TX-0 COMPUTER
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE 39, MASSACHUSETTS

M-5001-27-1

TX-0 INSTRUCTION CODE

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I. ABBREVIATIONS

AC : ACcumulator

LR : Live Register

XR : Index Register

PC : Program Counter

MBR : Memory Buffer Register

PFR : Program Flag Register

PETR: PhotoElectric Tape Reader

TAC : Toggle Switch Accumulator

TBR : Toggle Switch Buffer Register

LP1 : Light Pen FF

LP2 : Light Gun FF

C(AC): "Contents of AC"

$\longrightarrow$: "Replaces"

$\overline{X}$: Complement of X:

X	$\overline{X}$
0	1
1	0

$\cap$: Intersect; and; logical product.

$\cup$: Union; inclusive or; logical sum.

$\wedge$: Partial add; inequivalence; exclusive or.

mod n: Modulo n ; y = x mod n means x = kn + y for some integer k, $0 \leq y \leq n-1$.

x	y	$x \cap y$	$x \cup y$	$x \wedge y$
0	0	0	0	0
0	1	0	1	1
1	0	0	1	1
1	1	1	1	0

II. ADDRESSABLE COMMANDS

(A) STORE CLASS

MNEMONIC	OCTAL VALUE	OPERATION	SYMBOLIC DESCRIPTION
STO y	000000 + y	Store	C(AC)→C(y)
Place the contents of AC in register y. The previous contents of y are destroyed. Contents of AC remain unchanged.			
SIR y	100000 + y	Store Live Register	C(LR)→C(y)
The contents of LR are placed in register y. The previous contents of Y are destroyed. Contents of LR are unchanged.			

II. ADDRESSABLE COMMANDS

(B) ADD CLASS

MNEMONIC	OCTAL VALUE	OPERATION	SYMBOLIC DESCRIPTION
ADD y	200000 + y	* Add the contents of register y to AC. Contents of y are unchanged.	C(y) + C(AC)→C(AC) *
LLR y	300000 + y	Load Live Register	C(Y)→C(IR)
The contents of register y replace the previous contents of LR. Contents of y are unchanged. Previous contents of LR are destroyed.			

* One's complement addition of 18-bit quantities.

