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TITLE	PALEX - AN ON-LINE DEBUGGING PROGRAM FOR PDP-5 AND PDP-8 COMPUTERS
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DECUS NO. 5/8-55

P A L E X

An On-Line Debugging Program for PDP-5 and PDP-8 Computers

by R. Berger

July 15, 1966

Introduction

One problem with programs written in Program Assembly Language (PAL) for operation on a PDP-5/8 computer is the danger of an untested program being self destructive, running wild, or destroying other programs residing in memory such as loading programs. PALEX prevents any of the above unwanted operations from occurring while it gives the operator-programmer valuable debugging information and enables him to make changes in his program and try out the modified program. Once running, PALEX cannot be destroyed by any program or instruction in memory, the operator need not touch any manual console controls, and all required information is printed in easy to read format on the Teletype console.

PALEX

PALEX is a four page symbolically relocatable program which is loaded into a vacant area of PDP-5/8 memory and operates upon any other program residing in memory. Some of the PALEX features are:

1. Self protective - Once running, PALEX cannot be destroyed by any program or instructions in memory or by the operator using the Teletype console.

2. Relocatable - The first line of information in the PALEX symbolic program is the only absolute address specified in the program, all other addresses being symbolically specified. Therefore, by changing the first line of the symbolic program (*6600) to a normally vacant area of memory and reassembling, PALEX will conform to each programmer's approach to page assignments.

3. Inquiry (Examine) - The operator can request and receive a four digit octal printout of the contents of any memory address.

4. Memory Contents Changing (Deposit) - Any four digit octal number can be deposited in any memory location (with the exception of the locations PALEX occupies and location 0000*) from the Teletype console.

5. Accumulator and Link - The simulated accumulator and/or link can be "examined", and changed.

6. Operating Limits - The operator can easily set the upper and lower address limits of his program. Before PALEX "executes" an instruction, the program counter and the address specified by the instruction (if it is a JMP, JMS, DCA or ISZ) are tested to see if the program counter is within the operator specified limits, not within PALEX limits, and not location 0000. If the instruction fails these tests, the operator is notified.

7. Starting Address - The operator can select any starting address for the program simulation. Stopping for inquiries and changes, restarting, and starting at different locations is easily achieved.

8. Printout - The operator may receive automatically on each line of printout:

   a) Program Counter - four digit octal value of the simulated program counter.

   b) Instruction - four digit octal value of the instruction being executed.

   c) Accumulator - four digit octal value of the simulated accumulator.

   d) Link - one digit octal value of the simulated link.

   e) Address - four digit octal value of the address, if any, that the instruction is dealing with. If the instruction uses indirect addressing, the final address desired is outputted as the "Address".

*Location 0000 in the PDP-5 is the Program Counter and should not be externally changed.

f) Contents of Address - four digit octal value of the information found in the "Address" after the instruction is "executed".

g) Indirect Address - if the instruction being "executed" uses indirect addressing, the octal value of the intermediate address will be outputted.

Note: Only the printouts associated with the particular instruction being "executed" are outputted, therefore, if the instruction is an IAC only a, b, c and d will be outputted. Two spaces are outputted after each set of digits.

9. Printout Control - The major drawback to this operation is the time consuming printout. To minimize this problem several time-saving operator options are included in PALEX:

a) 'S' Mode - The operator can request a shortened printout. In the S mode only the program counter, instruction, accumulator, and link are outputted (the F mode gives full printouts).

b) 'J' Mode - The operator can request printouts to occur only on transfer instructions (i.e. - JMS or JMP). The line length of this printout is determined by which mode (F or S) was selected prior to entering the J mode.

c) 'P' Mode - To avoid printouts during time consuming counting loops or for other similar routines, the 'P' mode may be specified. In this mode of operation the operator specifies the program location at which printing is to begin. When this location is reached, the printout will be determined by the mode prior to entering the 'P' mode (J, S or F).

10. Program Control - In addition to the aforementioned features, PALEX gives the operator complete program control via the teletype console:

a) The operator specifies the starting address of the program to be executed.

b) The operator can cause a pause in the simulation for examining, depositing and mode changing (mode changing can also be accomplished without causing a pause in simulation). He can then continue by

setting a new starting address or, more simply, hitting the letter 'C' on the keyboard.

c) Each time the mode is changed, the address of next instruction to be executed is outputted as an additional guide for the operator.

11. Diagnostic Printouts - If PALEX pauses in its program simulation, the operator is notified by a diagnostic printout. If an instruction dealing with a disallowed location (PALEX limits and location 0000) or a halt instruction is about to be executed, an X followed by the location of the instruction in question is outputted. If the instruction to be executed is outside the operator specified limits, an L followed by the location of that instruction is outputted.

If PALEX is in either the 'J' or 'P' modes and an 'X' printout occurs, the operator can "examine" the location specified by PALEX to discover the reason for the printout.

PALEX maintains an internal program counter, accumulator, and link in core memory. The instructions to be simulated are read one at a time and stored, the operation code field is decoded, the page and indirect bits are checked, and the address specified by the instruction is computed. The computed address is checked to insure the user's program does not attempt to operate within the four pages in which PALEX resides and the internal program counter is compared with the operator specified operation limits.

If the instruction is an Operate Instruction other than HALT, it is executed and the internal program counter, accumulator, and link are changed accordingly. All IOT instructions, HALT, and ION are suppressed completely so as to insure perfect output copy and program operation. PALEX can be made to execute all IOT instructions by changing the information in one memory location. All other instructions (AND, TAD, ISZ, DCA, JMS, JMP) are simulated by PALEX, insuring program control.

PALEX is written so as to enable the operator to easily change most program operations to better fit his own needs.

Console Control

The printout takes the form:

PC INST AC L ADD C(ADD) IADD

where PC is the Program Counter, INST is the instruction to be executed, AC is the accumulator, L is the link, ADD is the resulting specified address, C(ADD) is the contents of the specified address and IADD is the address used for indirect addressing.

To examine the contents of any core location, the sequence NNNN ← is used where NNNN is the four digit octal address to be examined (if the address contains zeros in the most significant bits, they may be left out as PALEX right adjusts each number received).

To deposit information in core location outside of those in which PALEX resides and location 0000, the sequence XXXX,NNNN followed by a carriage return is used where XXXX is the octal location in core and NNNN is the octal information to be deposited.

PALEX has been tested on the PDP-5 and PDP-8 using the MAINDEC 501 Instruction Test Program. The following is the PALEX printout to this instruction test with all options exercised and explanatory notes.

EXPLANATORY NOTES

1. The operator specifies the upper limit of the program by the sequence NNNNT where N is any octal digit and T represents the Top limit of the program. PALEX sends the carriage return and line feed and right adjusts the specified digits.

2. The lower program limit is specified by NNNNB where B represents the Bottom limit of the program. The lower limit should always be a larger octal number than the upper limit.

3. The simulation is directed to the proper starting address by the sequence NNNNØ where Ø represents the ØRIGIN. The simulation will immediately begin.

4. A trouble condition is specified by the sequence NNNNX followed by carriage return and line feed. The instruction to be executed at location 0200 is a HALT instruction which causes a trouble printout. This can be seen by observing the instruction on the previous line of printout which is 7402, the octal value of the HALT instruction.

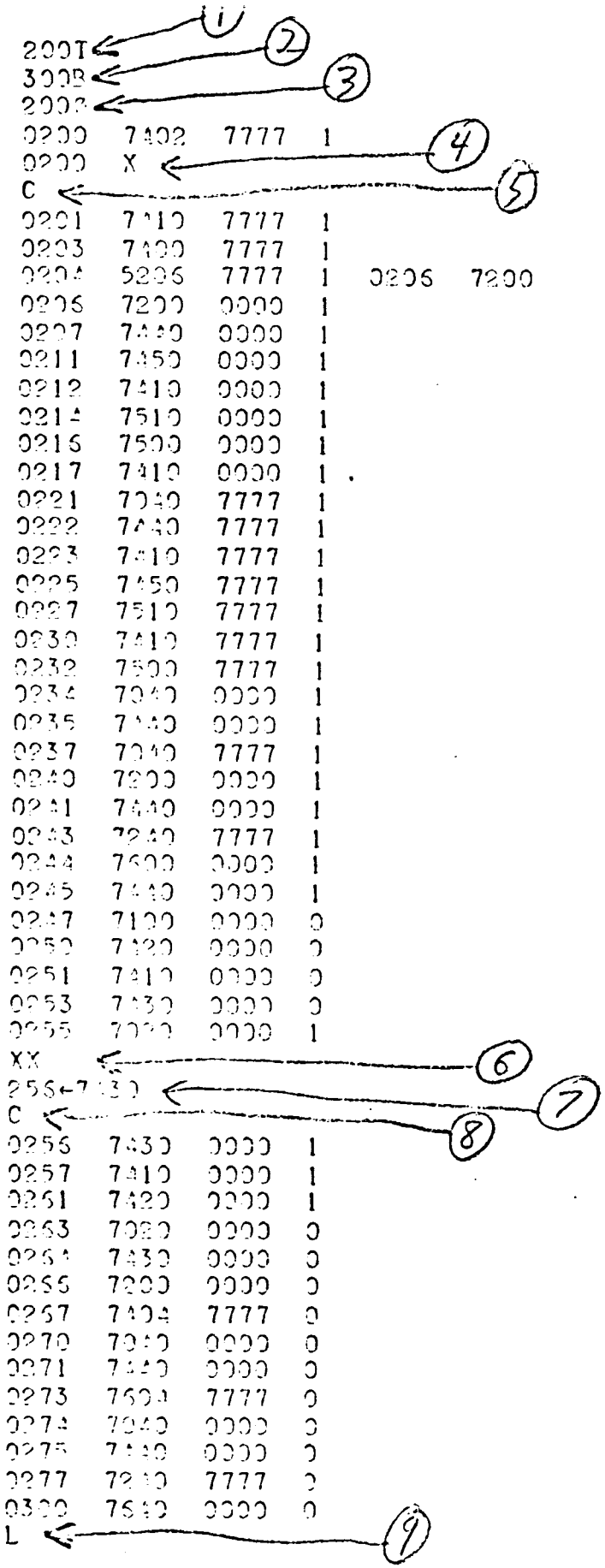
5. The simulation can be restarted at the point at which it paused by typing the letter C on the console keyboard. The letter C represents the CONTINUE key on the computer console. An alternate method of resuming simulation is by reseting the ØRIGIN. In this particular instance this could have been accomplished by typing the sequence 201Ø.

