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LINC-8 SIMULATOR TRAP PROCESSOR

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1. ABSTRACT

The LINC-8 Simulator Trap Processor handles Teletype input and output for LINC-8 and classic LINC programs when they are run on the PDP-12. It must be loaded into the PDP-12 core memory with any LINC-8 or classic LINC program which uses the keyboard, or any classic LINC program which uses the Teleprinter, in order for that program to run on the PDP-12.

The trap processor operates by using the PDP-12 Instruction Trap Facility to detect execution of either of the two LINC-8 Teletype input/output instructions by the user's program. It responds to user's execution of a Teletype instruction by executing coding to simulate the instruction's LINC-8 or classic LINC effect. After simulation of the instruction, the trap processor returns control to the user program.

Users may easily adapt the LINC-8 Simulator Trap Processor to their own purposes. Explicit instructions for a number of useful adaptions are provided in this document, along with enough information on the internal operation of the program to permit users to easily implement adaptions of their own invention. In this connection, attention is directed to the Dispatch Table Trap Processor, DEC-12-SI2A. It is a more suitable starting point for building extended trap processors which process a large number of different trapped instructions than is the LINC-8 Simulator Trap Processor.

An important limitation of the trap processor is that it is not interruptible. It may not be operated when the PDP-12 Program Interrupt is enabled.

This document applies to the machine readable program version bearing software product code DEC-12-SI1B-UA.

2. EQUIPMENT AND STORAGE REQUIREMENTS

2.1 Equipment

The LINC-8 Simulator Trap Processor is at present distributed in LINCtape form only, and therefore requires a PDP-12 with LINCtape control and at least one TU55 DECtape/LINCtape transport for program loading. The program itself will run on a minimum PDP-12.

The program operates correctly both in 4K PDP-12's and in PDP-12's having any amount of extended memory up to the 32K maximum total. Instruction traps originating in extended memory will be processed no differently than the same instruction traps originating in basic memory.

2.2 Storage

The program occupies most of the locations below 462, plus locations 700 to 717, all in PDP-12 memory segment 0.

3. LOADING, STARTING AND RESTARTING

3.1 Loading Procedure

The program is distributed on a DIAL tape. Load and start that copy of DIAL, and type into DIAL,

↓LO L8S1M,0)

(The symbol ↓ means Teletype LINE FEED.) means CARRIAGE RETURN.)

The LINC-8 Simulator Trap Processor will be loaded from the DIAL tape into the PDP-12 core memory, and the computer will halt.

3.2 Normal Starting Procedure (Start 400)

Press I/O Preset, and then Start 400. The program will turn on the Instruction Trap Enable Flip-Flop and halt with the Instruction Field set to 2 and the Data Field set to 3. Verify that the Instruction Trap Enable Flip-Flop is on by observing the console TRAP indicator. This indicator should be lit. If it is not, some kind of error has occurred. The error may be either a machine error or an operator error. Reload the trap processor and try again.

Now read in the user program. If the program is located on some specific block(s) of a LINCtape, mount the tape on either transport and execute an appropriate tape instruction from the console as if the machine were a LINC or a LINC-8. If the user program is a named file on a LAP6-3L or GUIDE tape, mount the tape on unit 0, set the LOCAL-OFF-REMOTE switch to REMOTE and press CONT. GUIDE or LAP6-3L* will be loaded, and the user program may be recalled using the usual GUIDE or LAP6 program loading procedure.

If the user program is on paper tape, read it in and start it using the usual paper tape loading and starting procedures, as described in the Binary Loader operating instructions, DEC-08-LBAA-D.

*LINC-8 and LINC users will recall that the GUIDE program starting procedure may be used with either GUIDE or LAP6-3L.

Switch the processor mode to the PDP-8 mode by executing the PDP instruction (octal:0002) before using the Binary Loader. Mode changing through use of I/O Preset in conjunction with the console Mode key should be avoided because I/O Preset clears the Instruction Trap Enable Flip-Flop.

3.3 Starting Procedure for Immediate GUIDE or LAP6-3L Loading and Starting (Start 20)

To automatically load and start a LINC-8 GUIDE or LAP6-3L tape along with the trap processor, load the trap processor from the DIAL tape as directed above, and then press I/O Preset, Start 20, rather than I/O Preset, Start 400. A GUIDE or LAP6-3L system will be read in from unit 0 and started.

This procedure duplicates the "Start 400" procedure given above, with the exception that the computer does not halt between the trap processor initialization and the loading and starting of the GUIDE or LAP6-3L system.

3.4 The Instruction Trap Enable Flip-Flop

Once a user program has been read in and started, the machine behaves like a LINC-8 or classic LINC with respect to Teletype input and output thereafter, but only if the Instruction Trap Enable Flip-Flop has been set. The PDP-12 Instruction Trap Enable Flip-Flop must be set in order for the trap processor to work. The state of this flip-flop is indicated by the TRAP light on the computer console. If the trap processor is loaded exactly as directed above, and if the user program is operated exactly as its instructions direct, the Trap Enable Flip-Flop will never be cleared, and will cause no problems. However, in practice it is sometimes cleared (by the operator pressing I/O PRESET for example), so some convenient methods for resetting it are included in the trap processor program in the form of the following restart procedures.

