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

M-5001-27

THE TX-0 INSTRUCTION CODE

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ABBREVIATIONS:

AC   :   ACcumulator

LR   :   Live Register

PC   :   Program Counter

MBR :   Memory Buffer Register.
          (Cleared on time pulse 1.1)

PETR: PhotoElectric Tape Reader

TAC :   Toggle Switch Accumulator

TBR :   Toggle Switch Buffer Register

LPO :   Light Pen FF

LPL :   Light Gun FF

C(AC):   "Contents of AC"

     :   "Replaces"

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

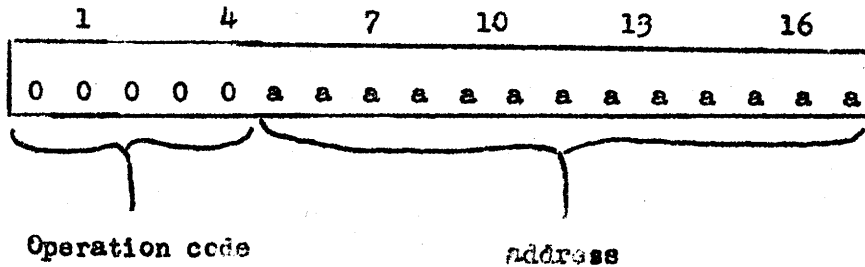| x	$\overline{X}$
0	1
1	0

$\cap$:   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
                    integr k. $0 \leq k \leq n - 1$.

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

ADDRESSABLE INSTRUCTIONS

Instruction Bits

1			4		7		10		13			16
0	0	0	0	0	a a a	a a	a a	a a a	a a	a a

Operation code   address

SYMBOL	OCTAL VALUE	ACTION
sto x	000000 + x	STOre the contents of the AC in register x. $\overline{C(AC)} \rightarrow C(x)$, $C(PC)+1 \rightarrow C(PC)$.
slr x	100000 + x	Store the contents of the LR in register x. $C(LR) \rightarrow C(x)$, $C(PC)+1 \rightarrow C(PC)$.
add x	200000 + x	ADD the contents of register x to the AC. $C(x) + C(AC) \rightarrow C(AC)$, $C(PC)=1 \rightarrow C(PC)$
llr x	300000 + x	Load the LR with the contents of register x. $C(x) \rightarrow C(LR)$, $C(PC)+1 \rightarrow C(PC)$
tra x	500000 + x	TRAnsfer control to register x. $x \rightarrow C(PC)$
trn x	400000 + x	TRansfer to register x if C(AC) is Negative. $AC_0 = 1$: $x \rightarrow C(PC)$, $AC_0 = 0$: $C(PC)+1 \rightarrow C(PC)$.

OPERATE MICRO COMMANDS

MNEMONIC	ACTION	SYMBOLIC DESCRIPTION
CLL	CLear Left 9 bits of AC	$0 \rightarrow C(AC)$ bits 0-8
CLR	CLear Right 9 bits of AC	$0 \rightarrow C(AC)$ bits 9-17
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).	$CRY\left[C(AC), C(MBR)\right]$ $= C(AC) \wedge C \rightarrow AC.$ $C_i = \left[C(MBR)_j \cap \overline{C(AC)}_j\right]$ $\cup \left[C_j \cap C(AC)_j\right].$ $i = 0, 1, \ldots, 17$ $j = (i+1) \bmod 18.$ $CRY\left[C(AC) \wedge C(MBR), C(MBR)\right]$ $= C(AC) + C(MBR)$
CYR	CYcle AC contents Right one binary position. (AC bit 17 goes to AC bit 0)	$C(AC)_i \rightarrow C(AC)_j$ $i = 0, 1, \ldots, 17$ $j = (i+1) \bmod 18$
SHR	shift AC contents right one binary position (AC bit 0 is unchanged, bit 17 is lost)	$C(AC)_i \rightarrow C(AC)_{i+1}.$ $i = 0, 1, 2, \ldots 16$
ANL	AND (logical product) MBR contents into Live register.	$C(MBR) \cap C(LR) \rightarrow C(LR).$
ORL	OR (logical sum) MBR contents into Live register	$C(MBR) \cup C(LR) \rightarrow C(LR).$
AMB IMB TBR MIR	transfer AC contents to MBR transfer LR contents to MBR transfer TBR contents to MBR. (inclusive or) transfer MBR contents to LR	$C(AC) \rightarrow C(MBR)$ $C(LR) \rightarrow C(MBR)$ $C(TBR) \cup C(MBR) \rightarrow C(MBR)$ $C(MBR) \rightarrow C(LR)$
TAC	transfer TAC ONES to AC (inclusive or)	$C(TAC) \cup C(AC) \rightarrow C(AC)$
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.	$C(LP1) \rightarrow C(AC)_0.$ $C(LP2) \rightarrow C(AC)_1.$ $0 \rightarrow C(LP1), 0 \rightarrow C(LP2)$

