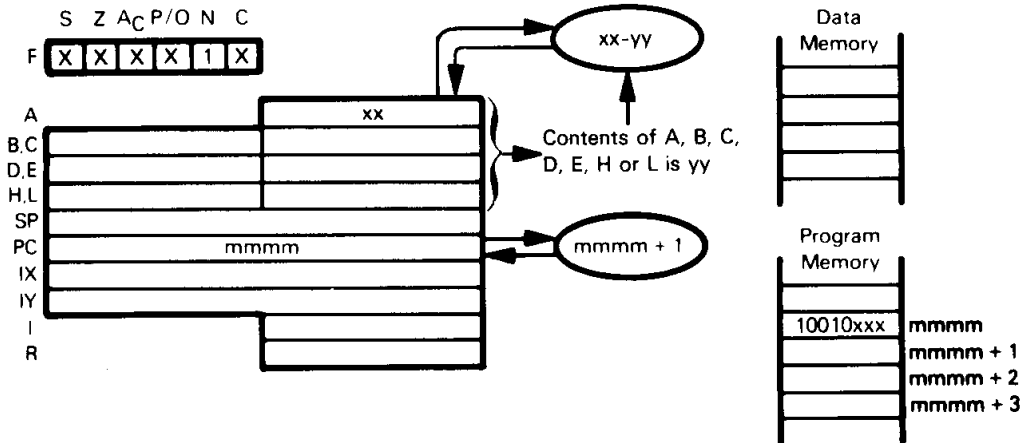
has executed, the Accumulator will contain BE_{16} .

3A = 0011 1010
 Two's comp of 7C = 1000 0100



Notice that the resulting carry is complemented.

SUB reg — SUBTRACT REGISTER FROM ACCUMULATOR



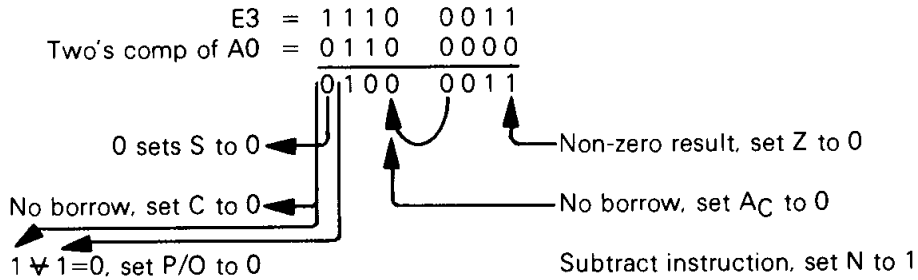
SUB	reg	
10010	xxx	
	000	for reg=B
	001	for reg=C
	010	for reg=D
	011	for reg=E
	100	for reg=H
	101	for reg=L
	111	for reg=A

Subtract the contents of the specified register from the Accumulator.

Suppose $xx=E3$ and Register H contains $A0_{16}$. After execution of

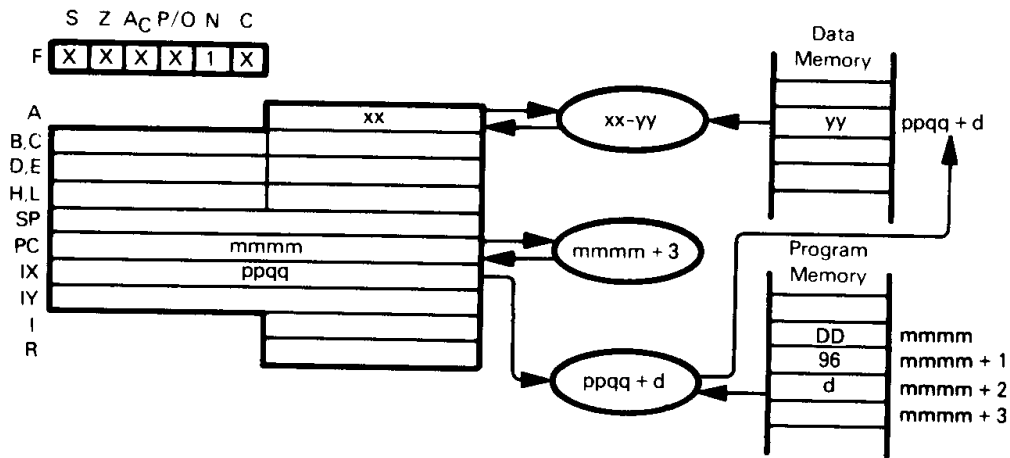
SUB H

the Accumulator will contain 43_{16} .