3.5 Normal Restart (Start 400)

If the Instruction Trap Enable Flip-Flop has been cleared, it may be set again (providing the trap processor has been loaded into core as directed above) by starting at location 400 in memory segment 0 (absolute address 00400). Note that the START 400 key may not be used for this unless the Instruction Field (IF) is set to 0 because START 400 takes the high order 5 bits of the starting address from the IF. Set 0400 into the Left Switches and use START LS, rather than Start 400. Use of this entry point sets the Trap Enable Flip-Flop and halts the computer. (Setting of the Trap Enable Flip-Flop may be confirmed by observing the console TRAP indicator.) Pressing continue after the computer has halted causes a transfer to location 400 in memory segment 2 (absolute address 04400), with the Data Field set to 3.

3.6 "User 20" Restart (Start 20)

Starting at location 20 in memory segment 0 (00020) sets the Trap Enable Flip-Flop and immediately transfers control to location 20 in memory bank 2 (absolute address 04020), with the Data Field set to 3. Note that the START 20 key may not be used for this unless the Instruction Field (IF) is set to 0 because START 20 takes the high order 5 bits of the 15 bit starting address from the IF. Set 0020 in the Left Switches and use Start LS, rather than using START 20.

3.7 GUIDE Load Restart (Start 700-717)

A third alternative is to start at any location between 700 and 717 in field 0. Use of any of these entry points sets the Trap Enable Flip-Flop and then loads and starts the LINC GUIDE or LAP6 system (if an appropriate tape is mounted on transport 0 and the LOCAL-OFF-REMOTE switch is set to REMOTE).

4. PROGRAM OPERATION

Once the LINC-8 or classic LINC user program and the LINC-8 Simulator Trap Processor have both been loaded into PDP-12 memory, the operating instructions for the user program apply, and the user program will behave as it would on a LINC-8 or classic LINC, and no special account need be taken of the fact that a PDP-12 rather than a LINC-8 or classic LINC is being used. There are a couple of minor exceptions to this. The PDP-12 console operates slightly differently from the LINC-8 console and the classic LINC console. Also, the characters which in the LINC are obtained by striking the CASE key and then some other key such as .,= and ▭ are obtained in the PDP-12 by striking a single Teletype key. The Teletype keys which are used to obtain the various LINC codes are indicated in the following diagram of the Teletype keyboard.

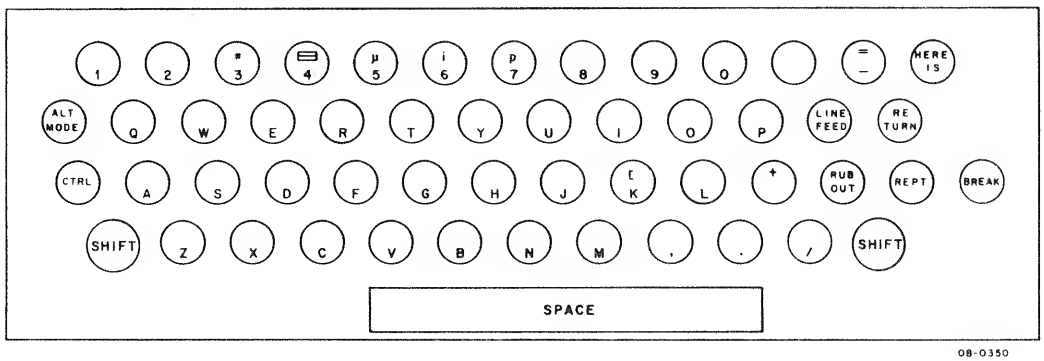

Figure 1. Location of LINC keys on the Teletype keyboard

An additional exception to strict classic LINC compatibility concerns "echoing" of keyboard characters. Characters typed into a user program running with the trap processor are automatically printed on the Teleprinter by the trap processor. Instructions for suppressing this feature are given in Section 6.6, Adaption to Suppress Teletype Character Echoing.

4.1 Illegal Teletype Characters

Some teletype keys, such as the semi-colon key, are not used for any LINC characters, either standard or special. These keys should not be struck when the trap processor is being used to run LINC or LINC-8 programs. If one of these illegal keys is struck, it is printed on the Teletype preceded by an up arrow, "↑". Control is not returned to the user's LINC-8 or classic LINC program until a legal character is struck.

The following Teletype keyboard characters are illegal:

!, ", TAB, (,), *, ?, @,], ↑, ;, <, >.

4.2 Undefined Instruction Error Stop

The trap processor halts at location 130 in memory segment 0 when any instruction other than a Teletype input or output instruction is given. The trapped instruction is contained in the accumulator, and the address of the instruction is in location 134 of memory segment 0.

5. INTERNAL OPERATION

5.1 Overview

Teletype input-output in LINC and LINC-8 programs involves only three instructions: Keyboard (mnemonic KBD; instruction code 515), Type Out (mnemonic TYP; instruction code 514) and Key Struck (mnemonic KST; instruction code 415). These are the only LINC-8 instructions whose operation involves the LINC-8 Simulator Trap Processor. The processing performed by the LINC-8 Simulator Trap Processor for the KBD and TYP instructions consists of detection of their execution by the user program, and execution of programming to reproduce in detail their LINC-8 or classic LINC effect. The KST instruction is a skip instruction which skips when the Teletype keyboard flag is set. This flag is set by the hardware when the operator strikes a Teletype key. The trap processor clears it when there is no keyboard character available for the user program to read in.

Processing for the trapped instructions KBD and TYP consists of three steps. Processing is initiated by the occurrence of an instruction trap. The first step consists of the identification of the instruction causing the trap. The second step is the execution of programming to simulate the LINC-8 effect of the particular trapped instruction. The final step is the return of control to the user program.

In addition to the "trap processor proper", which performs as described above, the program as distributed contains small amounts of code to implement the various console restarts described above.

