DIGITAL COMPUTER LABORATORY
UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

THE ILLIAC MINIATURE MANUAL

by
John Halton

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ILLIAC ORDER CODE

T ⇒	0[1]	1[2]	2[3]	3[3]	4	5
V						
0	$(AQ)'=2^{n}AQ$	$(AQ)'=2^{-n}AQ$	\$. $C'=n_R$	\$. If $A\geq 0$, $C'=n_R$	$N'=A$	$Q'=N$
1	$A'=0$ then 00	$A'=0$ then 10	Like 31	$A'=0$. \$. $C'=n_R$	$N'=A'=0$	$A'=0$ then 50
2	Like 00	Like 10	$C'=n_R$	If $A\geq 0$, $C'=n_R$	$(n_R)'_a=(A_R)_a$	Like 50
3	Like 01	Like 11	Like 33	$A'=0$. $C'=n_R$	$A'=0$. $(n_R)'_a=0$	Like 51
4	Like 00	Like 10	\$. $C'=n_L$	\$. If $A\geq 0$, $C'=n_L$	Like 40	Like 50
5	Like 01	Like 11	Like 35	$A'=0$. \$. $C'=n_L$	Like 41	Like 51
6	Like 00	Like 10	$C'=n_L$	If $A\geq 0$, $C'=n_L$	$(n_L)'_a=(A_L)_a$	Like 50
7	Like 01	Like 11	Like 37	$A'=0$. $C'=n_L$	$A'=0$. $(n_L)'_a=0$	Like 51
9	$A'=\frac{1}{2}$ then 00	$A'=\frac{1}{2}$ then 10	Like 39	$A'=\frac{1}{2}$. \$. $C'=n_R$	$N'=A'=\frac{1}{2}$	$A'=\frac{1}{2}$ then 50
S	Like 09	Like 19	Like 3S	$A'=\frac{1}{2}$. $C'=n_R$	$A'=\frac{1}{2}$. $(n_R)'_a=0$	Like 59
J	Like 09	Like 19	Like 3J	$A'=\frac{1}{2}$. \$. $C'=n_L$	Like 49	Like 59
F	Final Stop	...	...	...	...	...
L	Like 09	Like 19	Like 3L	$A'=\frac{1}{2}$. $C'=n_L$	$A'=\frac{1}{2}$. $(n_L)'_a=0$	Like 59

T ⇒	6[4]	7[5]	8	9	K
V					
0	...	$(AQ)'=-Q.N+2^{-39}A$	Read n bits[6]	...	$A'=A-Q-2^{-39}$
1	...	$(AQ)'=-Q.N$	$A'=0$ then 80[6]	5-H Input [10]	$A'=-Q-2^{-39}$
2	...	$(AQ)'=-Q.\lvert N\rvert+2^{-39}A$	Punch n bits[7]	L Output[11]	$A'=A-\lvert Q+2^{-39}\rvert$
3	...	$(AQ)'=-Q.\lvert N\rvert$	$A'=0$. Punch 0	...	$A'=-\lvert Q+2^{-39}\rvert$
4	...	$(AQ)'=Q.N+2^{-39}A$	...	...	$A'=A+Q+2^{-39}$
5	...	$(AQ)'=Q.N$	$A'=D$[8]	...	$A'=Q+2^{-39}$
6	$Q'=AQ/N$	$(AQ)'=Q.\lvert N\rvert+2^{-39}A$	$D'=A$[9]	Select Output[12]	$A'=A+\lvert Q+2^{-39}\rvert$
7	$A'=0$ then 66	$(AQ)'=Q.\lvert N\rvert$	$A'=D'=0$[9]	...	$A'=\lvert Q+2^{-39}\rvert$
9	...	$(AQ)'=-Q.N+2^{-40}$	$A'=\frac{1}{2}$ then 80[6]	...	$A'=\frac{1}{2}-Q-2^{-39}$
S	...	$(AQ)'=-Q.\lvert N\rvert+2^{-40}$	$A'=\frac{1}{2}$ then 82[7]	...	$A'=\frac{1}{2}-\lvert Q+2^{-39}\rvert$
J	...	$(AQ)'=Q.N+2^{-40}$	Like 85[8]	...	$A'=\frac{1}{2}+Q+2^{-39}$
L	$A'=\frac{1}{2}$ then 66	$(AQ)'=Q.\lvert N\rvert+2^{-40}$	$A'=\frac{1}{2}$ then 86[9]	...	$A'=\frac{1}{2}+\lvert Q+2^{-39}\rvert$