6. Any character typed which is not defined in PALEX is interpreted as a request for a pause in simulation. PALEX signals its reception of such a character by printing the character followed by the letter X and a carriage return and line feed.

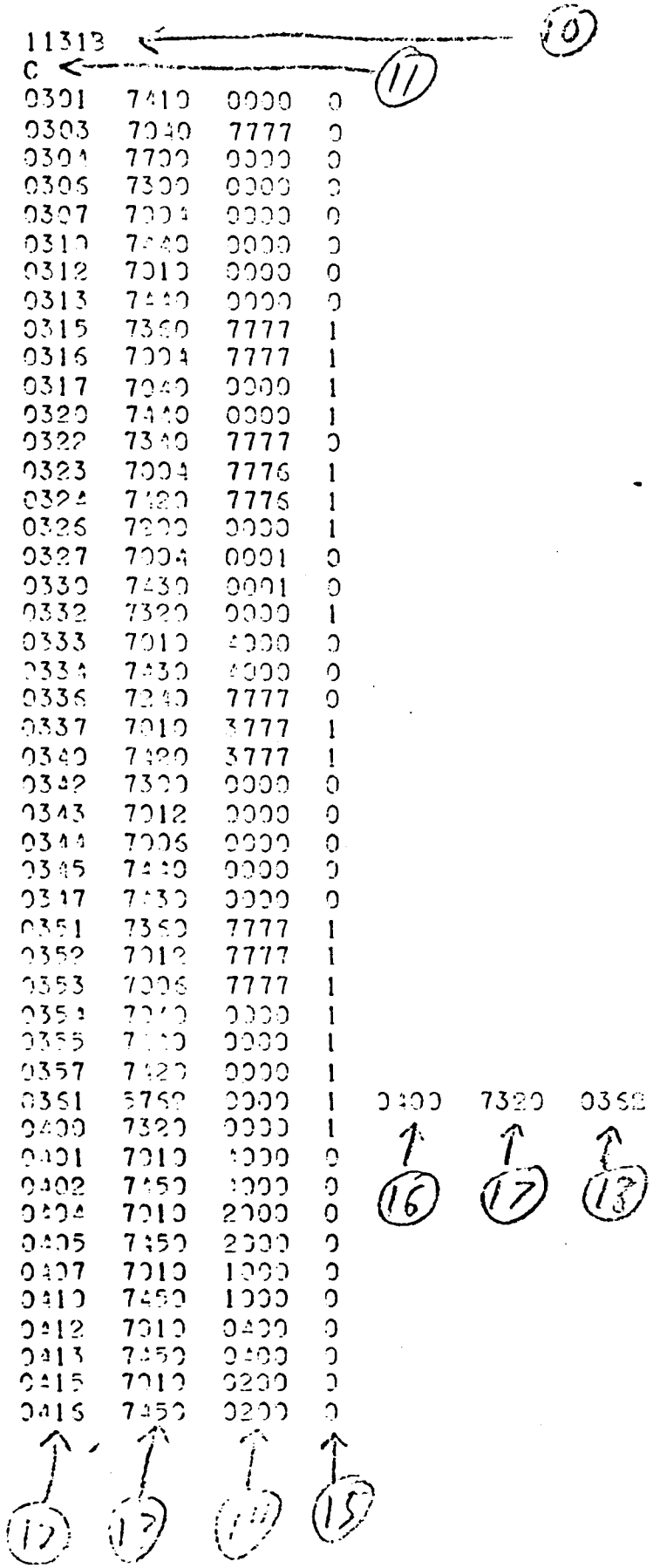
7. The "EXAMINE" operation is accomplished by the sequence NNNN← where NNNN is the octal value of the core location to be examined and the ASCII character "arrow" is generated by first depressing the shift key and then the letter Ø. PALEX will print out the four digit octal value of the contents of the specified location.

8. The simulation is restarted by sending the letter C which causes PALEX to restart the simulation at the point at which it stopped, regardless of what has taken place since that time.

9. PALEX checks its internal program counter against the operator specified limits for operation. When the program counter does not fall within these limits, the letter L is printed and the simulation halts. In the example shown, the operator has chosen the limits from 0200 to 0300. When PALEX is about to simulate the instruction at 0301, the limit test fails resulting in the L printout.


200T
300B
2003
0200 7402 7777 1
0200 X
C
0201 7410 7777 1
0203 7400 7777 1
0204 5206 7777 1 0206 7200
0206 7200 0000 1
0207 7440 0000 1
0211 7450 0000 1
0212 7410 0000 1
0214 7510 0000 1
0216 7500 0000 1
0217 7410 0000 1
0221 7040 7777 1
0222 7440 7777 1
0223 7410 7777 1
0225 7450 7777 1
0227 7510 7777 1
0230 7410 7777 1
0232 7500 7777 1
0234 7040 0000 1
0235 7440 0000 1
0237 7040 7777 1
0240 7200 0000 1
0241 7440 0000 1
0243 7240 7777 1
0244 7600 0000 1
0245 7440 0000 1
0247 7100 0000 0
0250 7120 0000 0
0251 7410 0000 0
0253 7430 0000 0
0255 7000 0000 1
XX
256←7430
C
0256 7430 0000 1
0257 7410 0000 1
0261 7420 0000 1
0263 7000 0000 0
0264 7430 0000 0
0265 7200 0000 0
0267 7404 7777 0
0270 7040 0000 0
0271 7440 0000 0
0273 7604 7777 0
0274 7040 0000 0
0275 7440 0000 0
0277 7240 7777 0
0300 7640 0000 0
L
1
2
3
4
5
6
7
8
9

```
11313
C
0301  7410  0000  0
0303  7040  7777  0
0304  7700  0000  0
0306  7300  0000  0
0307  7004  0000  0
0310  7440  0000  0
0312  7010  0000  0
0313  7440  0000  0
0315  7360  7777  1
0316  7004  7777  1
0317  7040  0000  1
0320  7440  0000  1
0322  7340  7777  0
0323  7004  7776  1
0324  7420  7776  1
0326  7200  0000  1
0327  7004  0001  0
0330  7430  0001  0
0332  7320  0000  1
0333  7010  4000  0
0334  7430  4000  0
0336  7240  7777  0
0337  7010  3777  1
0340  7420  3777  1
0342  7300  0000  0
0343  7012  0000  0
0344  7006  0000  0
0345  7430  0000  0
0347  7430  0000  0
0351  7350  7777  1
0352  7012  7777  1
0353  7006  7777  1
0354  7040  0000  1
0355  7040  0000  1
0357  7420  0000  1
0361  5750  0000  1  0400  7320  0352
0400  7320  0000  1
0401  7010  1000  0
0402  7450  1000  0
0404  7010  2000  0
0405  7450  2000  0
0407  7010  1000  0
0410  7450  1000  0
0412  7010  0400  0
0413  7450  0400  0
0415  7010  0200  0
0416  7450  0200  0
```



10. When the simulation halts due to an exceeded limit, a C (continue) will not restart the simulation since the trouble condition has not been rectified. The lower limit must be changed, and this is accomplished in the same way as at the beginning of the simulation. Both limits may be reset at any time but this procedure halts the simulation and a C must follow.