5.2 Console Starts and Restarts

The program is initially loaded into memory segment 2, and relocates itself into segment 0 as soon as it is started. This technique is used because it leads to a particularly simple procedure for loading the program directly from LINCtape using the console functions. See Section 6.3, Adaption for Convenient Loading of the Trap Processor from GUIDE and LAP6-3L Tapes, for a description of this procedure. If the routine had to be loaded into segment 0 directly, the console procedure for loading it would be more complicated than it is because the operator would have to set one of the 5-bit Field Registers to 0 before execution of the tape read instruction in order to load data into segment 0. As is, the user may initially load the program into any memory segment for which memory is physically present.

Both the "Start 20" and "Start 400" program starting procedures execute the trap processor relocator routine at symbolic location SETUP. This routine relocates the trap processor from the current instruction field into memory segment 0. Notice that the relocator routine is not itself relocated, since it is used only once. After the trap processor has been relocated, the locations 700 through 717 are filled with "JMP GUIDE". This operation provides for restarting of the GUIDE system using the Start Left Switches function when any tape instruction is set into the Left Switches.

5.3 Operation of the Instruction Trap Hardware

The trap processor operates with the Instruction Trap facility enabled, so execution of any trappable instruction (except tape instructions) by the user's program causes a transfer of control to location 141 in memory segment 0 (absolute address 00141). Also, the low order 12 bits of the address of the instruction following the trap instruction is stored in location 140, and the contents of the Instruction Field and Data Field when the trap occurred is stored in the Save Field Register.

5.4 Machine State Saving

The instructions between 140 and symbolic location FETCH saves registers and indicators whose contents will be affected by the operation of the trap processor. They will be restored before control is returned to the user program. Notice that the Overflow flip-flop and memory location 0 are both saved. They are both affected by the operations in the trap processor.

5.5 Instruction Identification

The code from symbolic location FETCH to OP14 obtains the instruction causing the trap and transfers control to the subroutine which performs the LINC-8 function of the particular instruction.

5.6 TYP Processing

TYP and TYP I (OPR14 and OPR I 14) are processed identically, by the subroutine beginning at OPI14. Note that exit from the subroutine does not occur until the Teleprinter has completely finished printing the character. This assures that the printer will be ready to accept a new character the next time the subroutine is entered.

5.7 KBD Processing

The routine begins at tag OP15 and ends just before tag INIT. It has three functions. The functions are interrelated and are not performed in any simple sequence by the routine. Consequently, the following discussions of them do not reference specific pieces of code within the routine.

The first function performed is the translation of ASCII character code characters into LINC character code characters. (Part of the definition of the LINC KBD instruction is that characters which are read in by the instruction have the LINC character code.) This translation sometimes requires that two characters be passed to the user program when only one Teletype character has been typed. Some LINC "special" characters (?, =, u, , ., , [, _, :) did not have their own keys, and existed only by virtue of the convention that the "CASE" character followed by some other character was to be interpreted as a "special" character. The Teletype keyboard has a "SHIFT" facility whereby a single key may generate more than one character code, and, because of its ease of use, this "SHIFT" technique rather than the "CASE key" technique is used in the PDP-12 (and also the LINC-8) to generate the "special" characters. But since LINC programs "expect" to have special characters entered as two characters, and in general have no provision for accepting them in any other way, the trap processor must generate the appropriate pair of characters in response to the use of a single Teletype key.

The second function of this routine is the interpretation of the I bit. This bit, when raised, means, "Don't execute the next instruction until a character from the keyboard has been acquired. If no character has been typed, pause until the user types one."

The final function of the routine is the clearing of the keyboard flag. This is the flag which is sensed by the LINC KST instruction. Note that when two LINC characters are generated in response to one Teletype character, the flag is not cleared until after the second LINC character has been generated. This assures that the user program will "think" that the operator has struck the second character, and will execute the KBD instruction which collects that second character.

5.8 Return to User Program

The routine to return control to the user program begins at symbolic location RET and ends at OVN. The routine is entirely straightforward. It simply restores the various registers in the machine to their values prior to entry to the trap processor. Note that when the KBD instruction has been given the AC will get filled with some character code rather than with its contents at the time of trap processor entry.

6. LINC-8 SIMULATOR TRAP PROCESSOR ADAPTIONS

6.1 Adaption to Process Additional LINC-8 OPR's

LINC-8 and classic LINC installations often use instructions of the LINC OPR group for purposes other than control of the Teletype. For example, an installation may use OPR's 5, 6, 7, 10, 11 and 12 for controlling pen motion on an incremental plotter. Each OPR causes the pen to move one increment in one of six directions. In this section, we indicate how the LINC-8 Simulator Trap Processor may be "custom tailored" to process additional OPR's or other trapped instructions. In general, such modifications involve three steps:

a. extension of the trapped instruction identification routine to recognize trapped instructions other than the Teletype OPR's

b. addition of a routine to simulate the effect of the LINC-8 or LINC OPR instruction; and

c. return of control to the user program.

The extension to the trap identification routine consists simply of adding instructions to transfer control to a subroutine when one of the new OPR's is recognized. The new instructions should be added at

symbolic location OTHERS, and care should be taken to preserve the error stop which occurs when the trapped instruction is not recognized.

A routine which is entered when the new OPR's are given must be added to the program. The details of this routine are entirely dependent on the character of the new OPR.

Finally, the user program must be re-entered. This is accomplished by transferring control to symbolic location RET. Existing coding attends to the details of restarting the user program.