Notice that the resulting carry is complemented.

SUB (HL) — SUBTRACT MEMORY FROM ACCUMULATOR
SUB (IX+disp)
SUB (IY+disp)



The illustration shows execution of SUB (IX+d):

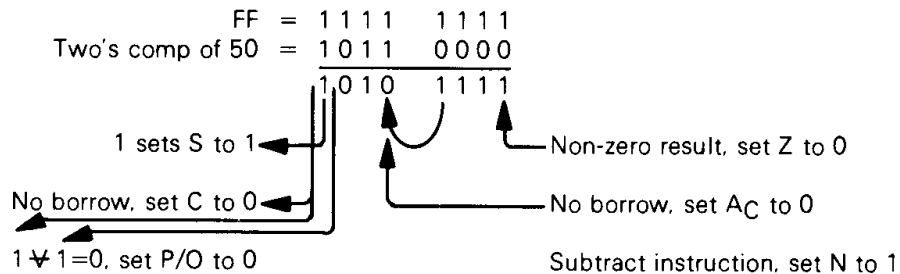
SUB (IX+disp)
 DD 96 d

Subtract contents of memory location (specified by the sum of the contents of the IX register and the displacement value d) from the Accumulator.

Suppose $ppqq=4000_{16}$, $xx=FF_{16}$, and memory location $40FF_{16}$ contains 50_{16} . After execution of

SUB (IX+0FFH)

the Accumulator will contain AF_{16} .



Notice that the resulting carry is complemented.

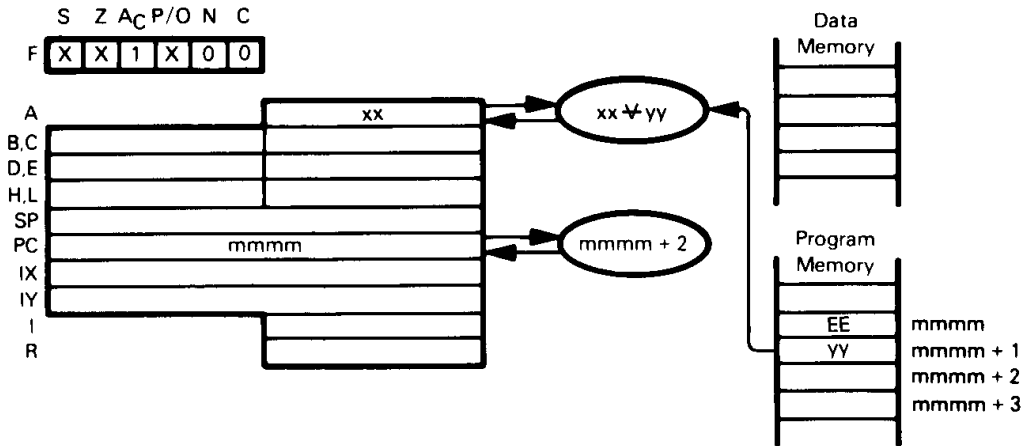
SUB (IY+disp)
 FD 96 d

This instruction is identical to SUB (IX+disp), except that it uses the IY register instead of the IX register.

SUB (HL)
 96

Subtract contents of memory location (specified by the contents of the HL register pair) from the Accumulator.

XOR data — EXCLUSIVE-OR IMMEDIATE WITH ACCUMULATOR



XOR data
EE yy

Exclusive-OR the contents of the second object code byte with the Accumulator.