11. The C restarts the simulation at the point of halting.

12. The first four digits of printout specify the octal value of the Program Counter.

13. The second four digit octal number specifies the instruction being executed.

14. The third set of digits is the value of the accumulator.

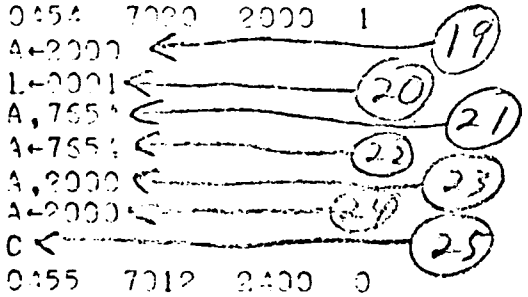
15. The link is displayed as a one digit number.

16. The final address specified by the instruction is shown as a four digit octal number.

17. The contents of the address specified by the instruction after execution is displayed as a four digit octal number.

18. If the final address was made accessable by use of indirect addressing, the indirect address used is shown as a four digit octal number. In the example shown, the instruction at 0361 translates to JMP I 0362 where 0400 is the contents of 0362, 0400 is shown as the final address, 0362 is the indirect address, and 7320 is the contents of 0400.

```
0420  7010  0100  0
0421  7450  0100  0
0423  7010  0040  0
0424  7450  0040  0
0426  7010  0020  0
0427  7450  0020  0
0431  7010  0010  0
0432  7450  0010  0
0434  7010  0004  0
0435  7450  0004  0
0437  7010  0002  0
0440  7450  0002  0
0442  7010  0001  0
0443  7450  0001  0
0445  7010  0000  1
0446  7420  0000  1
0450  7440  0000  1
0452  7320  0000  1
0453  7012  2000  0
0454  7020  2000  1
A←2000
L←0001
A,7554
A←7554
A,2000
A←2000
C
0455  7012  2400  0
0456  7020  2400  1
0457  7012  2500  0
0460  7020  2500  1
0461  7012  2520  0
0462  7020  2520  1
0463  7012  2521  0
0464  7020  2524  1
0465  7012  2525  0
0466  7020  2525  1
0467  7410  2525  1
0471  7006  2526  1
0472  7420  2526  1
0474  7006  2532  1
0475  7420  2532  1
0477  7006  2552  1
0500  7420  2552  1
0502  7006  2652  1
0503  7420  2652  1
0505  7006  3252  1
0506  7420  3252  1
0510  7006  5252  1
0511  7420  5252  1
0513  7006  5253  0
```



19. The value of the simulated accumulator can be requested by the sequence A← . PALEX interprets the A to mean the internal address at which the simulated accumulator is stored. Therefore, A is translated by PALEX to a four digit octal number.

20. Similarly, the link is examined by the L ← sequence.

21. The accumulator may be changed by the sequence A,NNNN followed by a carriage return, where NNNN is the information to be deposited in the accumulator.

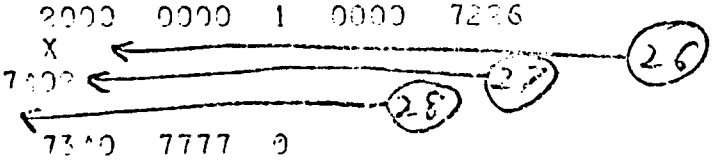
22. Its new value may be checked.

23. It may be changed as often as necessary. Inquiring and changing the accumulator and link cause a halt in simulation.

24. Same as 22.

25. The simulation is restarted by a C character.

```
0514  7430  5253  0
0516  7006  5255  0
0517  7430  5255  0
0521  7006  5265  0
0522  7430  5265  0
0524  7006  5325  0
0525  7430  5325  0
0527  7006  5525  0
0530  7430  5525  0
0532  7006  5525  0
0533  7430  5525  0
0535  7300  0000  0
0536  7001  0001  0
0537  7450  0001  0
0541  7001  0002  0
0542  7012  0000  1
0543  7420  0000  1
0545  7440  0000  1
0547  7240  7777  1
0550  7001  0000  0
0551  7440  0000  0
0553  7041  0000  1
0554  7440  0000  1
0556  5757  0000  1  0600  0000  0557
0600  2000  0000  1  0000  7236
0600  X
601←7400
6020
0602  7340  7777  0
0603  3326  0000  0  0726  7777
0604  7440  0000  0
0605  2326  0000  0  0726  0000
0610  2325  0000  0  0726  0001
0611  7510  0000  0
0613  7300  0000  0
0614  3326  0000  0  0726  0000
0615  7001  0001  0
0616  7450  0001  0
0620  2326  0001  0  0726  0001
0621  5215  0001  0  0615  7001
0615  7001  0002  0
0616  7450  0002  0
0620  2326  0002  0  0726  0002
0621  5215  0002  0  0615  7001
0615  7001  0003  0
0616  7450  0003  0
0620  2326  0003  0  0726  0003
0621  5215  0003  0  0615  7001
```



26. An invalid condition causes an X error printout and halts the simulation. In the example shown, the instruction at 0600 translates to ISZ Z 0000. Location 0000 is considered to be an invalid location by PALEX. Although the printout is complete, the instruction was not executed.

27. By examining the contents of location 0601, it is seen to be a halt instruction.

28. Rather than continuing to the halt instruction and then continuing again, the operator chose to reset the origin.

```
0615  7001  0004  0
0616  7450  0004  0
0620  2326  0004  0  0726  0004
0621  5215  0004  0  0615  7001
S0615 <-------------------------- 29
0615  7001  0005  0
0616  7450  0005  0
0620  2326  0005  0
0621  5215  0005  0
0615  7001  0006  0
0616  7450  0006  0
0620  2326  0006  0
0621  5215  0006  0
0615  7001  0007  0
F0616 <-------------------------- 30
0616  7450  0007  0
0620  2326  0007  0  0726  0007
0621  5215  0007  0  0615  7001
0615  7001  0010  0
0616  7450  0010  0
0620  2326  0010  0  0726  0010
J0621 <-------------------------- 31
0621  5215  0010  0  0615  7001
0621  5215  0011  0  0615  7001
0621  5215  0012  0  0615  7001
0621  5215  0013  0  0615  7001
0621  5215  0014  0  0615  7001
S0615 <-------------------------- 32
0615  7001  0015  0
0616  7450  0015  0
0620  2326  0015  0
0621  5215  0015  0
0615  7001  0015  0
0616  7450  0015  0
J0620 <-------------------------- 33
0621  5215  0016  0
0621  5215  0017  0
0621  5215  0020  0
0621  5215  0021  0
0621  5215  0022  0
F0615 <-------------------------- 34
0615  7001  0023  0
0616  7450  0023  0
0620  2326  0023  0  0726  0023
0621  5215  0023  0  0615  7001
0615  7001  0024  0
```

29. When a full line of printout is not required, the 'S' mode may be selected. This is accomplished by depressing the S key on the teletypewriter. This may be done at any time, since PALEX does not look for characters from the 33 ASR until the end of each line of printout. PALEX outputs the address of the next instruction to be executed after each change of mode. In the 'S' mode, the address, contents of address, and indirect address are suppressed. S is chosen to mean the short printout mode.

30. The full printout mode is selected by depressing the letter F.

31. At times the operator may only be interested in instructions which cause a deviation from the main stream of the program. In the 'J' mode only JMP and JMS instructions are printed although all instructions are still executed. When the 'J' mode is entered, PALEX is already in either the S or F mode, and the J mode printout reflects this.

32. To end the 'J' mode, select either the S or F mode.

33. If PALEX is in the 'S' mode upon entering the 'J' mode, the J printout will be of the shortened form.

34. Selecting either the 'S' or 'F' mode will terminate the 'J' mode.

```
0616  7450  0024  0
0620  2326  0024  0  0726  0014
0621  5015  0024  0  0615  7001
0615  7001  0025  0
0616  7450  0025  0
617P
C
0617  5223  0000  1  0623  2326
0623  2326  0000  1  0726  0000
0625  7420  0000  1
0627  7200  0000  1
0630  3326  0000  1  0726  0000
0631  0326  0000  1  0726  0000
0632  7440  0000  1
0634  7240  7777  1
0635  0326  0000  1  0726  0000
0636  7410  0000  1
0640  7240  7777  1
0641  3326  0000  1  0726  7777
0642  7410  0000  1
0644  0326  0000  1  0726  7777
0645  7440  0000  1
0647  7240  7777  1
0650  0326  7777  1  0726  7777
0651  7040  0000  1
0652  7440  0000  1
0654  7300  0000  0
0655  1327  7777  0  0727  7777
0656  7430  7777  0
0660  7010  0000  0
0661  7410  0000  0
0663  7410  7777  0
0664  1330  0000  1  0730  0001
0665  7410  0000  1
0667  7120  0000  1
0671  7040  7777  1
0672  1330  0000  0  0730  0001
0673  7440  0000  0
0675  7430  0000  0
0677  7240  7777  0
0700  1327  7775  1  0727  7777
0701  7430  7775  1
0702  7001  7777  1
0703  7040  0000  1
0704  7440  0000  1
0705  7300  0000  0
0707  3010  0000  0  0010  0000
0710  0010  0000  0  0010  0000
0711  1010  0000  0  0010  0000
10←0000
C
0712  7440  0000  0
0714  0410  0000  0  0001  5430  0010
0715  1010  0001  0  0010  0001
10←0001
1←5430
C
0716  7041  7777  0
0717  1330  0000  1  0730  0001
```

35. At this point, it is observed that the program is in a long counting loop. Because of the simulation and printout time, this loop might take an excessively long time. From the program listing it is seen that the exit from this loop is at 0617 (JMP . + 4). The 'P' (suspend print) mode is desirable when this type of situation arises. When in the 'P' mode, PALEX compares the internal program counter with the operator specified address. If these two numbers are not identical, PALEX executes the instruction but suppresses the entire printout. When these two octal values match, the printout is resumed in the 'S', 'F', and/or 'J' mode previously selected, and the 'P' mode is canceled. The 'P' mode is selected by the sequence NNNNP where NNNN is the address at which PALEX should resume outputting.

