A PROGRAMMING SYSTEM FOR HYBRID COMPUTER COMPUTATION

by

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Chairman, Departmental Committee on Theses

ABSTRACT

Simulation of dynamic systems is often limited by the computer hardware it is running on. Digital simulation is often slow and analog computation lacks the ability to do operations such as delays and nonlinear functions. Hybrid computation is a technique to combine digital and analog computers into a system which has the best features of each type of computer. This thesis is an attempt to produce a programming system to reduce the problems presently involved in hybrid computing. A system of digital computer programs was created which automate many operations needed in hybrid computing. Also a hybrid block operation's interpreter was developed to allow high speed parallel operation of the analog and digital computers. Tests of this system show capabilities and features which improve the operation and programming of hybrid computers. The total system gives the user a powerful and simple system for improving his simulation computations.

ACKNOWLEDGEMENTS

I would like to acknowledge my thesis advisor, Richard S. Sidell, for the ideas, suggestions, and guidance he has given me during my undergraduate education and during the preparation of this thesis.

I also want to express my thanks to my parents who have supported and assisted me during my education, and to my mother who suffered through the typing of this thesis.

Thank you very much.

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INTRODUCTION

Hybrid computation includes all computing techniques which combine features of digital and analog computation in the solution of a problem. The term hybrid computer is now used to characterize computer systems involving linkages between general-purpose digital computers and electronic analog computers. Digital and analog computers each have characteristics which lend them to certain forms of computation.

Analog computers are excellant systems or simulating continous systems.

Analog computers:

1) Treat all variables in continuous form.
2) All components operate in parallel.
3) Computation speed is not effected by problem complexity.
4) Operations such as multiplication, addition, integration are easily done.
5) Provisions exsist for system modification during simulation.

Digital computers are best suited for logic operations, control signal generation, and data manipulation.

Digital computers:

1) Have the facility to memorize numerical and nonnumerical data indefinitely.
2) They perform logical operations and decision making using numerical or nonnumerical data.
3) Floating point arithmetic eliminates scale-factors.
4) Information can be handled in discrete form.
5) Digital programs can control and modify themselves, or analog systems by control signals.

An outline of hybrid operations is shown in table 1.

ROLES OF DIGITAL COMPUTERS IN HYBRID COMPUTATION AND SIMULATION

I.) Digital supervision by digital system:

- a) Supervisory control of analog-computer studies:
- b) Storage and reduction of results:
- c) Report preparation.

II.) Digital "Housekeeping" functions:

- a) Set coefficient and function-generator settings.
- b) Perform static checking.
- c) Run diagnostic programs.
- d) Do digitally controlled patching.

III.) Combined analog-digital simulation:

- a) Open-loop combinations.
  - 1) Digital operations on analog-computer outputs without feedback.
  - 2) Analog operation on digital-computer outputs without feedback.
- b) Digital simulation of a digital computer.
  - 1) Simulate closed loop digital controller.
- c) Closed-loop combined simulation:
  - 1) Parallel signal processing with feedback.
  - 2) Digital signal generation, recording, and control.
  - 3) Data sampling and coefficient modification.

Table 1.