NOTATION. Primes indicate register contents after operation T: first (type)digit. V: second (variant) digit. AQ: the 79-bit number, $a_0, a_1, a_2, \ldots, a_{39}, q_1, \ldots, q_{39}$ (omitting q_0): where A is the 40-bit number $a_0, a_1, \ldots, a_{39}$, and Q is $q_0, q_1, \ldots, q_{39}$, a_0 and q_0 being 2's complement sign-digits. \$: Machine ~~stops~~ if black switch on OBEY. Note that V's described as "..." result in hang up or incorrect results and should be avoided. If V = 8,K,N,F, machine stops. C: control (location of next instruction). n: number in the address-part (ten least-significant bits) of order being obeyed. $\underline{n}_R$, $\underline{n}_L$: right and left-hand orders in location n. N: The 40-bit number in location n. $\underline{A}_R$, $\underline{A}_L$: right and left-hand orders in accumulator, treated as an order-pair. $(\ldots)_a$: address-part (ten least-significant bits) of the order ... D: contents of specified drum-location. Read and punch refer to 5-hole teleprinter-tape, i.e., Input and Output.

T ⇒ V	S	J	F	L
0	$A'=A-Q$	$Q'=Q$ and N (13	$A'=A-N-2^{-39}$	$A'=A-N$
1	$A'=-Q$	$A'=0$. $Q'=Q$ and N (13	$A'=-N-2^{-39}$	$A'=\ -N$
2	$A'=A-\lvert Q\rvert$	Like J0	$A'=A-\lvert N+2^{-39}\rvert$	$A'=A-\lvert N\rvert$
3	$A'=-\lvert Q\rvert$	Like J1	$A'=-\lvert N+2^{-39}\rvert$	$A'=-\lvert N\rvert$
4	$A'=A+Q$	Like J0	$A'=A+N+2^{-39}$	$A'=A+N$
5	$A'=Q$	Like J1	$A'=N+2^{-39}$	$A'=N$
6	$A'=A+\lvert Q\rvert$	Like J0	$A'=A+\lvert N+2^{-39}\rvert$	$A'=A+\lvert N\rvert$
7	$A'=\lvert Q\rvert$	Like J1	$A'=\lvert N+2^{-39}\rvert$	$A'=\lvert N\rvert$
9	$A'=\frac{1}{2}-Q$	$A'=\frac{1}{2}$. $Q'=Q$ and N (13	$A'=\frac{1}{2}-N-2^{-39}$	$A'=\frac{1}{2}-N$
S	$A'=\frac{1}{2}-\lvert Q\rvert$	Like J9	$A'=\frac{1}{2}-\lvert N+2^{-39}\rvert$	$A'=\frac{1}{2}-\lvert N\rvert$
J	$A'=\frac{1}{2}+Q$	Like J9	$A'=\frac{1}{2}+N+2^{-39}$	$A'=\frac{1}{2}+N$
F	...	...	Prog. Check Stop	...
L	$A'=\frac{1}{2}+\lvert Q\rvert$	Like J9	$A'=\frac{1}{2}+\lvert N+2^{-39}\rvert$	$A'=\frac{1}{2}+\lvert N\rvert$

Notes. 1) If n=0, machine stops. n interpreted modulo 64. $a'_0=a_1$, $a'_1=a_2$, ..., $a'_{39}=q_1$, $q'_1=q_2$, ... , $q'_{39}=0$, q_0 unchanged. (Repeat n times.)