II. ADDRESSABLE COMMANDS

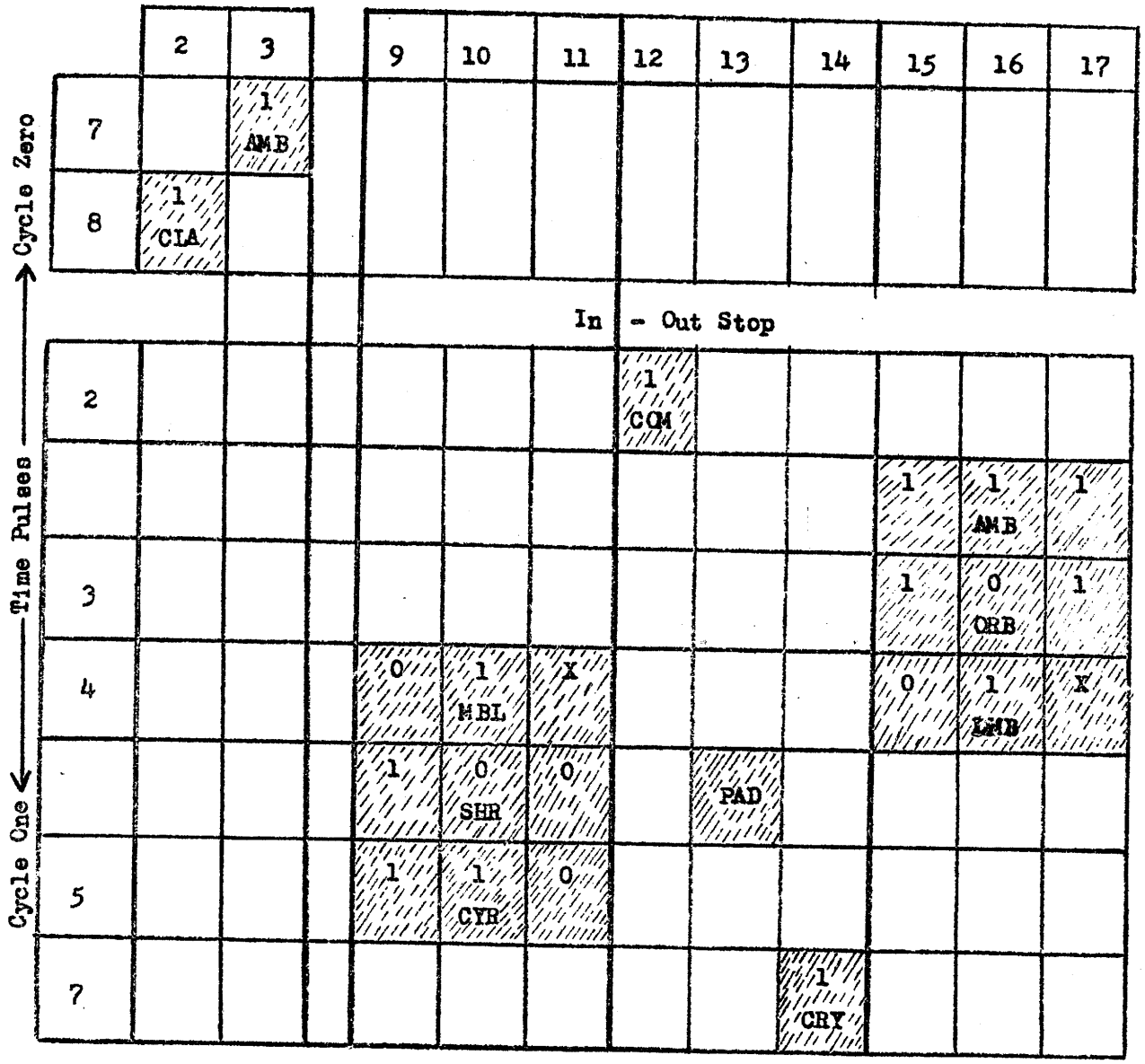
(C) TRANSFER CLASS

MNEMONIC	OCTAL VALUE	OPERATION	CONDITIONS AND SYMBOLIC DESCRIPTION	
			$y \rightarrow C(PC)$	$C(PC)+1 \rightarrow C(PC)$
TRN y	400000 + y	Transfer on Negative AC	$C(AC)_0 = 1$	$C(AC)_0 = 0$
If the AC bit 0 is a one, take next instruction from register y. Otherwise, take next instruction in sequence.				
TRA y	500000 + y	Transfer	Always	Never
The next instruction is taken from Register y.				

III. OPERATE CLASS COMMANDS

(A) MICRO ORDER CHART

Instruction bits



X - Bit may be either zero or one

III. OPERATE CLASS COMMANDS

(B) IN OUT GROUP CHART

Instruction bits 6, 7, and 8

Instruction bits 4 and 5	000	001	010	011	100	101	110	111
00	NOP	1.1 TAC	1.2 TBR	1.1 PEN	** SEL	SPARE	1.2 RPF	1.6 SPF
01	IOS EX0	IOS EX1	IOS EX2	IOS EX3	IOS EX4	IOS EX5	IOS EX6	IOS EX7
10	** CPY	* IOS R1L	IOS DIS	* IOS R3L	IOS PRT	IOS	IOS P6H	IOS P7H
11	1.8 HLT	0.6 CLL	0.6 CLR	SPARE	SPARE	SPARE	SPARE	SPARE

Any of the commands enclosed in this boarder may be used together with the micro commands listed in the preceding chart.

* R1L and R3L will remain operable until the new magnetic and paper tape control logic is completed and operating reliably.