Suppose $xx=3A_{16}$. After the instruction

XOR 7CH

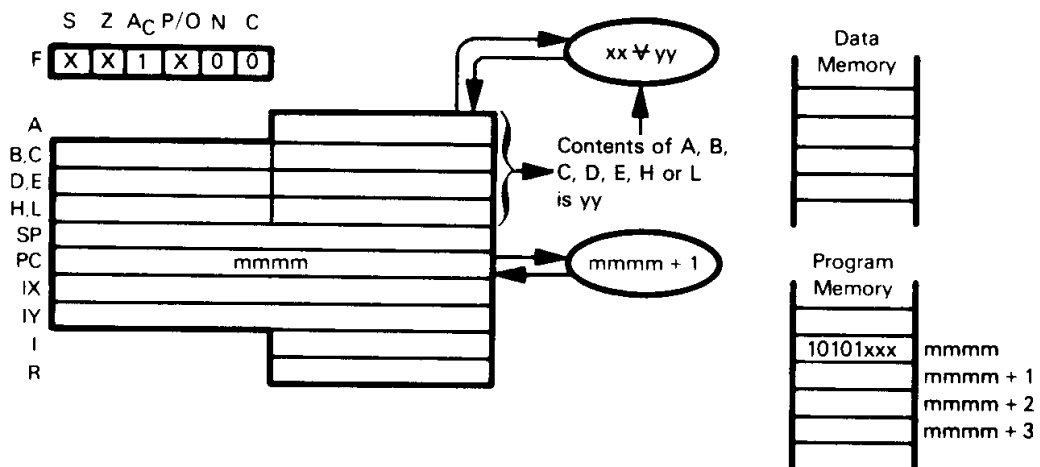
has executed, the Accumulator will contain 46_{16} .

3A =	0011	1010	
7C =	0111	1100	
	0100	0110	

0 sets S to 0
Non-zero result, set Z to 0
Three 1 bits, set P/O to 0

The Exclusive-OR instruction is used to test for changes in bit status.

XOR reg — EXCLUSIVE-OR REGISTER WITH ACCUMULATOR



XOR reg
 10101 xxx
 000 for reg=B
 001 for reg=C
 010 for reg=D
 011 for reg=E
 100 for reg=H
 101 for reg=L
 111 for reg=A

Exclusive-OR the contents of the specified register with the Accumulator.

Suppose $xx = E3_{16}$ and Register E contains $A0_{16}$. After the instruction

XOR E

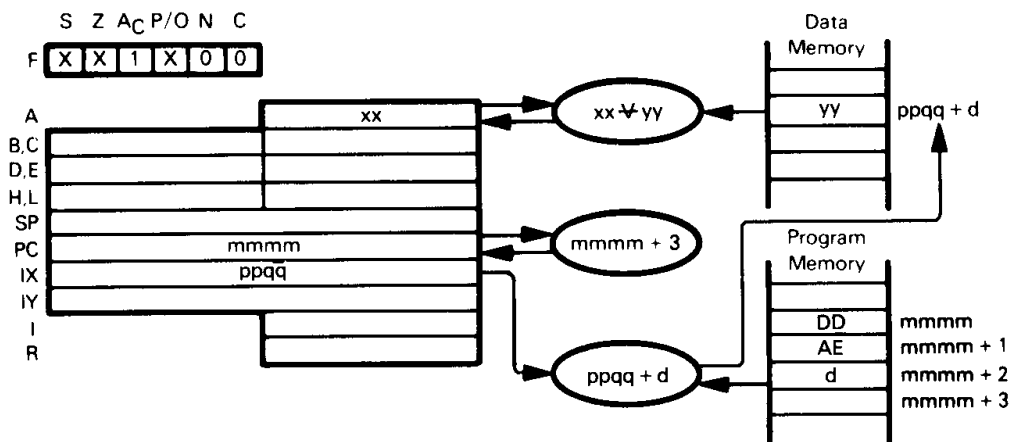
has executed, the Accumulator will contain 43_{16} .

E3 =	1 1 1 0	0 0 1 1	
A0 =	1 0 1 0	0 0 0 0	
	0 1 0 0	0 0 1 1	

0 sets S to 0 ←
 Non-zero result, set Z to 0
 Three 1 bits, set P/O to 0

The Exclusive-OR instruction is used to test for changes in bit status.