6.2 Example: Operating the XY12 Plotter Control with LINC or LINC-8 OPR's

Suppose that a LINC-8 or LINC user is operating an incremental plotter with 6 OPR instructions which work as follows:

OPR	5 (0505)	- lower pen
OPR	6 (0506)	- raise pen
OPR	7 (0507)	- move drum up 1 unit
OPR	10 (0510)	- move drum down 1 unit
OPR	11 (0511)	- move pen right 1 unit
OPR	12 (0512)	- move pen left 1 unit

Suppose further that each OPR "pauses" until the completion of the plotter operation caused by its execution. That is, execution of an OPR is not completed, and execution of the following instruction does not begin until the plotter operation caused by the OPR is completed. This "paused" mode of operation obtains whether or not the instruction's I bit is set.

The XY12 plotter control used the following PDP-8 mode commands:

PLSF	(6501)	- Skip on Plotter Flag
PLCF	(6502)	- Clear Plotter Flag
PLPU	(6504)	- Pen Up
PLPR	(6511)	- Pen Right
PLDU	(6512)	- Drum Up
PLDD	(6514)	- Drum Down
PLPL	(6521)	- Pen Left
PLPD	(6524)	- Pen Down

The plotter flag is set by the completion of a plotter command affecting the pen or the drum. It is cleared by the PLCF command only. The pen and drum commands do not affect the plotter flag.

The following modifications to the LINC-8 Simulator Trap Processor will enable it to run LINC or LINC-8 programs which operate the plotter in the manner described above:

1. Replace the instruction at symbolic location OTHER with the following instruction:

```
OTHER,      JMP PLOT
```

2. Add this subroutine to the program just after symbolic location ENDX. (Actually, the routine could be inserted anywhere before TABE, which is the last location loaded into memory segment 0 by the loading sequence.)

```
/
/SUBR TO RUN XY12 CONTROL FROM LINC
/MODE USING TRAPPED OPRS.
PLOT,           STA I                   /SAVE INSTRUCTION
PLINST,           0
                BCL I                   /IGNORE INSTRUCTION I BIT
                  I
                ADA I
                -OPR-12
                APO I                   /OPR 12 OR LESS?
                JMP PLERR               /NO.  ERROR
                ADA I                   /YES. OK SO FAR
                  6
                APO                     /OPR 5 OR MORE?
                JMP PLERR               /NO.  ERROR
                ADA I                   /YES. OBTAIN COMMAND
                ADD PLTAB-1
                STC .+1
                HLT                     /BECOMES ADD PLTAB + N
                STC  PLGO
                PDP
                PMODE
                PLCF
PLGO,           HLT                     /PLPU,PLPR, ETC
                PLSF
                JMP .-1
                LINC
                LMODE
                JMP RET                 /RETURN TO USER
/
/INSTRUCTION NOT RECOGNIZED
PLERR,          LDA
                PLINST
                JMP ERR                 /DO ERROR STOP
                PDP
                PMODE
PLTAB,          PLPD                    /PEN DOWN. OPR 5
                PLPU                    /PEN UP
                PLDU                    /DRUM DOWN
                PLDD                    /DRUM UP
                PLPR                    /PEN RIGHT
                PLPL                    /PEN LEFT .OPR 12
                LINC
                LMODE
```

These modifications are most easily made by modifying the program's source and reassembling the program, as opposed to manually inserting the new instructions from the computer console.

6.3 Adaption for Convenient Loading of the Trap Processor from a GUIDE or LAP6-3L Tape

A particularly convenient way of using the trap processor with an existing GUIDE or LAP6-3L tape is to copy the program in exactly its present form onto some otherwise unused tape blocks and subsequently load it directly from these tape blocks using console functions. The advantage of this loading procedure is that it involves only the tape with the programs which are to be run with the trap processor. No separate DIAL tape is required for program loading purposes.

Procedures are given below for copying the trap processor onto a GUIDE or LAP6-3L tape and for subsequently reading it back into core for use with a LINC or LINC-8 program. Note that the program is stored in pairs of blocks which begin at blocks having block numbers which are multiples of 10 - e.g., blocks 10 and 11, or 230 and 231. This is done so that the tape group instructions WCG and RCG may be used to effect the tape operations involving the programs.

Notice also that this procedure may be used with LINCtapes other than GUIDE or LAP6-3L tapes.

Procedure to Copy the Trap Processor onto a GUIDE or LAP6-3L Tape:

1. Load the Trap Processor from a DIAL tape using the usual procedure.
2. Press I/O Preset.
3. Mount a GUIDE or LAP6-3L tape on unit 0.
4. Set in the Left and Right Switches:

Left	Right
0705	1XX0

(XX0 is the first tape block of the pair of blocks in which the program is to be stored.)

5. Press DO. The Trap Processor will be written into the designated tape block.

Procedure to Load the Trap Processor from a GUIDE or LAP6-3L Tape:

1. Press STOP. Mount the GUIDE or LAP6-3L tape on unit 0.
2. Press I/O Preset.
3. Set in Left and Right Switches:

Left	Right
0701	1XX0

(XX0 is the first tape block of the pair of blocks onto which the program has been copied.)

4. Press DO. The Trap Processor will be read into memory segment 2.

5. Press Start 20. The Trap Processor will relocate itself from segment 2 into segment 0 and the GUIDE or LAP6-3L System will be loaded and started.