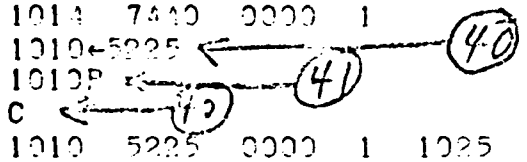
36. Selecting the P mode halts the simulation, requiring a C (continue) stimulus for PALEX to resume. In this instance, it took PALEX approximately 30 seconds to finish this loop on the PDP-5 and approximately 6 seconds on the PDP-8.

37. The contents of auto-index register 0010 is examined and found to be 0000. This can also be seen by examining line 0707. The instruction at 0707 is DCA Z 10 (3010) and the accumulator was previously cleared.

38. The instruction at 0714 is AND I Z 10 (0410) which indexes the auto-index register as shown in the address printout column.

39. The indexing is confirmed by examining. The contents of address 0001 as shown on line 0714 is also confirmed.

```
0720  7440  0000  1
0722  1202  7340  1  0602  7340
0723  7000  7340  1
0724  5725  7340  1  1000  7300  0725
1000  7300  0000  0
1001  3222  0000  0  1022  0000
1002  3223  0000  0  1023  0000
1003  1223  0000  0  1023  0000
1004  1224  0001  0  1024  0001
1005  3223  0000  0  1023  0001
1006  2222  0000  0  1022  0001
1007  7510  0000  0
1011  1222  0001  0  1022  0001
1012  7041  7777  0
1013  1223  0000  1  1023  0001
1014  7440  0000  1
1015  7420  0000  1
1020  7220  0000  0
1021  5203  0000  0  1003  1223
1003  1223  0001  0  1023  0001
1004  1224  0002  0  1024  0001
1005  3223  0000  0  1023  0002
1006  2222  0000  0  1022  0002
1007  7510  0000  0
1011  1222  0002  0  1022  0002
1012  7041  7776  0
1013  1223  0000  1  1023  0002
1014  7440  0000  1
1010←5225
1010P
C
1010  5225  0000  1  1025  7300
1025  7300  0000  0
1026  3222  0000  0  1022  0000
1027  3223  0000  0  1023  0000
1030  1223  0000  0  1023  0000
1031  1224  0001  0  1024  0001
1032  3223  0000  0  1023  0001
1033  2222  0000  0  1022  0001
1034  7510  0000  0
1035  1222  0001  0  1022  0001
1037  7041  7777  0
1040  7010  3777  1
1041  7010  5777  1
1042  7010  6777  1
1043  7010  7377  1
1044  7010  7577  1
1045  7010  7677  1
1046  7010  7737  1
1047  7010  7757  1
1050  7010  7767  1
```



40. Once more a counting loop is encountered. From the MAINDEC 501 program listing it is seen that the exit from this loop is in location 1010. Examining location 1010 confirms the listing (JMP C11 + 1).

41. The P mode is set for location 1010.

42. PALEX is instructed to continue. This loop took PALEX about 1 1/2 minutes on the PDP-5 to execute without printing. On the PDP-8, PALEX required only 15 seconds to complete this counting loop. The loop consists of 12 instructions executed 4096 times each. If this loop was executed on a PDP-5, it would take approximately one second; therefore, PALEX requires approximately 90 times longer to execute an instruction (average). The printout occurs at 10 characters per second. A full line of printout requires up to 4.1 seconds. In the 'S' mode a line of printout requires 2.3 seconds.

```
1051   7010   7773   1
1052   7010   7775   1
1053   7010   7776   1
1054   7010   7777   0
1055   1223   0000   1   1023   0001
1056   7440   0000   1
1060   7420   0000   1
1062   1222   0001   1   1022   0001
1063   7041   7777   1
1064   7004   7777   1
1065   7004   7777   1
1066   7004   7777   1
1067   7004   7777   1
1070   7004   7777   1
1071   7004   7777   1
1072   7004   7777   1
1073   7004   7777   1
1074   7004   7777   1
1075   7004   7777   1
1076   7004   7777   1
1077   7004   7777   1
1100   7004   7777   1
1101   1223   0000   0   1023   0001
1102   7440   0000   0
1104   7430   0000   0
1106   7200   0000   0
1107   5230   0000   0   1030   1223
1030   1223   0001   0   1023   0001
1031   1224   0002   0   1024   0001
1032   3223   0000   0   1023   0002
1033   2222   0000   0   1022   0002
1034   7610   0000   0
1035   1222   0002   0   1022   0002
1037   7041   7776   0
1040   7010   3777   0
1041   7010   1777   1
1042   7010   4777   1
1043   7010   6377   1
1044   7010   7177   1
1045   7010   7477   1
1046   7010   7637   1
1047   7010   7717   1
1050   7010   7747   1
1051   7010   7763   1
1052   7010   7771   1
1053   7010   7774   1
1054   7010   7776   0
1035P
C
A←4730
C
1022←5700
C
1022←6516
C
1035   5310   0000   1   1110   7200
1110   7200   0000   1
1111   3313   0000   1   1113   0000
1112   4313   0000   1   1113   1113
1114   7440   0000   1
1116   1313   1113   1   1113   1113
1120   7450   1113   1
```

(43) ← 1035P

(44) ← A←4730

(45) ← 1022←5700

(46) ← 1022←6516

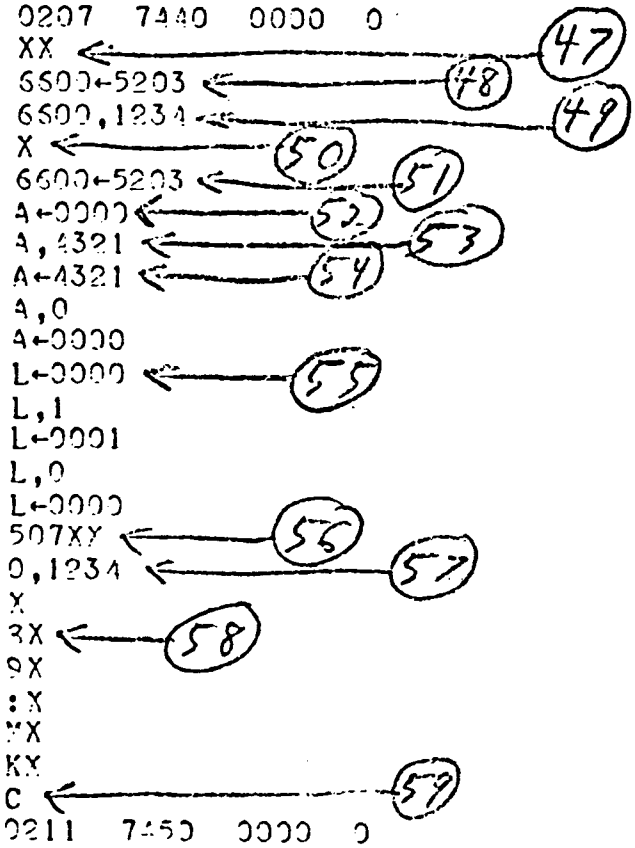
43. Here we find another counting loop, this one consisting of 43 instructions executed 4096 times each. Once again the 'P' mode is set. PALEX will require almost five minutes to execute these 176,128 instructions on the PDP-5 and about 53 seconds on the PDP-8.

44. Until the loop is exited, no printout should occur. After a few minutes, the operator chose to see if the simulation was proceeding by checking to see if the value in the accumulator had changed. A 'C' was required to restart simulation.

45. A minute later the operator chose to see how far the simulation had proceeded by examining the MAINDEC 501 internal loop counter at location 1022. Again a 'C' is required to restart.