2) If n=0, machine stops. n interpreted modulo 64. $a'_0=a_0$, $a'_1=a_0$, ... , $a'_{39}=a_{38}$, $q'_1=a_{39}$, ... , $q'_{39}=q_{38}$, q_0 unchanged. (Repeat n times.)

3) After $; black switch to START, order obeyed; white switch to EXECUTE, FETCH, and RUN, C' = ... becomes C' = next (except that $C'=n_R$ becomes $C'=\text{next}_R$).

4) Quotient in Q rounded by forcing $q_{39}=1$. Residue in A. If initially $\lvert A\rvert>\lvert N\rvert$, or if $\lvert A\rvert=\lvert N\rvert$ and $A\geq 0$, machine stops after dividing.

5) All multiplications leave $q'_0=0$.

6) n must be divisible by 4. AQ is shifted left 4 places; a'_{36} to a'_{39} become the 4 least-significant bits on one line of 5-hole tape. If a hole is punched in the most-significant (5th hole) position on any line of the tape, the line is passed over. (Repeat n/4 times.)

7) n must be divisible by 4. a_0 to a_3 are punched in the 4 least-significant positions on one line of 5-hole tape; then shift AQ left 4 places. (Repeat n/4 times.)

8) 40-bit order: 85 11 TV p. (a) If T≠0,1,8,9; left shift AQ 11 places, word at drum-location p is read into A, and TV p obeyed. (b) If T=0,1,8, or 9; as before, only TV p is omitted.

9) 40-bit order: 86 11 TV p. (a) If T≠0,1,8,9; A is read into drum-location p; then left shift AQ 11 places, then do TV p. (b) If T=0,1,8, or 9; TV p is omitted. 87 orders similarly.

10) A'=0, right shift AQ 4 places; then a'_{36} to a'_{39} become the four least-significant bits on a line of tape and a'_0 becomes the most-significant (5th hole) bit. Note that n must be 4.

11) Punch tape as follows: n has ten bits, $n_0, n_1, \dots , n_9$. n_0 to n_3 are punched in the four least-significant positions, and n_9 in the most-significant (5th hole) position. The number of times that this character is punched is given by dividing the number $n_4, n_5, n_6, n_7, n_8, n_9$ by 4 and rounding up to the next integer. Also, right shift AQ by $(n_4 \dots n_9)$ places.

12) 96 1F selects punch; 96 65F selects cathode ray tube; 96 129F selects printer.

13) This is the logical product which has a "1" where both Q and N have one, otherwise a "0".

TIMING:	0V n and 1V n:	16n µs	80, 81:	4 ms/character
	2, 3, 4, 5, J:	55 µs	82, 92:	17 ms/character on punch
	3 (not executed)	18 µs		1 ms/character on display
	6:	800 µs	K, S, F, L:	90 µs
	7:	700 µs	96:	50 ms

THE TAPE CODE

Tape Holes	Characters F/S	Characters L/S	n for 92 Orders
o	0	P	2F
o 0	1	Q	66F
o 0	2	W	130F
o 00	3	E	194F
o0	4	R	258F
o0 0	5	T	322F
o00	6	Y	386F
o000	7	U	450F
0o	8	I	514F
0o 0	9	O	578F
0o 0	+	K	642F
0o 00	-	S	706F
0o0	N	N	770F
0o0 0	J	J	834F
0o00	F	F	898F
0o000	L	L	962F
0 o	Delay	Delay	3F
0 o 0	$(Tab)	D	67F
0 o 0	CR/LF	CR/LF	131F
0 o 00	(	B	195F
0 o0	L/S=Letter-Shift		259F
0 o0 0	,	V	323F
0 o00	)	A	387F
0 o000	/	X	451F
00o	Delay	Delay	515F
00o 0	=	G	579F
00o 0	.	M	643F
00o 00	F/S=Number-Shift		707F
00o0	'	H	771F
00o0 0	:	C	835F
00o00	x	Z	899F
00o000	Space	Space	963F