OPERATE MICRO COMMANDS---IN-OUT ORDERS

MNEMONIC	ACTION	SYMBOLIC DESCRIPTION
R1L	Read ONE Line of tape from PETR into AC bits 0, 3, 6, 9, 12, 15, with CYR before read	
R3L	Read THREE Lines of tape from PETR into AC bits 0, 3, 6, 9, 12, 15, with CYR before each read.	
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	
P6H	Punch one SIX-bit line of Flexo tape (without seventh hole) from AC bits 2, 5, 8, 11, 14, 17. NOTE: Lines without seventh hole are ignored by PETR	
P7H	same as P6H, but with SEVENTH hole	
HLT	HaLT the computer (chime sounds).	
EXO through EX7	operate users EXTernal equipment	

Bit numbers: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

X COORDINATE — Y COORDINATE

Left-side labels: ACCUMULATOR (INPUT-OUTPUT), OCTAL DIGIT DIVISION, BIT NUMBERS, PEN, DIS, PRT, P6H, P7H, R1L, R3L, LP0 LP1

Mnemonics in grid: CLL, CIR, QD0, QD1, QD2, PEN, COM, TAC, AMB, TBR, LMB, MLR, ORL, ANL, PAD, SHR, CYR, CRY, QD3

Notes:
[AMB occurs before COM]

MLR & LMB used together interchange C(LR) & C(MBR)

[Do not use PAD with SHR or CYR]

TIMING: (cycle) (time pulse) — 0.8, IN OUT STP, 1.1, 1.2, 1.3, 1.4, 1.7, 1.8

IN-OUT GROUP (BITS 4-8)				
	QD0	QD1 QD2	QD3	
0	NOP EKO	-	HLT	-
1	EX1 RLL	-	-	-
2	EX2 DIS	-	-	-
3	EX3 R3L	-	-	-
4	EX4 PNT	-	-	-
5	EX5	-	-	-
6	EX6 P6H	-	-	-
7	EX7 P7H	-	-	-