46. A short time later the operator again examines this counter for progress.

```
1124  7001  0000  0
1125  7440  0000  0
1127  5730  0000  0  0201  7410  1130
0201  7410  0000  0
0203  7400  0000  0
0204  5206  0000  0  0206  7200
0206  7200  0000  0
0207  7440  0000  0
XX
6600←5203
6600,1234
X
6600←5203
A←0000
A,4321
A←4321
A,0
A←0000
L←0000
L,1
L←0001
L,0
L←0000
507XX
0,1234
X
3X
9X
:X
;X
KX
C
0211  7450  0000  0
0212  7410  0000  0
0214  7510  0000  0
0215  7500  0000  0
0217  7410  0000  0
0221  7040  7777  0
0222  7440  7777  0
0223  7410  7777  0
0225  7450  7777  0
0227  7510  7777  0
0230  7410  7777  0
0232  7500  7777  0
0234  7040  0000  0
0235  7410  0000  0
0237  7040  7777  0
0240  7200  0000  0
0241  7410  0000  0
0243  7240  7777  0
0244  7600  0000  0
0245  7440  0000  0
0247  7100  0000  0
0250  7420  0000  0
0251  7410  0000  0
0253  7430  0000  0
0255  7020  0000  1
0256  7430  0000  1
0257  7410  0000  1
0261  7420  0000  1
0263  7020  0000  0
0264  7430  0000  0
0266  7200  0000  0
```



47. These ASCII characters are valid as defined by PALEX: A, B, C, F, J, L, Ø, P, S, T, comma, carriage return, arrow, 0, 1, 2, 3, 4, 5, 6, 7. All other characters sent from the teletypewriter are regarded as requests for a halt in simulation. PALEX notes reception of such a character by outputting an X. In the example shown, the operator requested a halt in simulation with an X.

48. Location 6600 is examined.

49. An attempt is made to deposit 1234 into location 6600.

50. PALEX will not allow information to be deposited within its own limits (6600-7577). The X is outputted by PALEX to tell the operator of this invalid operation.

51. Upon examining location 6600 once again, it is seen that PALEX did not accept the invalid information.

52. The accumulator is examined.

53. The value of the accumulator is changed.

54. The change is checked.

55. The link is examined and changed.

56. If an invalid character is typed prior to completing an operation, the complete operation is disregarded by PALEX and an X is outputted.

57. No information can be deposited into location 0000.

58. The digits 8 and 9 are invalid as well as all other non-defined characters.

59. The simulation is restarted by a C.

OPERATING INSTRUCTIONS

1. Load program to be simulated into memory.
2. Load PALEX via the BIN Loader (S.A. = 7777).
3. Turn teletypewriter on an on line.
4. Load address 6600 (or the selected starting address, if reassembled).
5. Depress start.
6. Set operating limits for simulation from the keyboard. The address of the first instruction in the program listing (not necessarily the starting address) is used as to TØP limit. This is done by the sequence NNNNT. The address of the last instruction in the listing is specified by the sequence NNNNB. This latter number should always be greater than the former. The operating limits can also be used to operate on a small portion of a program.
7. The starting address is specified by the sequence NNNNØ. Simulation will begin immediately in the 'F' mode.
8. Mode changing may be done at any time (see explanatory notes).

```
                                    / PALEX WITHOUT IOT
          *6600
6600 6046 BEGIN,  TLS               / CLEAR OUTPUT FLAG
6601 5602         JMP I ATIWA
6602 7002 ATIWA,  TIW
6603 7553 AHELP,  HELP
6604 4603 START,  JMS I AHELP       / IS PC WITHIN LIMITS
6605 1371         TAD FG5           / YES, CHECK WAIT FLAG
6606 7640         SZA CLA           / SHOULD WE WAIT
6607 5776         JMP I ATW         / YES
6610 3370         DCA FG4           / NO CLEAR MOD. PRINTOUT FLAG
6611 3371         DCA FG5           / CLEAR WAIT FLAG
6612 3375         DCA FG3           / CLEAR JMP+JMS PRINTOUT FLAG
6613 1351         TAD PC            / GET PROGRAM COUNTER
6614 0362         AND MASK1         / TRIM
6615 3360         DCA PAGE          / STORE STARTING ADDRESS OF PAGE
6616 1751         TAD I PC          / GET INSTRUCTION
6617 3352         DCA INST          / STORE INSTRUCTION
6620 1352         TAD INST          / GET INSTRUCTION
6621 0364         AND MASK4         / TRIM
6622 3354         DCA ADD           / STORE ADDRESS
6623 1352         TAD INST          / GET INSTRUCTION
6624 7006         RTL               / CHECK TO SEE
6625 7006         RTL               / IF ADDRESS IS
6626 7710         SPA CLA           / ON PAGE ZERO
6627 1360         TAD PAGE          / NOT PAGE ZERO,GET PAGE ADDRESS
6630 1354         TAD ADD           / GET ADDRESS
6631 3354         DCA ADD           / STORE ADDRESS
6632 7420         SNL               / IS IT INDIRECT
6633 5246         JMP VALUE         / NO
6634 1352         TAD INST          / CHECK FOR IOT + OPR
6635 7710         SPA CLA
6636 5241         JMP .+3           / YES
6637 1354         TAD ADD           / NO
6640 4672         JMS I ACKAIR      / CHECK AUTO INDEX
6641 1354         TAD ADD           / YES GET ADDRESS
6642 3356         DCA IADD          / STORE IN INDIRECT ADDRESS
6643 1756         TAD I IADD        / GET ACTUAL ADDRESS
6644 3354         DCA ADD           / STORE IN ADDRESS
6645 7001         IAC               / NOTE INDIRECT ADDRESS
6646 3365 VALUE,  DCA DOIADD        / 1 IF YES, 0 IF NO
6647 1352         TAD INST          / GET INSTRUCTION
6650 0363         AND MASK2         / TRIM
6651 1374         TAD CONOP         / SET UP SIMULATION OF
6652 3300         DCA MEMOP         / INSTRUCTION
6653 1352         TAD INST          / GET INSTRUCTION
6654 0363         AND MASK2         / TRIM
6655 7106         CLL RTL           / SET UP SIMULATION
6656 7006         RTL               / OF INSTRUCTION
6657 1366         TAD CONI          / WITH A
6660 3261         DCA PDP           / PROPER JUMP
6661 5662 PDP,    JMP I AO          / JUMP TO PROPER ROUTINE
6662 6674 AO,     SVAL              / FOR AND
6663 6674 A1,     SVAL              / FOR TAD
6664 6674 A2,     SVAL              / FOR ISZ
6665 6674 A3,     SVAL              / FOR DCA
6666 6710 A4,     SJMS              / FOR JMS
6667 6716 A5,     SJMP              / FOR JMP
6670 6723 A6,     SIOT              / FOR IOT
6671 6731 A7,     SOPR              / FOR OPR
6672 7307 ACKAIR, CKAIR
6673 7366 AVALID. VALID
```

```
6674  4673  SVAL,   JMS I AVALID
6675  1357  SGET,   TAD LINK        / GET LINK
6676  7010          RAR             / POSITION LINK
6677  1353          TAD ACC         / GET ACCUMULATOR
6700  0000  MEMOP,  0000            / SIMULATE INSTRUCTION
6701  7410          SKP             / WAS IT A SKIP
6702  2361          ISZ NEWPC       / YES, SET NEW PROGRAM COUNTER
6703  2361          ISZ NEWPC       / NO, SET NEW PROGRAM COUNTER
6704  3353          DCA ACC         / STORE ACCUMULATOR
6705  7004          RAL             / POSITION LINK
6706  3357          DCA LINK        / STORE LINK
6707  5773          JMP I PRINT     / OUTPUT INFO.
6710  4673  SJMS,   JMS I AVALID
6711  1351          TAD PC          / SET UP JMS SIMULATION
6712  7001          IAC             / BY STORING PC+1
6713  3754          DCA I ADD       / IN ADDRESS
6714  7001          IAC             /-AND JUMP TO ADDRESS+1
6715  7410          SKP             / DONT REDHECK
6716  4673  SJMP,   JMS I AVALID
6717  1354          TAD ADD         / GET ADDRESS
6720  2375          ISZ FG3         / SET JMP+JMS PRINTOUT FLAG
6721  3361          DCA NEWPC       / SET NEW PROGRAM COUNTER
6722  5773          JMP I PRINT     / PRINT INFO.
6723  1352  SIOT,   TAD INST        / OPR+IOT GET INSTRUCTION
6724  2370          ISZ FG4         / SET MODIFIED OUTPUT FLAG
6725  1372          TAD CON3        / CHECK FOR
6726  7100          CLL             / ION
6727  7200          CLA             / DO NOT ALLOW      SEE NOTE
6730  5340          JMP SOPRS       / ION TO BE EXECUTED
6731  1352  SOPR,   TAD INST        / GET INSTRUCTION
6732  0377          AND AHLT        / CHECK FOR
6733  1367          TAD MHLT        / HALT INSTRUCTION
6734  2370          ISZ FG4         / IS IT
6735  7640          SZA CLA         / A HALT
6736  5342          JMP OP          / NO
6737  2371          ISZ FG5         / YES
6740  2361  SOPRS,  ISZ NEWPC       / SET NEW PROGRAM COUNTER
6741  5773          JMP I PRINT     / OUTPUT INFO.
6742  1352  OP,     TAD INST        / GET INSTRUCTION
6743  3300          DCA MEMOP       / SET UP SIMULATION
6744  5275          JMP SGET        / OF INSTRUCTION
6745  7300  NO,     CLA CLL         / NOT VALID
6746  2371          ISZ FG5         / SET WAIT FLAG
6747  2361          ISZ NEWPC       / SET NEW PROGRAM COUNTER
6750  5773          JMP I PRINT     / OUTPUT INFO.
                / NOTE, IF INST AT 6727 IS CLA
                / NO IOT WILL BE EXECUTED
                / IF INST AT 6727 IS SNA CLA
                / ALL IOT EXCEPT ION WILL BE EXECUTED
```

```
6751  0000  PC,      0
6752  0000  INST,    0
6753  0000  ACC,     0
6754  0000  ADD,     0
6755  0000  CADD,    0000
6756  0000  IADD,    0
6757  0000  LINK,    0000
6760  0000  PAGE,    0000
6761  0200  NEWPC,   0200
6762  7600  MASK1,   7600
6763  7000  MASK2,   7000
6764  0177  MASK4,   0177
6765  0000  DØIADD,  0000
6766  5662  CØN1,    JMP I AD
6767  0376  MHLT,    0-7402
6770  0000  FG4,     0
6771  0000  FG5,     0
6772  1777  CØN3,    0-6001
6773  7200  PRINT,   PRNT
6774  0754  CØNØP,   AND I ADD
6775  0000  FG3,     0
6776  7074  ATW,     TIXX
6777  7402  AHLT,    7402
```