(5th hole, 8 hole, sprocket hole, 4 hole, 2 hole, 1 hole)

ILLIAC PROGRAMMING

I. GENERAL INFORMATION.

1. Locations consist of 40 bits. Considered as either (a) a fixed-point number in the range $+1 > x \geq -1$ ($x_0, x_1, x_2, \ldots, x_{39}$; x_0 being the sign-digit in 2-complement number system, x_1 the most, and x_{39} the least-significant bit); or (b) an order-pair each having ($t_0, t_1, t_2, t_3, v_0, v_1, v_2, v_3, s_0, s_1, n_0, n_1, n_2, \ldots, n_9$; t_0 to t_3 form the sexadecimal type-digit and v_0 to v_3 the variant-digit, T and V together giving the function of the instruction; s_0 and s_1 are spare; and n_0 to n_9 specify an address, $n=0,1,2,\ldots,1023$).

2. The high-speed memory contains 1024 locations, corresponding to the addresses n. When considered as an order pair, the halves of a location are referred to as the left and right-hand orders, n_L and n_R, and the former is obeyed first, unless a jump intervenes. Order-pairs are obeyed in the consecutive numerical order of their addresses, unless jump-instructions occur.

3. The arithmetic unit contains a number-register, N, an accumulator, A, and a quotient-register, Q. The unit can obtain the negative, the modulus, or the negative modulus of the numbers in N or Q, and can form the logical product of the contents of Q and N. It can place 0 or ½ (000...0 or 010...0) in A and can add the number in N or Q into A (the logical product of N and Q is formed in Q), with or without an added 2^{-39} (000...1). It can also transfer numbers from N to A, from Q to N, from A to memory, and from memory to N. It cannot transfer numbers directly from A to Q, or from Q to memory. The double-length product of Q and N, or the numbers derived from N, can be formed in AQ, treated as a 79-bit register; and conversely, the quotient when AQ is divided by N can be formed in Q. AQ can also be shifted right or left. The address portions of A can be transferred to memory, and the sign of A can be tested. Unconditional jumps and jumps conditional on the sign of A are provided.

4. The drum-memory consists of one magnetic drum, with 200 tracks, each divided into 64 sectors of one 40-bit word. Drum addresses run from 0 to 12799, thus using 14 bits. The orders referring to the drum occupy a full location (see Order-Code) and the drum-address, p, is in the digits $v_2, v_3, s_0, s_1, n_0, n_1, \ldots, n_9$, in the right-hand half of the location. If $p \geq 12800$, the machine will stop. The digits n_4 to n_9 specify the sector. Locations 0 to 2559 contain fixed routines and it is only possible to read from, but not to write onto, these locations. If $T \neq 0,1,8,9$ (see Order-Code, notes (8) and (9)), only $v_3, s_0, s_1, n_0, \ldots, n_9$ are read into p, so that only drum-locations 0 to 8191 are accessible.

Timing. Consecutively-numbered sectors are arranged five apart on the drum (physical order, 0,13,26,39,52,1,14,27,40,53,2,15, ...) and all sectors with the same number are simultaneously accessible through 200 reading and writing heads. The drum rotates once in 16.9 millisec., so the word-time unit is 264 microsec.(w.t.) Drum instructions must be in the control unit one w.t. before the required sector is reached, so the minimum access time is 528 microsec., or 2 w.t. The average initial access time is therefore $\frac{1}{2}(2+65)=33\frac{1}{2}$ w.t., or 8.9 msec. The sequential access time is 5 w.t., or 1320µs.