6.4 Adaption for Convenient Loading with a User Program from a DIAL Tape

The LINC-8 Simulator Trap Processor is designed to be loaded into memory ahead of user programs. In normal use, it is loaded into memory segment 2, and relocates itself into segment 0 as soon as it is started in order to leave segment 2 free for user programming. It is not difficult to modify the trap processor so that it may be loaded directly into segment 0. This modification may be made in the assembly source of the program, and this modified source may be assembled along with a DIAL source of the user program. Such a source may be obtained from a LAP6 source through use of the program CONVERT. The resulting program may then be filed and retrieved from LINCtape as a single binary program. However, once the program is loaded from LINCtape, one of the trap processor restarts must be executed in order to initialize the trap processor and set the Instruction Trap Enable Flip-Flop.

Production of a source modified for segment 0 loading consists of the following three steps:

1. Insert the pseudo-op SEGMNT 0 before the first line of code in the source program.
2. Replace the instructions in location 20 and symbolic location RST400 with "JMP INIT". This step prevents entry to the trap processor relocating program.
3. Delete all instructions after symbolic location TABE. These instructions comprise the trap processor relocation routine, which is no longer needed.

6.5 Adaption for Loading of Programs Other than GUIDE and LAP6-3L by the Trap Processor

It is easy to modify the trap processor to load programs other than GUIDE or LAP6-3L when using the automatic loading and starting feature. The code which implements the load and start feature begins at symbolic location GUIDE+1. It is quite straightforward:

```
GUIDE,      JMP  INIT          /INITIALIZE TRAP PROCESSOR
            LDF  2
            RDC                /READ GUIDE START BLOCK
            7400               /INTO QUARTER 3, SEGMENT 2
            LDF  3
            LIF  2
            DJR
            JMP  1400          /START GUIDE
```

As an example, suppose that the trap processor is to be used with a LAP6 version other than LAP6-3L. Suppose the LINC-8 or classic LINC console procedure for loading and starting the other LAP6 version consists of executing the double-word tape instruction RCG 7300, and then pushing "START 20". The trap processor will perform this operation if the code at symbolic location GUIDE is replaced by the following:

```
GUIDE,      JMP         INIT        /INITIALIZE TRAP PROCESSOR
            LDF         2
            LDA         I           /PUT RCG 7300 IN
            RCG                     /4016 AND 4017
            STA
            2016
            LDA         I
            7300
            STA
            2017
            LDF         3
            LIF         2
            JMP         16          /JUMP TO 4016
```

The instruction RCG 7300 is inserted into locations 16 and 17 in memory bank 2 - i.e., 4016 and 4017 - and is immediately executed from these locations.* The next instruction is taken from location 4020. This is the starting location of the program.

6.6 Adaption to Suppress Teletype Character Echoing

The trap processor echoes characters typed by the computer operator on the console teleprinter in addition to transmitting them to the user program. This character "echoing" may be suppressed by removing seven instructions beginning at symbolic location L001. After modification, the section of the program near L001 should look like this:

```
L00,        STC         AC          /STORE IT FOR TRANSFER
            STC         UPC         /CLEAR LEFT OVER BUFFER
            IOB
            KRBA                    /READ CHAR AND
                                    /CLEAR KEYBOARD FLAG
L001,       JMP         RET         /RETURN TO USER PROGRAM
/
/ILLEGAL CHARACTER
RETX,       LDA I                   /PRINT UP ARROW.
              .
              .
              .
              .
```

*One might ask here, "What happens if the RCG instruction fails at, say, block 301? The computer will try to execute the RCG again from the beginning, but the instruction will have been destroyed by the arrival in core of block 300." The answer is that when the PDP-12 tape control retries an instruction, it does not read the instruction from core a second time. It uses the same data it obtained when the instruction was read initially.

```
0000                    *20
0001                    /LINC-8 SIMULATOR TRAP PROCESSOR, DEC-12-SI1B.
0002                    /
0003                    /COPYRIGHT 1969, DIGITAL EQUIPMENT CORP.
0004                    /MAYNARD, MASS.
0005                    /
0006                    /D. LANGBEIN, 27 MAY 1969
0007                    /REVISED 21 JULY 1969
0010                    /REVISED 8 AUGUST 1969
0011                    /
0012                    /OPERATION DEFINITIONS FOR LINC MODE ASSEMBLY
0013                    /OF PDP-8 MODE IOT INSTRUCIONS
0014                    KCCA=6032
0015                    KRSA=6034
0016                    KRBA=6036
0017                    TSFA=6041
0020                    TLSA=6046
0021                    RMFA=6244
0022                    /
0023                    /SOME LINC-8 DEFINITIONS
0024                    OPR=500
0025                    KBD=515
0026                    /
0027                    *20
0030    0020  6463              JMP     ST20    /BECOMES JMP INIT
0031    0021  0643              LDF     3
0032    0022  0602              LIF     2
0033    0023  0006              DJR
0034    0024  6020              JMP     20      /GO TO 20 IN SEGMENT 2
0035                                            /(04020)
0036                    /
0037                    /400 RESTART
0040    0025  6466      RST400, JMP     ST400   /BECOMES JMP INIT
0041    0026  0643              LDF     3
0042    0027  0602              LIF     2
0043    0030  0006              DJR
0044    0031  0000              HLT
0045    0032  6400              JMP     400     /GO TO 400 IN SEGMENT 2
0046                                            /(04400)
0047                    /
0050                    /START GUIDE
0051    0033  6356      GUIDE,  JMP     INIT
0052    0034  0642              LDF     2
0053    0035  0700              RDC             /READ GUIDE START BLOCK
0054    0036  7400              7400            /INTO QUARTER 3,SEGMENT 2
0055    0037  0643              LDF     3
0056    0040  0602              LIF     2
0057    0041  7400              JMP     1400    /START GUIDE
0060                    /
0061                    /ERROR STOP
0062                    *130
0063    0130  0000      ERR,    HLT             /UNIDENTIFIED INSTRUCTION
0064    0131  6221              JMP     RET     /IN AC AT HLT, RETURNS TO
0065                                            /USER W AC CLEARED WHEN
0066                                            /CONTINUE PRESSED.
0067                    /
0070                    /MISC CONSTANTS
0071                    *134
0072    0134  0000      PC,     0               /ADDRESS OF TRAPPED
0073                                            /INSTRUCTION
0074    0135  0070      M70,    70
0075    0136  0001      ONE,    1
```