/ PRØGRAM CØUNTER
/ INSTRUCTIØN
/ ACCUMULATØR
/ ADDRESS
/ CØNTENTS ØF ADDRESS
/ INDIRECT ADDRESS
/ LINK
/ ADDRESS ØF PAGE
/ NEW PRØGRAM CØUNTER

/ INDIRECT ADDRESS FLAG

/ MINUS HALT
/ MØDIFIED PRINTØUT FLAG
/ WAIT FLAG
/ MINUS IØN
/ PRINTØUT RØUTINE

/ JMP +JMS PRINTØUT FLAG

/ HALT

```
                *BEGIN+200
7000  6031  TI,     KSF              / IS THERE A CHARACTER TØ INPUT
7001  5761          JMP I ASTR       / NØ JMP TØ START
7002  7300  TIW,    CLA CLL          / YES CLEAR AC + LINK
7003  6031          KSF              / IS THERE A CHARACTER TØ INPUT
7004  5203          JMP .-1          / NØ WAIT
7005  6036          KRB              / YES INPUT CHARACTER
7006  3312  TICT,   DCA SCRLF        / STØRE TEMPØRARILY
7007  1312          TAD SCRLF        / GET CHARACTER
7010  4722          JMS I AØUT       / ØUTPUT IT
7011  1252          TAD TTAD         / SET UP
7012  3220          DCA ATTAD        / FØR CHECKING
7013  1253          TAD TJMP         / CHARACTER
7014  3224          DCA ATJMP        / SET UP CØUNTER,
7015  1254          TAD VAL          / JUMPS AND
7016  3255          DCA CTR          / CØMPARISØNS
7017  1312          TAD SCRLF        / GET CHARACTER
7020  1323  ATTAD,  TAD T12          / CHECK CHARACTER
7021  2220          ISZ .-1          / MØVE CHECKER
7022  2224          ISZ .+2          / MØVE JUMPER
7023  7450          SNA              / IS THERE A MATCH
7024  5741  ATJMP,  JMP I ATIX-1     / YES JUMP
7025  2255          ISZ CTR          / NØ MØVE CØUNTER
7026  5220          JMP ATTAD        / CHECK NEXT CHARACTØR
7027  7300          CLA CLL          / LAST CHARACTER FAILED
7030  1312          TAD SCRLF        / GET CHARACTER
7031  0247          AND MASK3        / CHECK TØ SEE
7032  1360          TAD M60          / IF IT IS A NUMBER
7033  7640          SZA CLA          / IS IT A NUMBER
7034  5277          JMP TIXX+3       / NØ
7035  1251          TAD TITP         / YES
7036  7104          CLL RAL          / PREPARE
7037  7104          CLL RAL          / TØ ADD
7040  7104          CLL RAL          / NUMBER TØ
7041  3251          DCA TITP         / STØRED NUMBER
7042  1312          TAD SCRLF        / GET NUMBER
7043  1360          TAD M60          / TRIM
7044  1251          TAD TITP         / ADD TØ ØLD NUMBERS
7045  3251          DCA TITP         / STØRE NUMBERS AND
7046  5202          JMP TIW          / WAIT
7047  7770  MASK3,  7770
7050  0000  TIAD,   0                / HØLD PARTIALLY ASSEMBLED DIGIT
7051  0000  TITP,   0                / HØLD ADDRESS
7052  1323  TTAD,   TAD T12
7053  5741  TJMP,   JMP I ATIX-1
7054  7763  VAL,    0-15
7055  7763  CTR,    0-15
7056  1251  TICM,   TAD TITP        / CØMMA RECEIVED
7057  3250          DCA TIAD         / PUT ADDRESS INTØ TIAD
7060  3251          DCA TITP         / AND CLEAR TITP
7061  5202          JMP TIW          / AND WAIT
7062  1250  TIRT,   TAD TIAD        / CARRIAGE RETURN RECEIVED
7063  4362          JMS VALID1       / CHECK FØR VALID ADDRESS
7064  5304          JMP TICK         / NØT VALID
7065  1251  TØK,    TAD TITP         / VALID, DEPØSIT DIGITS
7066  3650          DCA I TIAD       / INTØ ADDRESS
```

```
7067  3250  TIX,    DCA TIAD      / CLEAR TIAD
7070  3251          DCA TITP      / CLEAR TITP
7071  4312          JMS SCRLF     / SEND CARRIAGE RETURN,LINE FEED
7072  2702          ISZ I XFG5    / SET WAIT FLAG
7073  5202          JMP TIW       / WAIT
7074  7300  TIXX,   CLA CLL       / GET OLD
7075  1303          TAD ØPC       / PROGRAM COUNTER
7076  4740          JMS I ASND4   / OUTPUT IT
7077  1306          TAD EX        / SEND LETTER
7100  4722          JMS I AØUT    / X
7101  5267          JMP TIX       / INITIALIZE.
7102  6771  XFG5,   FG5           / WAIT FLAG
7103  0000  ØPC,    0             / ØLD PRØGRAM CØUNTER
7104  1250  TICK,   TAD TIAD      / CHECK FØR ADDRESS
7105  5741          JMP I ATCK    / ØF ACC. + LINK
7106  0330  EX,     330           / X
7107  1651  TIAR,   TAD I TITP    /-ARRØW RECEIVED
7110  4740          JMS I ASND4   / ØUTPUT CØNTENTS ØF
7111  5267          JMP TIX       / ADDRESS REQUESTED, INITIALIZE
7112  0000  SCRLF,  0             / SEND CARRIAGE RETURN,LINE FEED
7113  1320          TAD TCR       / GET CR
7114  4722          JMS I AØUT    / ØUTPUT
7115  1321          TAD TLF       / GET LF
7116  4722          JMS I AØUT    / ØUTPUT
7117  5712          JMP I SCRLF   / EXIT
7120  0215  TCR,    215           / CARRIAGE RETURN
7121  0212  TLF,    212           / LINE FEED
7122  7336  AØUT,   ØUTPUT        / ADDRESS ØF ØUTPUT RØUTINE
7123  7475  T12,    0-303         / 0-C
7124  0027  T13,    303-254       / C-CØMMA
7125  0037  T14,    254-215       / CØMMA-CARRIAGE RETURN
7126  7656  T15,    215-337       / CARRIAGE RETURN-ARRØW
7127  0036  T18,    337-301       / ARRØW-A
7130  7765  T19,    301-314       / A-L
7131  7775  T20,    314-317       / L-Ø
7132  0005  T21,    317-312       / Ø-J
7133  7767  T22,    312-323       / J-S
7134  0015  T23,    323-306       / S-F
7135  0004  T24,    306-302       / F-B
7136  7756  T25,    302-324       / B-T
7137  0004  T26,    324-320       / T-P
```

```
7140  7270  ASND4,   SEND4
7141  7517  ATCK,    TCK
7142  7264  ATIX,    C                 / CØNTINUE
7143  7056           TICM              / CØMMA
7144  7062           TIRT              / CARRIAGE RETURN
7145  7107           TIAR              / ARRØW
7146  7453  A,       ACM               / ACCUMULATØR
7147  7456  L,       LNK               / LINK
7150  7460  Ø,       ØRG               / ØRIGIN
7151  7467  J,       TRAN              / JMP + JMS ØNLY
7152  7474  S,       SHØRT             / SHØRT
7153  7501  F,       FULL              / FULL
7154  7436           ABØT              / BØTTØM
7155  7433           ATØP              / TØP
7156  7441           APNT              / PRINT
7157  7770  MN10,    0-10
7160  7520  MS0,     0-260
7161  6604  ASTR,    START
7162  0000  VALID1,  0                 / CHECK FØR VALID ADDRESS
7163  7450           SNA                 / IS ADDRESS ZERØ
7164  5374           JMP GØØD+1          / YES, NØ GØØD
7165  7100           CLL                 / NØ CHECK FURTHER
7166  1376           TAD MEND            / IS IT GREATER THAN
7167  7430           SZL                 / THIS PRØGRAM
7170  5373           JMP GØØD            / YES Ø.K.
7171  1377           TAD MBEGIN          / NØ, IS IT LESS
7172  7420           SNL                 / THAN THIS PRØGRAM
7173  2362  GØØD,    ISZ VALID1          / YES, SET UP EXIT
7174  7300           CLA CLL             / NØ
7175  5762           JMP I VALID1        / EXIT
7176  0201  MEND,    0-END-1
7177  0777  MBEGIN,  END-BEGIN+1
```

```
                *BEGIN+400
7200    1346    PRNT,   TAD APC         / GET PRØGRAM CØUNTER
7201    3345            DCA LØC         / STØRE PRØGRAM CØUNTER
7202    4763            JMS I ASIPT     / IF PRINTØUT IS DESIRED