5. Input and Output are normally through 5-hole teleprinter-tape. See Order-Code and Tape-Code for details. Note that CR/LF (0 o 0) and Tab (0 o 0) must be followed by Delay (0 o , or 00o), on output, to allow carriage time to move.
When the output-switch is on 'C.R.T.', output is switched to the Cathode-Ray Tube Display. Three tubes are provided (in parallel); two for visual use and one for photographic recording. The usual order is 82 16F, which brightens the point $x=d(a_8 2^{-1}+a_9 2^{-2}+ \dots +a_{15} 2^{-8})$, $y=d(a_0 2^{-1}+a_1 2^{-2}+ \dots +a_7 2^{-8})$ on the screen, the origin being at bottom-left and d being the dimension of the accessible square area of screen. The 16 most-signif. bits of A are thus displayed, and then AQ is shifted up (left) by 16 places. This takes 800 microsec. The order 82 8F brightens the point given by x=same as in last displayed point, $y=d(a_0 2^{-1}+ \dots +a_7 2^{-8})$; this takes 400 microsec.
The order 92 769F advances the film in the camera by one frame.

6. SYMBOLIC ADDRESS DECIMAL ORDER INPUT (SADOI).
This routine is stored on the drum, in part of 0 to 2559, and 11058 to 12799. During input, it uses locations 0 to 15, 32 to 562, and 999 to 1023 of the high-speed store.
Reading of programme-tape is begun by a hold-start or clear-start. In either case, contents of 2 to 998 are read into words 11758 to 12754 of drum. The programme being input is then read into the drum, word 11756+n corresponding to location n in the high-speed memory.
Orders are punched in the form, TV nD, where T and V are sexadecimal function-digits, n is the address in decimal notation, and D is a directive-letter (K,S,N,J,F, or L).
Symbolic addresses are written (...); all teletype signs may be used inside the parentheses, but only the last (rightmost) five printed characters are recognized by SADOI. General order is TV n(A), and its address is n+(A). (This is an 'inside symbolic address', ISA). The address (A) refers to an order-pair; general order-pair is punched as (A) (B) ... (D) TV n(P) (M) (N) ... (Q) T'V' n'(P'). The non-underlined symbolic addresses are 'outside symbolic addresses', OSA, and all become numerically equivalent to the location of the order-pair. (The orders may, of course, be in non-symbolic form, TV nD, if desired). Forward and backward references are equally acceptable.

7. Directives used with SADOI.

K. This directive sets the relativizer, $\hat{r}$, which is stored in 1001 and is added to any address terminated by L, and determines the address in which the next order-pair is stored. Subsequent order-pairs are then stored in consecutive locations until the next K-directive is read. The K-order itself is never stored, and the next instruction is always stored in a left-hand location.

00 K. If the last read order-pair is stored in m, set $\hat{r}$=m+1. Order pairs following go into m+1, m+2, ...

00 nK. (n≠0). Set $\hat{r}$=n. Following instructions go into n, n+1, ...

01 nK. $\hat{r}$ unchanged. If $\hat{r}$=m, following instructions go into m+n, m+n+1,...

02 nK. Set $\hat{r}$ to the address-part of the preceding order (can be a symbolic address). If this order appears as a left-hand order, it will not be stored. A symbolic address must have been set previously by an OSA, i.e. be a backward reference. Following order-pairs now go into m+n, m+n+1, ... , if $\hat{r}$=m.

F. Fixed address. TV nF is interpreted as TV n, n being put into binary form. Note that 00F00F, 80F00F, and LL4095FLL4095F are the 40-bit numbers 0,-1, and -2^{-39}, respectively.

L. Relative address. TV nL is interpreted as TV (m+n), if $\hat{r}$=m.

S. TV nSd, where d=2,3,4, ... ,F, or L, is interpreted as follows. If the order is a left-hand one, the contents of d_R are added to the order TV n before it is stored. If it is a right-hand order, the contents of all of d are added to the order-pair, ... TV n, to which the order pair belongs. The contents of 2,3,4, ... ,14, and 15 are called S-parameters. The right-hand half of an S-parameter may, but the left-hand half may not, contain an ISA.