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0076                    /
0077                    /TRAP ENTRY AND MACHINE STATE SAVING
0100                    *141
0101        0141  4242          STC     AC      /SAVE AC
0102        0142  0261          ROL  I  1       /SAVE LINK
0103        0143  4225          STC     LC
0104        0144  0005          QAC             /GET H 0 11 Q REG BITS
0105        0145  0241          ROL     1
0106        0146  0455          QLZ             /GET L 0 BIT
0107        0147  2136          ADD     ONE
0110        0150  4232          STC     Q       /SAVE IT
0111        0151  2136          ADD ONE
0112        0152  0454          FLO             /GET OVERFLOW BIT IF ON
0113        0153  0011          CLR
0114        0154  4222          STC     OVL     /SAVE IT,0=OFF, 1=ON
0115        0155  0057          SET     17      /SAVE LOCATION 0
0116        0156  0000          0
0117                    /
0120                    /INSTRUCTION IDENTIFICATION.
0121        0157  0002          POP
0122                    PMODE
0123        4160  6234  FETCH,  RIB             /READ INTERRUPT BUFFER
0124        4161  0335          AND     M70     /GET INSTRUCTION FIELD
0125        4162  1371          TAD     CDFX    /MAKE IT INTO A CDF N
0126        4163  3364          DCA     .+1
0127        4164  7402          7402            /BECOMES CDF N
0130        4165  7240          STA             /SET AC TO -1
0131        4166  1140          TAD     140     /COMPUTE ADDRESS OF
0132        4167  3334          DCA     PC      /TRAPPED INSTRUCTION
0133        4170  1734          TAD  I  PC      /OBTAIN INSTRUCTION
0134                                          /CAUSING TRAP
0135        4171  6201  CDFX,   CDF             /SET DATA FIELD TO 0
0136        4172  6141          LINC
0137                    LMODE
0140        0173  1460          SAE  I          /IS IT KBD?
0141        0174  0515          KBD
0142        0175  0467          SKP             /NO
0143        0176  6250          JMP     DOKBD   /YES,
0144        0177  1460          SAE  I          /IS IT KBD I?
0145        0200  0535          KBD  I
0146        0201  0467          SKP             /NO,
0147        0202  6250          JMP     DOKBD   /YES,
0150        0203  1460          SAE  I          /OPR I 14?
0151        0204  0534          OPR  I  14
0152        0205  0467          SKP             /NO
0153        0206  6212          JMP     OP14    /YES
0154        0207  1460          SAE  I          /OPR 14?
0155        0210  0514          OPR     14
0156        0211  6130  OTHERS, JMP     ERR     /PUT JMP TO
0157                                          /CHECKS FOR OTHER
0160                                          /INSTRUCTIONS HERE,
0161        0212  1000  OP14,   LOA             /OUTPUT, GET CHARACTER
0162        0213  0242          AC
0163        0214  0500          IOB
0164        0215  6046          TLSA            /OUTPUT IT
0165        0216  0500          IOB
0166        0217  6041          TSFA            /CHECK IF DONE
0167        0220  6216          JMP     .-2
0170                    /
0171                    /RETURN TO USER PROGRAM
0172        0221  1020  RET,    LDA  I          /EXIT TRAP PROCESSOR
0173        0222  0000  OVL,    0
0174        0223  2247  ADD     OVN     /3777 CAUSES OV
```