XOR (HL) — EXCLUSIVE-OR MEMORY WITH ACCUMULATOR
XOR (IX+disp)
XOR (IY+disp)



The illustration shows execution of XOR (IX+disp):

$$\underbrace{\text{XOR}}_{\text{DD AE}} \underbrace{(\text{IX}+\text{disp})}_{\text{d}}$$

Exclusive-OR contents of memory location (specified by the sum of the contents of the IX register and the displacement value d) with the Accumulator.

Suppose $xx=E3_{16}$, $ppqq=4500_{16}$, and memory location $45FF_{16}$ contains $A0_{16}$. After the instruction

$$\text{XOR (IX+OFFH)}$$

has executed, the Accumulator will contain 43_{16} .

$$\begin{array}{r} E3 = 1110 \ 0011 \\ A0 = 1010 \ 0000 \\ \hline 0100 \ 0011 \end{array}$$

0 sets S to 0

Non-zero result, set Z to 0

Three 1 bits, set P/O to 0

$$\underbrace{\text{XOR}}_{\text{FD AE}} \underbrace{(\text{IY}+\text{disp})}_{\text{d}}$$

This instruction is identical to XOR (IX+disp), except that it uses the IY register instead of the IX register.

$$\underbrace{\text{XOR (HL)}}_{\text{AE}}$$

Exclusive-OR contents of memory location (specified by the contents of the HL register pair) with the Accumulator.

8080A/Z80 COMPATIBILITY

Although the Z80 microprocessor can certainly be used on its own merits, one of its important characteristics is its compatibility with the 8080A microprocessor. This compatibility has the following features:

**8080A/Z80
COMPATIBILITY
FEATURES**

- 1) All 8080A machine language instructions are also Z80 machine language instructions.
- 2) All 8080A registers are also Z80 registers (see Table 3-6).
- 3) Almost all 8080A programs will run on a Z80, with some minor differences to be noted later.
- 4) The Z80 has instructions, registers, and other features not present on the 8080A, so Z80 programs will not generally run on 8080A processors.

Note that this compatibility does not extend to assembly language source statements since Z80 assemblers and 8080A assemblers use different operation code mnemonics. **Table 3-7 contains a list of the 8080A mnemonic codes and the corresponding Z80 codes, while Table 3-8 is the same list organized by Z80 codes.**

**8080A/Z80
ASSEMBLY
LEVEL
CONVERSION**

Readers should note the binary coding limitations that this compatibility places on the extra features of the Z80 microprocessor. The 8080A has some unused operation codes (see Table 3-9) that are used for some of the Z80's extra instructions. But there are simply not enough such codes to cover the large number of features in a simple form.

**8080A
UNUSED
OPERATION
CODES**

Thus, many of the added Z80 instructions require a 2-byte operation code. The first byte is CB, DD, ED, or FD. Note the following meanings of these codes from Table 3-9:

**2-BYTE
OPERATION
CODES**

- CB — a register or bit operation
- DD — an operation involving register IX
- ED — a miscellaneous non-8080A instruction not covered elsewhere
- FD — an operation involving register IY

The second byte of the operation code describes the actual operation to be performed.

The end result is that these multi-byte instructions execute rather slowly (and use more memory) because an additional memory access is required. The reader should be aware of this variation in execution times and try to use faster executing instructions when possible. This warning particularly applies to the extra shift instructions (RLC, RRC, RL, RR, SRA, SRL) and to instructions involving the index registers IX and IY.

**FASTER AND
SLOWER
EXECUTING
INSTRUCTIONS**

There are a few minor incompatibilities between the 8080A and the Z80. These are:

**8080A/Z80
INCOMPATIBILITIES**

- 1) The Z80 uses the P (or P/O) flag to indicate two's complement overflow after arithmetic operations. The 8080A always uses this flag for parity.
- 2) The Z80 and 8080A execute the DAA instruction differently. On the Z80, this instruction will correct decimal subtraction as well as decimal addition. On the 8080A, it will correct only decimal addition.
- 3) The Z80 rotate instructions clear the AC flag. The 8080A rotate instructions do not affect the AC flag.