J. Decimal fraction input directive. The order-pair 00F00nF will be stored as the number n.2^{-39}. The order-pair 00F00nJ is stored as the number n.10^{-12}.(n is limited to 12 decimal digits.) Note that 40F00nJ, 80F00nJ, and NOF00nJ correspond to $\frac{1}{2}$+n.10^{-12}, -1+n.10^{-12}, respectively.

N. Action-directive. 2V nN (if 999>n) causes the programme to be read down from the drum into the high-speed store, and the machine then proceeds to obey the programme, starting at location n (right or left, according to V). The N-order is not stored as part of the programme, nor is the previous order, if the N-order is a right-hand one. The instructions 00F 26 nL, 26 1N cause the programme to be obeyed, starting at $(m+n)_L$, if $\hat{r}$=m. After an interlude, if more tape is to be read into the programme, a jump to 999_L causes $\hat{r}$ to be set to the right-hand address of the number in Q; following instructions then go into m, m+1, ... , if $\hat{r}$=m. A jump to 1014_R leaves $\hat{r}$ unchanged. If the address in A_R is m, following orders go into m, m+1, ... The contents of the high-speed store are written back onto the drum (modified by the interlude) when either of these jump-instructions are obeyed. If n>999, the jump is interpreted as one to n-906.

24 999N. Stops input with an Obey-Stop.

26 999N. Used with an OSA, this simply marks the OSA.

26 1000N. Used for special interludes. This order precedes the first order-pair to be obeyed. Follow the last order-pair to be obeyed by a normal N-jump. Then only the orders between the two N-orders will be read down into the high-speed store for the interlude. To end the interlude, jump as for a regular interlude. Only S-parameters and the words read down are put back onto the drum after a special interlude.

22 1000N. Set the relativizer by a K-order; then put 00 nF 22 1000N. The order-pairs following are stored on the drum at n, n+1, ... To stop the process, write a directive or begin an interlude. Use no symbolic addresses.

26 (1469+k)N. Used for fast interludes. During input, blocks of instructions are read into the high-speed store beginning at 563, until (a) 45 order-pairs have been read-in, (b) a K-Directive is read, (c) a 2V nN order with 999>n is read, or (d) an S-directive is used and the S-parameter has a right ISA. Thus 26 (1469+k)N causes the current block of orders to be obeyed, starting at 563+k. End fast interludes by a jump to 93_L.

8. Library routines stored on the drum. The following routines are stored in 0 to 2559. P16 (Infraprint), Y1 (Transfer blocks of words from memory to drum or vice versa), N12 (Infraput), R1 (Square root), S4 (Exponential), S5 (Natural Logarithm/32), T4 (New Tan^{-1}), T5 (Sine and Cosine), F1 (Solution of ordinary differential equations), and A6 (Floating-point decimal arithmetic along with floating decimal functions). (R)OV nK, where R is the routine title, e.g. P16, and OV nK is a K-directive, causes routine R to be read into the programme according to the directive. Entries to the routine may be made by referring to the symbolic address (R).

9. Method of formation of instructions by SADOI during input. (a) Put N(1) in A. (b) Shift A left 8 bits and put TV in binary at right of A. (c) Shift A left 12 bits and store in 1. (d) Read the numerical part of the address, n, into right of A, in binary, and store in 0. (e) Read the next character. If it is '(', there is an ISA, (C) , which is either translated (back-reference) or noted (forward-reference), and put in the right of 1. If character is a directive, for K, N, F, form N(0)+N(1) and store at 1; for L, add $\hat{r}$ also; for Sk, add N(k) also; for J, form N(1)+N(0).2^{39}.10^{-12}, roughly. For F, L, Sk, and J, now go on to next instruction. At every second reading-in, the order-pair is stored.