```
0175    0224  1020          LDA  I          /GET LINK
0176    0225  0000  LC,     0
0177    0226  0321          ROR  I  1       /RESTORE LINK
0200    0227  0040          SET     0       /RESTORE LOCATION 0
0201    0230  0017          17
0202    0231  1020          LDA  I          /RESTORE Q REGISTER
0203    0232  0000  Q,      0
0204    0233  0314          ROR     14      /LOADS Q REGISTER
0205                                        /FROM AC
0206    0234  1000          LDA             /OBTAIN ADDRESS FOR RETURN
0207    0235  0140          140             /TO USER PROGRAM
0210    0236  1620          BSE  I
0211    0237  6000          JMP
0212    0240  4246          STC     RTJ
0213    0241  1120          ADA  I          /RESTORE AC
0214    0242  0000  AC,     0
0215    0243  0006          DJR             /INHIBIT ZERO CLOBBERING
0216    0244  0500          IOB             /IN USERS MEMORY SEGMENT
0217    0245  6244          RMFA            /RESTORE INTERRUPT BUFFER
0220    0246  0000  RTJ,     HLT             /BECOMES JMP TO USER PROG.
0221    0247  3777  OVN,     3777
0222                /
0223                /KBD PROCESSING
0224    0250  0325  DOKBD,   ROR  I  5       /PUT TRAPPED INSTRUCTION
0225                                        /I BIT INTO COMPUTER
0226                                        /LINC BIT
0227    0251  1020          LDA  I          /GET LEFTOVER CHAR,
0230    0252  0000  UPC,     0               /IF ANY
0231    0253  0450          AZE             /LEFTOVER CHARACTER?
0232    0254  6323          JMP     LOO     /YES, DELIVER IT TO USER
0233    0255  0435  LP,      KST  I          /NO, FRESH CHARACTER?
0234    0256  6262          JMP     GRC     /YES,  GO READ IT
0235    0257  0452          LZE             /NO, PAUSE?
0236    0260  6255          JMP     LP      /YES, HANG IN THERE
0237                                        /TILL KEY STRUCK.
0240    0261  6323          JMP     LOO     /NO, RETURN TO USER W. AC
0241                                        /CLEARED
0242                /
0243                /READ AND TRANSLATE A KEYBOARD CHARACTER
0244    0262  0011  GRC,     CLR
0245    0263  0500          IOB
0246    0264  6034          KRSA            /READ A CHARACTER
0247    0265  1120          ADA  I          /CALCULATE CHARACTER CON-
0250    0266  7602          -175            /VERSION TABLE INDEX IN
0251    0267  0301          ROR     1       /HALF WORDS
0252    0270  1560          BCL  I
0253    0271  3700          3700
0254    0272  1120          ADA  I          /ADD BASE ADDRESS OF TABLE
0255    0273  0401          TAB
0256    0274  4276          STC     .+2     /HALF-WORD PICKUP ADDRESS
0257    0275  1300          LDH             /GET THE LINC CHARACTER,
0260    0276  0000          0
0261    0277  1420          SHD  I          /IS IT AN UNDEFINABLE?
0262    0300  7600          7600
0263    0301  6337          JMP     RETX    /YES, ECHO UPARROW
0264    0302  1120          ADA  I          /IS IT UPPER CASE?
0265    0303  7722          -55
0266    0304  0451          APO
0267    0305  6317          JMP     LOW     /NO,
0270                /
0271                /ITS AN UPPER CASE CHARACTER
0272    0306  1120          ADA  I          /MAKE IT LINC CODE
0273    0307  0011          11
```

```
0274    0310  0451          APO             /DELETE MINUS ZEROES
0275    0311  0011          CLR
0276    0312  4252          STC     UPC     /SAVE IT FOR USE AFTER
0277                                        /CASE CHARACTER IS OUTPUT
0300    0313  1020          LDA  I          /GET CASE CHARACTER
0301    0314  0023          23
0302    0315  4242          STC     AC      /STORE FOR TRANSFER
0303    0316  6221          JMP     RET     /EXIT
0304                /
0305                /LOWER CASE CHARACTERS
0306    0317  1120  LOW,    ADA  I          /MAKE IT LINC CODE
0307    0320  0055          55
0310    0321  0451          APO
0311    0322  0011          CLR
0312    0323  4242  LOO,    STC     AC      /STORE IT FOR TRANSFER
0313    0324  4252          STC     UPC     /CLEAR LEFT OVER BUFFER
0314    0325  0500          IOB
0315    0326  6036          KRBA            /READ CHAR AND
0316                                        /CLEAR KEYBOARD FLAG
0317    0327  6350  LOO1,   JMP     PRINT   /ECHO
0320    0330  1460          SAE  I          /C, R,?
0321    0331  0215          215
0322    0332  6221          JMP     RET     /NO, EXIT
0323    0333  1020          LDA  I          /YES, THROW IN
0324    0334  0212          212             /A FREE LINE FEED
0325    0335  6350          JMP     PRINT
0326    0336  6221          JMP     RET
0327                /
0330                /ILLEGAL CHARACTER
0331    0337  1020  RETX,   LDA  I  /PRINT UP ARROW
0332    0340  0336          336
0333    0341  6350          JMP     PRINT
0334    0342  0500          IOB             /ECHO OFFENDING
0335    0343  6036          KRBA            /CHARACTER,
0336    0344  6350          JMP     PRINT
0337    0345  0017          COM
0340    0346  0261          ROL  I  1       /SET LINK BIT
0341                                        /TO KEYBOARD "PAUSE" VALUE
0342    0347  6255          JMP     LP
0343                /
0344                /PRINT A CHARACTER
0345                /ENTER W ASCII CHAR IN AC
0346    0350  0002  PRINT,  PDP
0347                        PMODE
0350    4351  6046          TLS
0351    4352  6041          TSF
0352    4353  5352          JMP     .-1
0353    4354  6141          LINC
0354                        LMODE
0355    0355  6000          JMP     0
0356                /INITIALIZE THE TRAP PROCESSOR
0357    0356  0011  INIT,   CLR
0360    0357  4252          STC     UPC     /CLEAR LEFT OVER CHARACTER
0361    0360  0001          AXO             /BOILER PLATING FOR GUIDE
0362                                        /RESTART
0363    0361  0024          SFA             /GET SPEC, FNS, REG,
0364    0362  1620          BSE  I          /SET TRAP ENABLE BIT
0365    0363  1000          1000
0366    0364  0004          ESF             /READ IT BACK OUT
0367    0365  6000  ENDX,   JMP     0       /RETURN
0370                *400
0371    0400  6025          JMP     RST400  /GO TO START 400
0372                                        /CONTROL ROUTINE
```