** See Memo M-5001-28, "Programming for the Magnetic Tape System."

III. OPERATE CLASS COMMANDS

(C) MICRO-ORDERS

MNEMONIC	ACTION	SYMBOLIC DESCRIPTION
CLA	CLear AC	$0 \rightarrow C(AC)$
AMB	transfer AC contents to MBR	$C(AC) \rightarrow C(MBR)$
MBL	transfer MBR contents to LR	$C(MBR) \rightarrow C(LR)$
LMB	transfer LR contents to MBR. Note: LMB & MBL, if used simultaneously, interchange C(LR) and C(MBR).	$C(LR) \rightarrow C(MBR)$
CYR	CYcle AC contents Right one binary position. (AC bit 17 goes to AC bit 0)	$C(AC)_i \rightarrow C(AC)_j$ $i = 0, 1, \ldots, 17$ $j = (+1) \bmod 18$
SHR	shift AC contents right one binary position (AC bit 0 is unchanged, bit 17 is lost)	$C(AC) \rightarrow C(AC)_{i+1}$, $i = 0, 1, 2, \ldots 16$
ANB	ANd (logical product) LR contents into MBR.	$C(LR) \cap C(MBR) \rightarrow C(MBR)$
ORB	OR (logical sum) LR contents into MBR.	$C(LR) \cup C(MBR) \rightarrow C(MBR)$
COM	COMplement AC	$\overline{C(AC)} \rightarrow C(AC)$
PAD	Partial ADd MBR to AC (for each MBR one, complement the corresponding AC bit.)	$C(MBR) \wedge C(AC) \rightarrow (AC)$
CRY	A CarRY digit is a ONE if in the next least significant digit, either AC = 0 and MBR = 1, or AC = 1 and carry digit = 1. The carry digits so determined are partial added to the AC by CRY. PAD and CRY used together give a full one's complement addition of C(MBR) to C(AC).	$CRY\ [C(AC), C(MBR)] = C(AC) \wedge C \rightarrow AC$. $C_i = [C(MBR)_j \cap \overline{C(AC)_j}],$ $\cup [C_j \cap C(AC)_j]$ $i = 0, 1, \ldots, 17$ $j = (i+1) \bmod 18$. $CRY\ [C(AC) \wedge C(MBR), C(MBR)]$ $= C(AC) + C(MBR)$

III. OPERATE CLASS COMMANDS

(D) IN-OUT GROUP COMMANDS WHICH CAN BE USED WITH MICRO-ORDERS SPECIFIED BY BITS 9-17.

OCTAL CODE	MNEMONIC	ACTION	CYCLE AND TIME PULSE
631000	CLL	CLear Left 9 bits of AC	0.6
632000	CLR	CLear Right 9 bits of AC	0.6
607000	SPF	Set Program Flag contents from MBR	1.6
606000	RPF	Read Program Flag contents into MBR. (inclusive or)	1.2
602000	TBR	transfer TBR contents to MBR. (inclusive or)	1.2
601000	TAC	transfer TAC ones to AC (inclusive or)	1.1
603000	PEN	set AC bit 0 from light PEN FF, and AC bit 1 from light gun FF. (FF's contain one if pen or gun saw displayed point). Then clear both light pen and light gun FF's.	1.1
620000	CPY	CoPY synchronizes transmission of information between in-out equipment and computer	**
621000	R1L	Read ONE Line of tape from PETR into AC bits 0, 3, 6, 9, 12, 15 with CYR before read	IOS
623000	R3L	Read THREE Lines of tape from PETR into AC bits 0, 3, 6, 9, 12, 15, with CYR before each read	IOS
622000	DIS	DISplay a point on scope (AC bits 0-8 specify X coordinate, AC bits 9-17 specify Y coordinate) NOTE: Scope coordinate (0,0) is at center of scope	IOS
626000	P6H	Punch one SIX-bit line of Flexo tape (without seventh hole) from AC bit 2, 5, 8, 11, 14, 17. NOTE: Lines without seventh hole are ignored by PETR	IOS

OCTAL CODE	MNEMONIC	ACTION	TIME PULSE
627000	P7H	same as P6H, but with SEVENTH hole	IOS
610000 through 617000	EX0 through EX7	operate user's EXTernal equipment	IOS
600000	NOP	perform No in-out group OPeration	
630000	HLT	HaLT the computer (chime sounds).	1.8