7203    1761            TAD I AADD      / GET ADDRESS
7204    3355            DCA NUM         / STØRE ADDRESS
7205    1755            TAD I NUM       / GET CØNTENTS ØF ADDRESS
7206    3762            DCA I ACADD     / STØRE IN CADD
7207    1357            TAD FG1         / CHECK FØR
7210    7650            SNA CLA         / JMS + JMP ØNLY FLAG
7211    5215            JMP ØN+1        / NØ
7212    1760            TAD I AFG3      / YES , CHECK FØR
7213    7650            SNA CLA         / JMS + JMP PRINTØUT FLAG
7214    5751    ØN,     JMP I ASTART    / NØ.PRINTØUT
7215    4252            JMS PRINTE      / CHECK FØR
7216    0001    ØUT1,   0001            / PRØGRAM CØUNTER PRINTØUT
7217    4252            JMS PRINTE      / CHECK FØR
7220    0001    ØUT2,   0001            / INSTRUCTIØN PRINTØUT
7221    4252            JMS PRINTE      / CHECK FØR
7222    0001    ØUT3,   0001            / ACCUMULATØR PRINTØUT
7223    1344            TAD ØUT4        / CHECK FØR
7224    7650            SNA CLA         / LINK PRINTØUT
7225    5240            JMP ØUT5-1      / NØ LINK PRINTØUT
7226    1747            TAD I ALINK     / GET LINK
7227    1356            TAD NUMB        / CØNVERT TØ ASCII
7230    4336            JMS ØUTPUT      / ØUTPUT
7231    1353            TAD SPC         / ØUTPUT
7232    4336            JMS ØUTPUT      / TWØ
7233    1353            TAD SPC         / SPACES AFTER
7234    4336            JMS ØUTPUT      / LINK
7235    1764            TAD I AFG4      / CHECK FØR
7236    7640            SZA CLA         / MØDIFIED PRINTØUT
7237    5265            JMP CRLF        / YES, ØUTPUT CR,LF
7240    4252            JMS PRINTE      / CHECK FØR
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7241  0001  ØUT5,   0001              / ADDRESS PRINTØUT
7242  4252           JMS PRINTE       / CHECK FØR
7243  0001  ØUT6,   0001              / CØNTENTS ØF ADDRESS PRINTØUT
7244  1752           TAD I ADØIAD     / CHECK FØR
7245  7650           SNA CLA          / INDIRECT ADDRESS
7246  5265           JMP CRLF         / NØ, SEND CR,LF
7247  4252           JMS PRINTE       / YES, CHECK FØR
7250  0001  ØUT7,   0001              / INDIRECT ADDRESS PRINTØUT
7251  5265           JMP CRLF         / SEND CR,LF
7252  0000  PRINTE,  0                / CHECK FØR PRINTØUTS
7253  1652           TAD I PRINTE     / GET FLAG
7254  2252           ISZ PRINTE       / SET EXIT
7255  7650           SNA CLA          / IS FLAG SET
7256  5652           JMP I PRINTE     / NØ,. EXIT
7257  1745           TAD I LØC        / YES, GET DIGITS
7260  2345           ISZ LØC          / SET UP FØR NEXT ENTRANCE
7261  4270           JMS SEND4        / ØUTPUT FØUR ØCTAL DIGITS
7262  5652           JMP I PRINTE     / EXIT
7263  6771  AFG5,    FG5              / WAIT FLAG
7264  3663  C,       DCA I AFG5       / CØNTINUE, CLEAR WAIT FLAG
7265  4667  CRLF,    JMS I ACRLF      / SEND CR,LF
7266  5751           JMP I ASTART     / JMP TØ START
7267  7112  ACRLF,   SCRLF           / SENDS CR,LF
7270  0000  SEND4,   0000             / ØUTPUTS FØUR ØCTAL DIGITS
7271  3350           DCA TEMP         / STØRE DIGITS
7272  4322           JMS RØT          / RØTATE DIGITS RIGHT 9
7273  7767           0-11             / TIMES, MASK AND ØUTPUT
7274  4322           JMS RØT          / RØTATE DIGITS RIGHT 6
7275  7772           0-6              / TIMES, MASK AND ØUTPUT
7276  4322           JMS RØT          / RØTATE DIGITS RIGHT 3
7277  7775           0-3              / TIMES, MASK AND ØUTPUT
7300  4322           JMS RØT          / RØTATE DIGITS RIGHT 13
7301  7763           0-15             / TIMES, MASK AND ØUTPUT
7302  1353  SPACE,   TAD SPC          / GET SPACE
7303  4336           JMS ØUTPUT       / ØUTPUT
7304  1353           TAD SPC          / GET SECØND SPACE
7305  4336           JMS ØUTPUT       / ØUTPUT
7306  5670           JMP I SEND4      / EXIT
7307  0000  CKAIR,   0
7310  0320           AND MASK5        / CHECK FØR ADDRESS
7311  7640           SZA CLA          / LESS THAN 20
7312  5707           JMP I CKAIR      / NØ
7313  1761           TAD I AADD       / YES
7314  1321           TAD CAIR         / SET UP INSTRUCTIØN
7315  3316           DCA KAIR         / TØ INDEX
7316  0000  KAIR,    0                / AUTØ INDEX REGISTER
7317  5707           JMP I CKAIR      / RETURN
7320  7760  MASK5,   7760
7321  0400  CAIR,    AND I Z 0
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7322  0000  RØT,     0000              / RØTATES DIGITS AND ØUTPUTS
7323  1722            TAD I RØT         / GET NUMBER ØF RØTATES
7324  3355            DCA NUM           / STØRE NUMBER
7325  1350            TAD TEMP          / GET DIGITS TØ BE ØUTPUTTED
7326  7010            RAR               / RØTATE RIGHT
7327  2355            ISZ NUM           / MØRE
7330  5326            JMP .-2           / YES
7331  0354            AND MASK6         / NØ, TRIM DIGITS
7332  1356            TAD NUMB          / CØNVERT TØ ASCII
7333  4336            JMS ØUTPUT        / ØUTPUT
7334  2322            ISZ RØT           / SET UP EXIT
7335  5722            JMP I RØT         / EXIT
7336  0000  ØUTPUT,   0                 / ØUTPUTS ØNE CHARACTER
7337  6041            TSF               / READY TØ ØUTPUT
7340  5337            JMP .-1           / NØ
7341  6046            TLS               / YES, ØUTPUT
7342  7300            CLA CLL           /-CLEAR AC + LINK
7343  5736            JMP I ØUTPUT      / EXIT
7344  0001  ØUT4,     0001              / FLAG FØR LINK ØUTPUT
7345  0000  LØC,      0000              / HØLDS ADDRESS ØF DIGITS
7346  6751  APC,      PC                / PRØGRAM CØUNTER
7347  6757  ALINK,    LINK              / LINK
7350  0000  TEMP,     0000              / HØLDS DIGITS TØ BE ØUTPUTTED
7351  7000  ASTART,   TI                / START
7352  6755  AØIAD,    DØIADD            / INDIRECT ADDRESS INDICATØR
7353  0240  SPC,      0240              / SPACE
7354  0007  MASK6,    0007              / MASK FØR ØUTGØING CHARACTERS
7355  0000  NUM,      0000              / HØLD NUMBERS
7356  0260  NUMB,     0260              / CØNVERTS TØ ASCII
7357  0000  FG1,      0                 / JMS + JMP ØNLY FLAG
7360  6775  AFG3,     FG3               / JMS + JMP PRINTØUT FLAG
7361  6754  AADD,     ADD               / ADDRESS
7362  6755  ACADD,    CADD              / CØNTENTS ØF ACCUMULATØR
7363  7541  ASIPT,    SIPT              / SHØULD I PRINT
7364  6770  AFG4,     FG4               / MØDIFIED PRINTØUT FLAG
7365  6756  AIAD,     IADD              / INDIRECT ADDRESS
7366  0000  VALID,    0                 / CHECK FØR
7367  1761            TAD I AADD        / VALID ADDRESS
7370  4773            JMS I AVLD1
7371  5774            JMP I ANØ         / NØT VALID
7372  5766            JMP I VALID       / VALID
7373  7162  AVLD1,    VALID1
7374  6745  ANØ,      NØ
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                *BEGIN+600