Table 3-6. Register and Flag Correspondence between Z80 and 8080A

<u>Z80 Register</u>	<u>8080A Register</u>
A	A
A'	None
B	B
B'	None
C	C
C'	None
D	D
D'	None
E	E
E'	None
F	Least Significant Half of PSW
F'	None
H	H
H'	None
I	None
IX	None
IY	None
L	L
L'	None
R	None
PC	PC
SP	SP
<u>Z80 Register Pairs</u>	<u>8080A Register Pairs</u>
BC	B
DE	D
HL	H
AF	PSW
<u>Z80 Flags</u>	<u>8080A Flags</u>
C (Carry)	C (Carry)
H (Half-Carry)	AC (Auxiliary Carry)
N (Subtract)	None
P/O (Parity/Overflow)	P (Parity)
S (Sign)	S (Sign)
Z (Zero)	Z (Zero)

The Z80 is not compatible with the extra features of the 8085 microprocessor. The codes used for RIM and SIM on the 8085 are used for relative jumps (NZ and NC) on the Z80.

**8085/Z80
INCOMPATIBILITIES**

Instruction timings on the 8080A, 8085, and Z80 all differ. Programs that depend on precise instruction timings will therefore execute properly only on the processor for which they were written.

**TIMING
INCOMPATIBILITIES**

The N flag on the Z80 occupies bit 2 of the F register; the corresponding bit in the Processor Status Word of the 8080A is always a logic '1'.

Table 3-7 Correspondence between 8080A and Z80 Mnemonics

8080A Mnemonic		Z80 Mnemonic		8080A Mnemonic		Z80 Mnemonic	
ACI	data	ADC	A,data	LHLD	addr	LD	HL,(addr)
ADC	reg or M	ADC	A,reg or (HL)	LXI	rp,data16	LD	rp,data16
ADD	reg or M	ADD	A,reg or (HL)	MOV	reg,reg or M	LD	reg,reg or (HL)
ADI	data	ADD	A,data	MOV	reg or M,reg	LD	reg or (HL),reg
ANA	reg or M	AND	reg or (HL)	MVI	reg or M,data	LD	reg or (HL),data
ANI	data	AND	data	NOP		NOP	
CALL	addr	CALL	addr	ORA	reg or M	OR	reg or (HL)
CC	addr	CALL	C,addr	ORI	data	OR	data
CM	addr	CALL	M,addr	OUT	port	OUT	(port),A
CMA		CPL		PCHL		JP	(HL)
CMC		CCF		POP	pr	POP	pr
CMP	reg or M	CP	reg or (HL)	PUSH	pr	PUSH	pr
CNC	addr	CALL	NC,addr	RAL		RLA	
CNZ	addr	CALL	NZ,addr	RAR		RRA	
CP	addr	CALL	P,addr	RC		RET	C
CPE	addr	CALL	PE,addr	RET		RET	
CPI	data	CP	data	RLC		RLCA	
CPO	addr	CALL	PO,addr	RM		RET	M
CZ	addr	CALL	Z,addr	RNC		RET	NC
DAA		DAA		RNZ		RET	NZ
DAD	rp	ADD	HL,rp	RP		RET	P
DCR	reg or M	DEC	reg or (HL)	RPE		RET	PE
DCX	rp	DEC	rp	RPO		RET	PO
DI		DI		RRC		RRCA	
EI		EI		RST	n	RST	n
HLT		HALT		RZ		RET	Z
IN	port	IN	A,(port)	SBB	reg or M	SBC	A,reg or (HL)
INR	reg or M	INC	reg or (HL)	SBI	data	SBC	A,data
INX	rp	INC	rp	SHLD	addr	LD	(addr),HL
JC	addr	JP	C,addr	SPHL		LD	SP,HL
JM	addr	JP	M,addr	STA	addr	LD	(addr),A
JMP	addr	JP	addr	STAX	B or D	LD	(BC) or (DE),A
JNC	addr	JP	NC,addr	STC		SCF	
JP	addr	JP	P,addr	SUB	reg or M	SUB	reg or (HL)
JNZ	addr	JP	NZ,addr	SUI	data	SUB	data
JPE	addr	JP	PE,addr	XCHG		EX	DE,HL
JPO	addr	JP	PO,addr	XRA	reg or M	XOR	reg or (HL)
JZ	addr	JP	Z,addr	XRI	data	XOR	data
LDA	addr	LD	A,(addr)	XTHL		EX	(SP),HL
LDAX	B or D	LD	A,(BC) or (DE)				