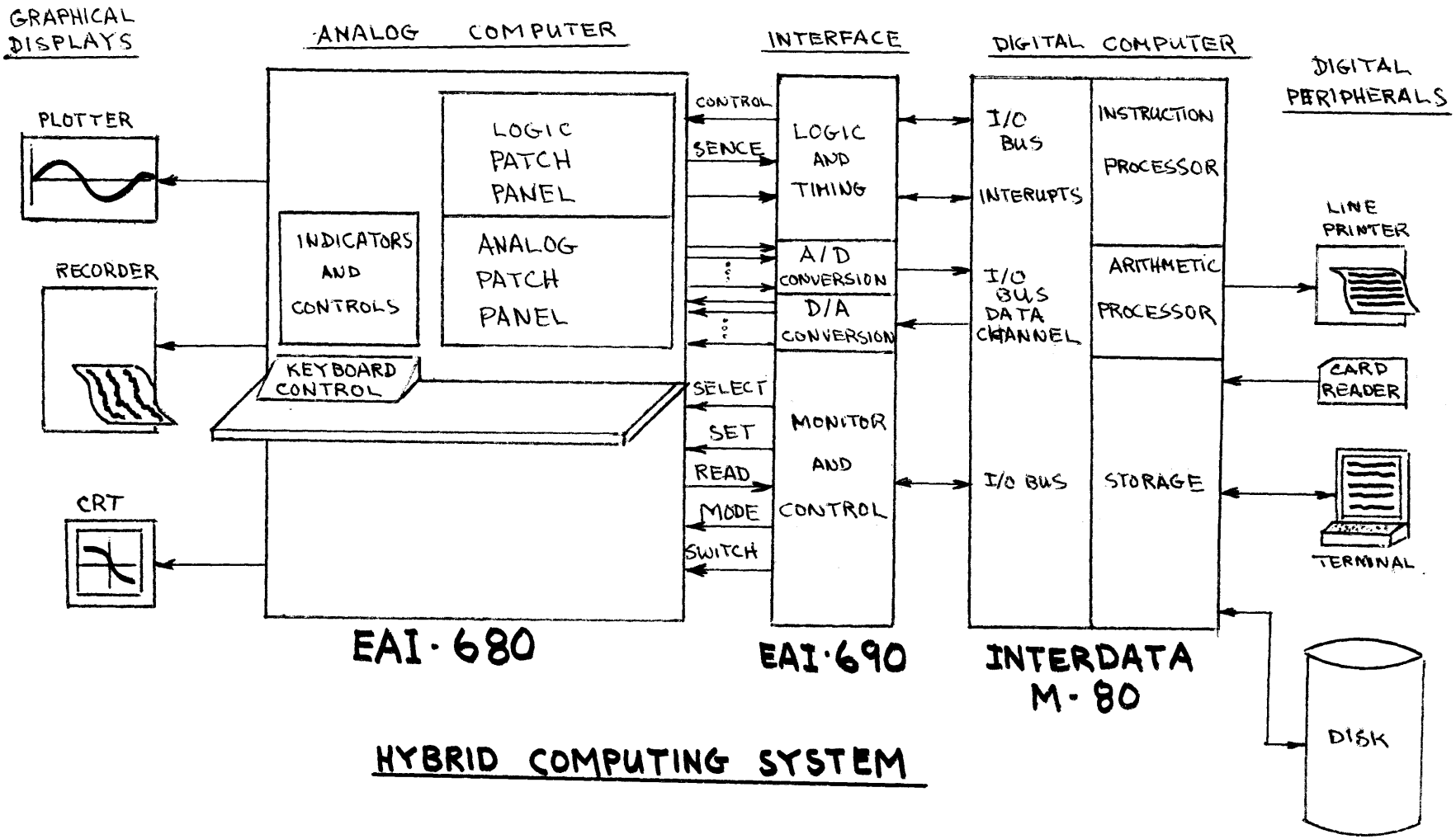
Hybrid computer techniques represent an effort to combine the best features of each type of computer to produce the optimal computing system. True hybrid computers are those systems which combine appreciable amounts of each type of hardware, and are capable of bilateral operation. (See fig. 2.) A system diagram of the Mechanical Engineering Joint Computer Facility hybrid computer is shown in figure 1.

Hybrid computation is ideally suited for several computation methods:

1) Sampled data system simulation.
2) Random process simulation.
3) Control system optimization.
4) Simulation of distributed parameter systems.
5) General simulation of systems which combine continuous and discrete signals.

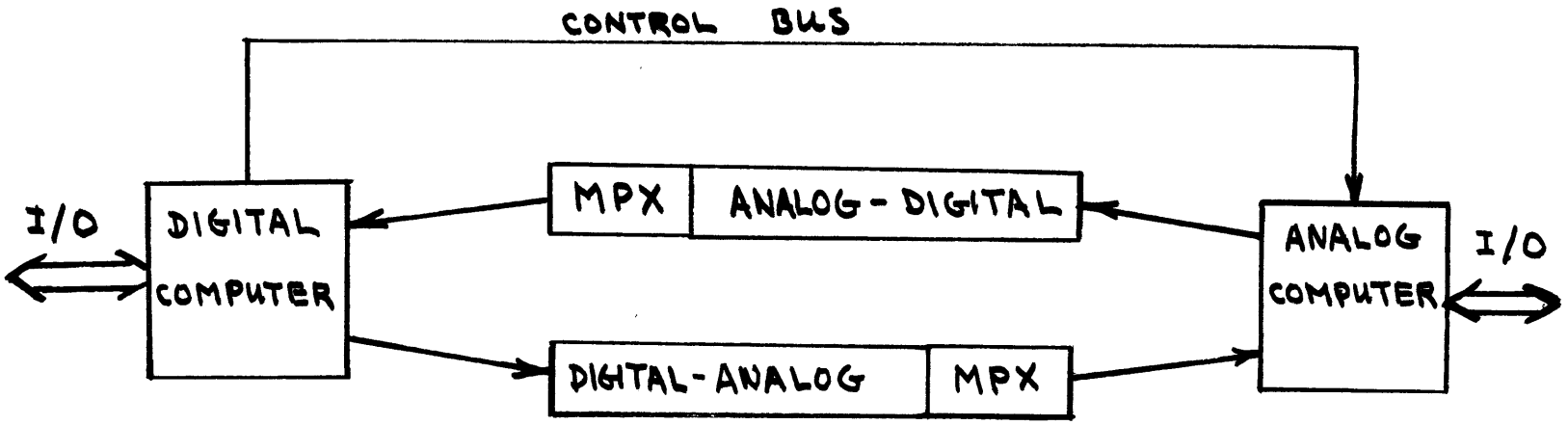
Presently hybrid computation is accomplished by programming the analog computer, and then writing a FORTRAN program for the digital computer using a number of data conversion and analog control subuoutines. The routines do operations such as send and recieve signals, set analog coefficients and control the operation of the analog computer.