7400  0000  MB0T,    0                / MINUS B0TT0M LIMIT
7401  0000  MT0P,    0                / MINUS T0P LIMIT
7402  7776  B0T,     7776             / B0TT0M LIMIT
7403  0001  T0P,     0001             / T0P LIMIT
7404  0000  VALID2,  0                / CHECK F0R VALID ADDRESS
7405  3376            DCA  END         / ST0RE ADDRESS
7406  1202            TAD  B0T         / GET B0TT0M LIMIT
7407  7040            CMA              / MAKE IT NEGATIVE
7410  3200            DCA  MB0T        / ST0RE IT
7411  1203            TAD  T0P         / GET T0P LIMIT
7412  7041            CIA              / MAKE IT APPR0PRIATE
7413  7001            IAC              / F0R CALCULATI0NS
7414  1202            TAD  B0T         / 0F LIMITS
7415  3201            DCA  MT0P        / ST0RE IT
7416  1376            TAD  END         / GET ADDRESS
7417  7450            SNA              /-IS IT ZER0
7420  5230            JMP  V0K+1       / YES, N0 G00D
7421  7100            CLL              / N0
7422  1200            TAD  MB0T        / IS IT 0UTSIDE
7423  7430            SZL              / 0F L0WER LIMIT
7424  5230            JMP  V0K+1       / YES, N0 G00D
7425  1201            TAD  MT0P        / N0, IS IT 0UTSIDE
7426  7430            SZL              / 0F UPPER LIMIT
7427  2204  V0K,      ISZ  VALID2      / N0, SET UP EXIT
7430  7300            CLA CLL          / CLEAR ACC + LINK
7431  5604            JMP I VALID2
7432  5604            JMP I VALID2     / EXIT
7433  1672  AT0P,     TAD I ATITP      / GET UPPER LIMIT
7434  3203            DCA  T0P         / ST0RE IT
7435  5645            JMP I TTIX       / WAIT
7436  1672  AB0T,     TAD I ATITP      / GET L0WER LIMIT
7437  3202            DCA  B0T         / ST0RE IT
7440  5645            JMP I TTIX       / WAIT
7441  1672  APNT,     TAD I ATITP      / GET ADDRESS AT WHICH
7442  7041            CIA              / PRINT0UT WILL START
7443  3646            DCA I YESP       / ST0RE IT
7444  5645            JMP I TTIX       / WAIT
7445  7067  TTIX,     TIX              / WAIT
7446  7540  YESP,     PTYES            / START 0F PRINT0UT ADDRESS
7447  6757  ALK,      LINK             / LINK
7450  6753  ACCUM,    ACC              / ACCUMULAT0R
7451  7357  AFLG,     FG1              / JMS+ JMP 0NLY FLAG
7452  6604  AST,      START            / START
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7453  1250  ACM,    TAD ACCUM      / A GET ADDRESS ØF ACCUMULATOR
7454  3672          DCA I ATITP    / STØRE IN TITP
7455  5673          JMP I ATIW     / WAIT
7456  1247  LNK,    TAD ALK        / L GET ADDRESS OF LINK
7457  5254          JMP ACM+1      / STORE IN TITP + WAIT
7460  1672  ØRG,    TAD I ATITP    / Ø GET ADDRESS
7461  3400          DCA I ANC      / PUT IN NEW PRØGRAM COUNTER
7462  3672          DCA I ATITP    / CLEAR TITP
7463  3666          DCA I AF5      / CLEAR WAIT FLAG
7464  4671          JMS I ASCRLF   / ØUTPUT CR,LF
7465  5652          JMP I AST      / JUMP TØ START
7466  6771  AF5,    FG5            / WAIT FLAG
7467  2651  TRAN,   ISZ I AFLG    / J SET JMS + JMP ØNLY FLAG
7470  5305          JMP WHERE      / JUMP TØ WHERE
7471  7112  ASCRLF, SCRLF         / CR,LF
7472  7051  ATITP,  TITP          / TITP
7473  7002  ATIW,   TIW           / WAIT
7474  3651  SHØRT,  DCA I AFLG    / S CLEAR JMS + JMP ØNLY FLAG
7475  3714          DCA I AØUT5    / CLEAR ADDRESS FLAG
7476  3715          DCA I AØUT6    / CLEAR CØNTENTS ØF ADD FLAG
7477  3716          DCA I AØUT7    / CLEAR INDIRECT ADD FLAG
7500  5305          JMP WHERE      / JUMP TØ WHERE
7501  3651  FULL,   DCA I AFLG    / F CLEAR JMS + JMP ØNLY FLAG
7502  2714          ISZ I AØUT5    / SET ADDRESS FLAG
7503  2715          ISZ I AØUT6    / SET CØNTENTS ØF ADD FLAG
7504  2716          ISZ I AØUT7    / SET INDIRECT ADD FLAG
7505  1734  WHERE,  TAD I ANC     / GET NEW PRØGRAM CØUNTER
7506  4735          JMS I ASD4     / ØUTPUT IT
7507  4671          JMS I ASCRLF   / SEND CR,LF
7510  1666          TAD I AF5      / CHECK WAIT FLAG
7511  7640          SZA CLA        / IS IT SET
7512  5673          JMP I ATIW     / YES, WAIT
7513  5652          JMP I AST      / NØ, JUMP TØ START
7514  7241  AØUT5,  ØUT5           / ADDRESS FLAG
7515  7243  AØUT6,  ØUT6           / CØNTENTS ØF ADD FLAG
7516  7250  AØUT7,  ØUT7           / INDIRECT ADD FLAG
7517  1331  TCK,    TAD MACC       / CHECK FØR ADDRESS ØF
7520  7450          SNA            / ACCUMULATØR
7521  5327          JMP ØK         / ØK
7522  1332          TAD MLK        / CHECK FØR ADDRESS ØF
7523  7650          SNA CLA        / LINK
7524  5327          JMP ØK         / ØK
7525  4671          JMS I ASCRLF   / NØ GØØD, SEND CR,LF
7526  5774          JMP I ATX      / SEND X
7527  5730  ØK,     JMP I ATØK     / ØK
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7530  7065  ATØK,    TØK                / ØK
7531  1025  MACC,    0-ACC              / ADDRESS ØF ACCUMULATOR
7532  7774  MLK,     ACC-LINK           / ACC-LINK
7533  7074  ATIXX,   TIXX               / WAIT
7534  6761  ANC,     NEWPC              / NEW PRØGRAM CØUNTER
7535  7270  ASD4,    SEND4              / OUTPUTS FOUR OCTAL DIGITS
7536  7000  ATI,     TI                 / START
7537  6751  TPC,     PC                 / PRØGRAM CØUNTER
7540  0000  PTYES,   0                  / START ØF PRINTØUT ADDRESS
7541  0000  SIPT,    0                  / SHØULD I PRINT
7542  1340           TAD PTYES.         / CHECK FØR START
7543  7450           SNA                / ØF PRINTØUT
7544  5350           JMP .+4            / DØNT CHECK
7545  1737           TAD I TPC          / CØMPARE PRØGRAM
7546  7640           SZA CLA            / CØUNTER WITH START ØF
7547  5736           JMP I ATI          / PRINT ADDRESS, NØ MATCH
7550  3340           DCA PTYES          / MATCH, START PRINTING
7551  5741           JMP I SIPT         / EXIT
7552  7162  VLD1,    VALID1
7553  0000  HELP,    0                  / HØUSEKEEPING
7554  1737           TAD I TPC          / GET PRØGRAM CØUNTER
7555  3775           DCA I AØPC         / PUT IT IN ØLD PRØGRAM CTR.
7556  1734           TAD I ANC          / GET NEW PRØGRAM CØUNTER
7557  3737           DCA I TPC          / PUT IT IN PRØGRAM CØUNTER
7560  1734           TAD I ANC          / GET NEW PRØGRAM CØUNTER
7561  4752           JMS I VLD1         / CHECK TØ SEE IF VALID
7562  5733           JMP I ATIXX        / NØ, SEND X
7563  1734           TAD I ANC          / YES
7564  4204           JMS VALID2         / CHECK TØ SEE IF
7565  7410           SKP                / WITHIN LIMITS
7566  5753           JMP I HELP         / YES
7567  1372           TAD EL             / NØ, SEND L
7570  4773           JMS I LØUT
7571  5645           JMP I TTIX         / WAIT
7572  0314  EL,      314                / L
7573  7336  LØUT,    ØUTPUT
7574  7077  ATX,     TIXX+3
7575  7103  AØPC,    ØPC                / ØLD PRØGRAM CØUNTER
7576  0000  END,     0                  / THE END
```