Table 3-8. Correspondence between Z80 and 8080A Mnemonics

Z80 Mnemonic		8080A Mnemonic		Z80 Mnemonic		8080A Mnemonic	
ADC	A,data	ACI	data	INC	rp	INX	rp
ADC	A,(HL)	ADC	M	INC	xy	---	---
ADC	A,reg	ADC	reg	INC	(xy + disp)	---	---
ADC	A,(xy + disp)	---	---	IND	---	---	---
ADC	HL,rp	---	---	INDR	---	---	---
ADD	A,data	ADI	data	INI	---	---	---
ADD	A,(HL)	ADD	M	INIR	---	---	---
ADD	A,reg	ADD	reg	JP	addr	JMP	addr
ADD	A,(xy + disp)	---	---	JP	C,addr	JC	addr
ADD	HL,rp	DAD	rp	JP	(HL)	PCHL	---
ADD	IX,pp	---	---	JP	M,addr	JM	addr
ADD	IY,rr	---	---	JP	NC,addr	JNC	addr
AND	data	ANI	data	JP	NZ,addr	JNZ	addr
AND	(HL)	ANA	M	JP	P,addr	JP	addr
AND	reg	ANA	reg	JP	PE,addr	JPE	addr
AND	(xy + disp)	---	---	JP	PO,addr	JPO	addr
BIT	b,(HL)	---	---	JP	Z,addr	JZ	addr
BIT	b,reg	---	---	JP	xy	---	---
BIT	b,(xy + disp)	---	---	JR	C,disp	---	---
CALL	addr	CALL	addr	JR	disp	---	---
CALL	C,addr	CC	addr	JR	NC,disp	---	---
CALL	M,addr	CM	addr	JR	NZ,disp	---	---
CALL	NC,addr	CNC	addr	JR	Z,disp	---	---
CALL	NZ,addr	CNZ	addr	LD	A,(addr)	LDA	addr
CALL	P,addr	CP	addr	LD	A,(BC) or (DE)	LDAX	B or D
CALL	PE,addr	CPE	addr	LD	A,I	---	---
CALL	PO,addr	CPO	addr	LD	A,R	---	---
CALL	Z,addr	CZ	addr	LD	(addr),A	STA	addr
CF	data	CMC	---	LD	(addr),BC or DE	---	---
CP	(HL)	CPI	data	LD	(addr),HL	SHLD	addr
CP	reg	CMP	M	LD	(addr),SP	---	---
CP	(xy + disp)	CMP	reg	LD	(addr),xy	---	---
CPD	---	---	---	LD	(BC) or (DE),A	STAX	B or D
CPDR	---	---	---	LD	BC or DE,(addr)	---	---
CPI	---	---	---	LD	HL,(addr)	LHLD	addr
CPIR	---	---	---	LD	(HL),data	MVI	M,data
CPL	---	CMA	---	LD	(HL),reg	MOV	M,reg
DAA	---	DAA	---	LD	I,A	---	---
DEC	(HL)	DCR	M	LD	R,A	---	---
DEC	reg	DCR	reg	LD	reg,data	MVI	reg,data
DEC	rp	DCX	rp	LD	reg,(HL)	MOV	reg,M
DEC	xy	---	---	LD	reg,reg	MOV	reg,reg
DEC	(xy + disp)	---	---	LD	reg,(xy + disp)	---	---
DI	---	DI	---	LD	rp,data16	LXI	rp,data16
DJNZ	disp	---	---	LD	SP,(addr)	---	---
EI	---	EI	---	LD	SP,HL	SPHL	---
EX	AF,AF'	---	---	LD	SP,xy	---	---
EX	DE,HL	XCHG	---	LD	xy,data16	---	---
EX	(SP),HL	XTHL	---	LD	xy,(addr)	---	---
EX	(SP),xy	---	---	LD	(xy + disp),data	---	---
EXX	---	---	---	LD	(xy + disp),reg	---	---
HALT	---	HLT	---	LDD	---	---	---
IM	m	---	---	LDDR	---	---	---
IN	A,(port)	IN	port	LDI	---	---	---
IN	reg,(C)	---	---	LDIR	---	---	---
INC	(HL)	INR	M	NEG	---	---	---
INC	reg	INR	reg	NOP	---	NOP	---
				OR	data	ORI	data