IV. OPERATE CLASS INSTRUCTIONS RECOGNIZED BY MACRO AND FLIT

MNEMONIC	OCTAL VALUE	OPERATION
opr	600000	No operation.
cla	700000	Clear entire AC to +0.
lro	600200	Clear LR to +0.
cal	700200	Clear AC and LR to +0.
*xro	600001	Clear XR to +0.
*cax	700001	Clear AC and XR to +0.
com	600040	Complement the AC.
clc	700040	Clear and complement: set AC to -0.
amz	640050	Add minus zero to AC.
cyl	640030	Cycle AC left one place.
cyr	600600	Cycle AC right one place
shr	600400	Shift accumulator right one place, bit 0 remains unchanged.
alr	640200	Place accumulator contents in live register.
alo	640220	ALR, then set AC to +0.
alc	640260	ALR, then set AC to -0.
all	640230	ALR, then cycle AC left once.
*axr	640001	Place AC contents in XR.
*axo	640021	AXR, then set AC to +0.
*axc	640061	AXR, then set AC to -0.
*alx	640031	AXR, then cycle AC left once.
*arx	640601	AXR, then cycle AC right once.
lac	700022	Place LR in AC.
lcc	700062	Place complement of LR in AC.
laz	700072	Add LR contents to Minus zero in AC.
lad	600032	Add LR to AC.
lpd	600022	Logical exclusive or of AC and LR is placed in AC. (partial add)
lcd	600072	Contents of LR minus those of AC are placed in AC.
cry	600012	Carry the contents of AC according to bits of LR. Result of this operation is same as if contents of LR were added to exclusive or of AC and LR. PAD followed by CRY is equivalent to LAD.
lal	700012	Place LR in AC cycled left once.
*lar	700622	Place LR in AC cycled right once.

* Not yet in operation

MNEMONIC	OCTAL VALUE	OPERATION
*xac	700120	Place index register in accumulator.
*xcc	700160	Place complement of XR in accumulator.
*xad	600130	Add index register to accumulator.
*xcd	600170	Contents of XR minus those of AC are placed in AC.
*xal	700110	XAC, then cycle AC left once.
ial	740222	Interchange AC and LR.
iad	640232	Interchange and add: AC contents are placed in the LR and the previous contents of the LR are added to AC.
*lxr	600003	Place LR in XR.
*xlr	600300	Place XR in LR.
*ixl	600303	Interchange XR and LR.
*rax	640203	Place LR in XR, then place AC in LR.
*rxa	700322	Place LR in AC, then place XR in LR.
ana	740027	Logical and of AC and LR is placed in AC.
anl	640207	Logical and of AC and LR is placed in LR.
ano	740207	ANL, then clear AC.
ora	740025	Logical or of AC and LR is placed in AC.
orl	640205	Logical or of AC and LR is placed in LR.
oro	740205	ORL, then clear AC.
hlt	630000	Stops computer.
cll	631000	Clear left half of AC to zero.
clr	632000	Clear right half of AC.
cpf	607000	The program flag register is cleared.
spf	647000	Place AC in program flag register.
rpf	706020	The program flag register is placed in AC.
tac	701000	Contents of test accumulator are placed in AC.
tbr	702020	Contents of test buffer register are placed in MBR.
dis	622000	Display point on CRT corresponding to contents of AC.
dso	662020	DIS, then clear AC.
pen	603000	Contents of light pen and light cannon flip-flops replace contents of AC bits 0 and 1. The flip-flops are cleared.

* Not yet in operation

MNEMONIC	OCTAL VALUE	OPERATION
*typ	625000	Read one character from on-line flexowriter into LR bits 12 through 17.
prt	624000	Print one on-line flexo character from bits 2, 5, etc. of AC.
pnt	624600	PRT, then cycle AC right once to set up another character.
pno	664020	PRT, then clear AC.
p6h	626600	Punch one line of paper tape; 6 holes from bits 2, 5, etc. of AC then cycle right once.
p6o	666020	p6h then clear AC.
p6s	726000	Clear AC and punch a line of blank tape.
p6b	766020	Punch a line of blank tape but save AC.
p7h	627600	Same as p6h, but punch 7th hole.
p7o	667020	p7h then clear AC.
rlc	721000	Read one line paper tape into AC bits 0, 3, etc.
rlr	721600	RlC, then cycle AC right once.
r3c	723000	Read three lines of paper tape.
rew+n	604010+n	Rewind tape unit n.
wrs+n	604014+n	Select tape unit n for writing a record.
rds+n	604004+n	Select tape unit n for reading a record.
bsr+n	604000+n	Backspace tape unit n by one record.
cpy	620000	Transmits information between the live register and selected input-output unit.

* Not yet in operation