SYMBOLIC OPERATE INSTRUCTIONS

SYMBOLIC OPERATE INSTRUCTIONS PRESENTLY RECOGNIZED BY THE MACRO CONVERSION PROGRAM

SYMBOL	OCTAL VALUE	DESCRIPTION--Micro commands used are enclosed in ( )
cll	700000	(CLL) clear left half of AC. $0 \rightarrow C(AC)$ bits 0-8
clr	640000	(CLR) clear right half of AC. $0 \rightarrow C(AC)$ bits 9-17
cla	740000	(CLL, CLR) clear AC. $0 \rightarrow C(AC)$
clc	740040	(CLL, CLR, COM) clear and complement AC. $\overline{0} \rightarrow C(AC)$
lro	600200	(MLR) clear LR to zero (MBR cleared at 1.1). $0 \rightarrow C(LR)$
cal	740200	(CLL, CLR, MLR) clear AC and LR. $0 \rightarrow C(LR)$, $0 \rightarrow C(AC)$
alr	600201	(AMB, MLR) transfer AC contents to LR. $C(AC) \rightarrow C(LR)$
ala	600221	(AMB, MLR, PAD) ALR, then clear AC. $C(AC \rightarrow C(LR)$, $(0 \rightarrow C(AC)$
alc	600261	(AMB, MLR, COM, PAD) ALR, then CLC. $C(AC) \rightarrow C(LR)$, $0 \rightarrow C(AC)$
anl	600305	(AMB, ANL) AND AC to LR. $C(AC) \cap C(LR) \rightarrow C(LR)$
ana	600325	(AMB, ANL, PAD) ANL, then clear AC. $C(AC) \cap C(LR) \rightarrow C(LR)$, $0 \rightarrow C(AC)$
orl	600105	(AMB, ORL) OR AC to LR. $C(AC) \cup C(LR) \rightarrow C(LR)$
ora	600125	(AMB, ORL, PAD) ORL, then clear AC. $C(AC) \cup C(LR) \rightarrow C(LR)$, $0 \rightarrow C(AC)$
lac	740022	(CLL, CLR, IMB, PAD) transfer LR contents to AC. $C(LR) \rightarrow C(AC)$
lcc	740062	(CLL, CLR, IMB, PAD, COM) LAC and complement. $C(LR) \rightarrow C(AC)$
lad	600032	(IMB, PAD, CRY) LR add to AC. $C(LR) + C(AC) \rightarrow C(AC)$
lpd	600022	(IMB, PAD) LR partial add to AC. $C(LR) \wedge C(AC) \rightarrow C(AC)$
cry	600012	(IMB, CRY) LR carry to AC. $CRY[C(AC), C(LR)] \rightarrow C(AC)$.
com	60040	(COM). complement AC. $C(AC) \rightarrow C(AC)$
cyl	600031	(AMB, PAD, CRY) cycle AC left. $C(AC)_i \rightarrow C(AC)_j$
cyr	600600	(CYR) cycle AC right. $C(AC)_j \rightarrow C(AC)_i$. $i = (j+1) \bmod 18$, $j = 0, 1, \ldots, 17$
shr	600400	(SHR) shift AC right. $C(AC)i \rightarrow C(AC) i+1$. $i = 0, 1, \ldots, 16$
amz	600051	(AMB, COM, CRY) add AC to minus zero. $\overline{0} + C(AC) \rightarrow C(AC)$

SYMBOL	OCTAL VALUE	DESCRIPTION--Micro commands used are enclosed in ( )
hlt	630000	(HLT) halt computer.
opr	600000	(--) no operation will be performed.
rlr	761600	(CLL, CLR, R1L, CYR) Read one line and cycle Right.
rlc	761000	(CLL, CLR, R1L) Read one Character.
r3c	763000	(CLL, CLR, R3L) Read three Lines.
dis	722000	(DIS) Display.
dsa	722021	(DIS, AMB, PAD). Display and clear AC.
dsc	722061	(DIS, AMB, COM, PAD) Display and CLC.
prt	624000	(PRT). Print one flexo character.
pnt	624600	(PRT, CYR) Print one flexo character and cycle right, in preparation to print the next.
pna	624021	(PRT, AMB, PAD) PRT and clear AC.
pnc	624061	(PRT, AMB, COM, PAD) PRT and CLC.
p6h	626600	(P6H, CYR) Punch six holes and cycle right.
p6a	626021	(P6H, AMB, PAD). P6H and clear AC.
p6s	766000	(CLL, CLR, P6H) Punch six spaces (feed one line of blank tape), 0→C(AC)
p7h	627600	(P7H, CYR) Punch seven holes and cycle right.
p7a	627021	(P7H, AMB, PAD) Punch seven holes and clear AC.
pen	600100	(PEN) Read LP FF's, then clear them.
tac	740004	(CLL, CLR, TAC) Read TAC (toggle AC) into cleared AC.
tbr	740023	(CLL, CLR, TBR, PAD) Read TBR (toggle MBR) into cleared AC.