--- indicates that there is no corresponding instruction.

Table 3-8. Correspondence between Z80 and 8080A Mnemonics (Continued)

Z80 Mnemonic		8080A Mnemonic		Z80 Mnemonic		8080A Mnemonic	
OR	(HL)	ORA	M	RR	(HL)	—	
OR	reg	ORA	reg	RR	reg	—	
OR	(xy + disp)	—		RR	(xy + disp)	—	
OTDR		—		RRA		RAR	
OTIR		—		RRC	(HL)	—	
OUT	(C),reg	—		RRC	reg	—	
OUT	(port),A	OUT	port	RRC	(xy + disp)	—	
OUTD		—		RRCA		RRC	
OUTI		—		RRD		—	
POP	pr	POP	pr	RST	n	RST	n
POP	xy	—		SBC	A,data	SBI	data
PUSH	pr	PUSH	pr	SBC	A,(HL)	SBB	M
PUSH	xy	—		SBC	A,reg	SBB	reg
RES	b,(HL)	—		SBC	A,(xy + disp)	—	
RES	b,reg	—		SBC	HL,rp	—	
RES	b,(xy + disp)	—		SCF		STC	
RET		RET		SET	b,(HL)	—	
RET	C	RC		SET	b,reg	—	
RET	M	RM		SET	b,(xy + disp)	—	
RET	NC	RNC		SLA	(HL)	—	
RET	NZ	RNZ		SLA	reg	—	
RET	P	RP		SLA	(xy + disp)	—	
RET	PE	RPE		SRA	(HL)	—	
RET	PO	RPO		SRA	reg	—	
RET	Z	RZ		SRA	(xy + disp)	—	
RETI		—		SRL	(HL)	—	
RETN		—		SRL	reg	—	
RL	(HL)	—		SRL	(xy + disp)	—	
RL	reg	—		SUB	data	SUI	data
RL	(xy + disp)	—		SUB	(HL)	SUB	M
RLA		RAL		SUB	reg	SUB	reg
RLC	(HL)	—		SUB	(xy + disp)	—	
RLC	reg	—		XOR	data	XRI	data
RLC	(xy + disp)	—		XOR	(HL)	XRA	M
RLCA		RLC		XOR	reg	XRA	reg
RLD		—		XOR	(xy + disp)	—	

— indicates that there is no corresponding instruction

Table 3-9. Unused 8080A Operation Codes and Their Z80 Meanings

8080A Operation Code	Z80 Use
08	EX AF,AF'
10	DJNZ disp
18	JR disp
20 (RIM on 8085)	JR NZ,disp
28	JR Z,disp
30 (SIM on 8085)	JR NC,disp
38	JR C,disp
CB	BIT, RES, RL, RLC, RR, RRC, SET, SLA, SRA, SRL
D9	EXX
DD	All instructions involving Register IX.
ED	ADC HL,rp LD A,i NEG
	CPD LD A,R OTDR
	CPDR LD (addr),rp OTIR
	CPI LD I,A OUT (C),reg
	CPIR LD R,A OUTD
	IM m LD rp,(addr) OUTI
	IN reg,(C) LDD RETI
	IND LDDR RETN
	INDR LDI RLD
	INI LDIR RRD
	INIR SBC HL,rp
FD	All instructions involving Register IY.