```
0373                    /
0374                    /
0375    0401    2323    TAB,    2323    /ALTMODE-CASE/ALTMODE-CASE
0376    0402    1376            1376    /RUBOUT-DEL/LEADER-NULL
0377    0403    7676            7676    /NOT USED
0400    0404    7676            7676    /N, U,
0401    0405    7676            7676    /N, U,
0402    0406    7676            7676    /BELL/N, U,
0403    0407    7656            7656    /TAB/L, F, -META
0404    0410    7676            7676    /N, U,
0405    0411    1276            1276    /CR-EOL/N, U,
0406    0412    7676            7676    /N, U,
0407    0413    7676            7676    /N, U,
0410    0414    7676            7676    /N, U,
0411    0415    7676            7676    /N, U,
0412    0416    7676            7676    /N, U,
0413    0417    7676            7676    /N, U,
0414    0420    7676            7676    /N, U,
0415    0421    2376            2376    /ALTMODE-CASE/N, U,
0416    0422    7614            7614    /N,U,/SPACE-SPACE
0417    0423    7676            7676    /EXC,PT/OBL,QUOTES
0420    0424    2265            2265    /NUMBER SIGN/OOLLAR SIGN-
0421    0425    6215            6215    /PERCENT-P,C/AMPERSAMO-AMPERSANO
0422    0426    1676            1676    /APOSTROPHE-AP,/OP PAREN
0423    0427    7676            7676    /CL PAREM/*
0424    0430    2063            2063    /PLUS-+/COMMA-,
0425    0431    1764            1764    /MINUS--/PERIOD-.
0426    0432    2100            2100    /SLASH-SLASH/ZERO-0
0427    0433    0102            0102    /1/2
0430    0434    0304            0304    /3/4
0431    0435    0506            0506    /5/6
0432    0436    0710            0710    /7/8
0433    0437    1176            1176    /9/N,U,
0434    0440    7676            7676    /SEMICOLON/<
0435    0441    6176            6176    /EQUAL SIGN-=/>
0436    0442    7676            7676    /?/AT SIGN
0437    0443    2425            2425    /A/B
0440    0444    2627            2627    /C/D
0441    0445    3031            3031    /E/F
0442    0446    3233            3233    /G/H
0443    0447    3435            3435    /I/J
0444    0450    3637            3637    /K/L
0445    0451    4041            4041    /M/N
0446    0452    4243            4243    /O/P
0447    0453    4445            4445    /Q/R
0450    0454    4647            4647    /S/T
0451    0455    5051            5051    /U/V
0452    0456    5253            5253    /W/X
0453    0457    5455            5455    /Y/Z
0454    0460    6621            6621    /LEFT,BRACK/BACK SLASH
0455    0461    7676            7676    /RT,BRACK/UP ARROW
0456    0462    7676    TABE,   7676    /BACK ARROW/N,U,
0457                    /
0460                    /INITIAL START 20
0461    0463    6474    ST20,   JMP     SETUP
0462    0464    6356            JMP     INIT
0463    0465    6472            JMP     GOMAN
0464                    /
0465                    /INITIAL START 400
0466    0466    6474    ST400,  JMP     SETUP
0467    0467    6356            JMP     INIT    /INITIALIZE TRAP PROCESSOR
0470    0470    0643            LDF     3
0471    0471    0000            HLT
```

```
0472    0472  0600  GOMAN,  LIF     0
0473    0473  6033          JMP     GUIDE   /THIS LANDS IN FIELD 0
0474                /TRAP PROCESSOR RELOCATOR
0475    0474  0057  SETUP,  SET     17
0476    0475  0000          0
0477    0476  1020          LDA  I  /SET UP RESTARTS
0500    0477  6356          JMP     INIT
0501    0500  1040          STA             /SET UP 20 RESTART
0502    0501  0020          20
0503    0502  4025          STC     RST400  /SET UP 400 RESTART
0504    0503  0640          LDF     0       /SET DATA FIELD TO 0
0505    0504  0061          SET  I  1       /SET UP MOVE COUNT
0506    0505  7334          -TABE+17
0507    0506  0062          SET  I  2       /SET TO-ADDRESS
0510    0507  2017          2017            /BIT 1 (2-010) SAYS USE DF
0511    0510  0063          SET  I  3       /SET FROM-ADDRESS
0512    0511  0017          17              /BIT 1 (0-000) SAYS USE IF
0513    0512  1023          LDA  I  3       /INCREM, 3,GET (3)
0514    0513  1062          STA  I  2       /INCREM,2,STORE (2)
0515    0514  0221          XSK  I  1       /INCREM, 1, SKIP IF 1=1777
0516    0515  6512          JMP     .-3     /1 NOT 1777, LOOP AGAIN
0517    0516  0062          SET  I  2       /SET UP FOR LEFT
0520    0517  2677          2677            /SWITCHES RESTART
0521    0520  0061          SET  I  1       /20 JMP GUIDE-S
0522    0521  7757          -20
0523    0522  1020          LDA  I
0524    0523  6033          JMP     GUIDE
0525    0524  1062          STA  I  2       /INC 2, STORE INTO (2)
0526    0525  0221          XSK  I  1       /END CHECK
0527    0526  6524          JMP     .-2
0530    0527  6017          JMP     17
```

0000 ERRORS

```
AC       4242
CDFX     4171
DOKBD    4250
ENDX     4365
ERR      4130
FETCH    4160
GOMAN    4472
GRC      4262
GUIDE    4033
INIT     4356
KBD      0515
KCCA     6032
KRBA     6036
KRSA     6034
LC       4225
LOO      4323
LOO1     4327
LOW      4317
LP       4255
M70      4135
ONE      4136
OPR      0500
OP14     4212
OTHERS   4211
OVL      4222
OVN      4247
PC       4134
PRINT    4350
Q        4232
-
```

```
RET     4221
RETX    4337
RMFA    6244
RST400  4025
RTJ     4246
SETUP   4474
ST20    4463
ST400   4466
TAB     4401
TABE    4462
TLSA    6046
TSFA    6041
UPC     4252
```