The goal of my project is to produce a programming system which will allow parallel operation of the analog and digital computer during hybrid runs. This system must be fast enough so that the digital computer will not add a large time delay to the signals it is processing. The system will sue digital operations to replace and compliment the analog computational elements, and to control and synchronize total system operation.



HYBRID COMPUTING SYSTEM

FIGURE 1.



BILATERAL HYBRID SYSTEM

FIGURE 2.

HYBRID SOFTWARE SYSTEM

To accomplish goal of this thesis I have developed an interpretive software system which can perform many functions necessary to simplify and automate hybrid computer operations. The capabilities designed into the system are show in table 2. The system has six basic states of operation.

1) Supervisor state.
   In this mode the system processes input from the user and determines the nature of the command. The supervisor handles all overhead and linkage operations required, and handles user interaction and error analysis. If the input is a command to perform an immeadiate operation the system performs the operation or gives control to another section which performs the operation, such as input/output or set up. If the input is code to be compiled, control is passed to the compile section. The supervisor is itself broken into several sections so that it is able to control linkage between the several main programs which make up the system.

2) Program compiler.
   In this mode the system inputs the users hybrid programming language statements and compiles them into an intermeadiate code. This code is stored in disk files which are referenced by the loader at load time.

3) Analog control.
   In this mode the system reads the users command and performs the desired operation on the analog system. Control operations normally done manually at the analog control console are done automatically by the digital computer.

4) Input/Output.
This mode controls the reading, printing, and plotting of data requested by the user. After control is passed from the supervisor to this section, the storage area referenced is located in the symbol table, and the operation performed. Scaled fraction data is used as the data type for the system. The present input output operations include reading, printing, and plotting, and are called by giving the operation, the storage area identifier, and any required parameters.

5) Loader.
This mode controls data base and program loading. The compiled program is loaded from the disk and the storage allocated by the compiler is initialized to the required form. Buffers, tables, and delay lines are cleared and special pointers and constants loaded. The system can now perform input/output or enter the hybrid interpreter section.

6) Hybrid Interpreter.
This mode controls the actual parallel operation of the analog and digital computers. The users hybrid program is translated from the intermeadiate form, generated by the compiler, into core addresses in the digital computer. The interpreter then synchronizes itself with an external real time clock and begins execution. The users program is executed line by line for the specified time. Automatic A/D and D/A conversions are performed each cycle. After the cycle is completed, the interpreter waits for the clock time step to finish and then restarts the cycle. If time steps specified are too small to complete a program cycle, error messages are given. (See fig. 4.)

A system structure and information flow diagram of the complete system is shown in figure 3.

GOALS OF SYSTEM

I.) Control capabilities:
- a) Program compilation.
- b) Program loader.
- c) Time synchronization.
- d) Analog computer control.
- e) Input/output controller.

II.) Block oriented programming:
- a) Mathematical operations.
- b) Automatic buffer input/output.
- c) Function table lookup and interpolate.
- d) Time delay line simulation.
- e) Data manipulation. (scaled fraction).
- f) Storage allocation.
- g) A/D, D/A automatic conversion.

III,) Analog setup and control:
- a) Servo pot setting.
- b) Analog mode control.
- c) Time Scale control.
- d) Analog device measurement.

IV) Automatic digital input/output:
- a) Plot buffers. (scaled fraction data vs. time)
- b) Print. (scaled fraction data)
  - 1) Buffers
  - 2) Tables
  - 3) Variables
- c) Read. (scaled fraction data)
  - 1) Variables
  - 2) Function tables
  - 3) Input buffers, delay line buffers

Table 2.

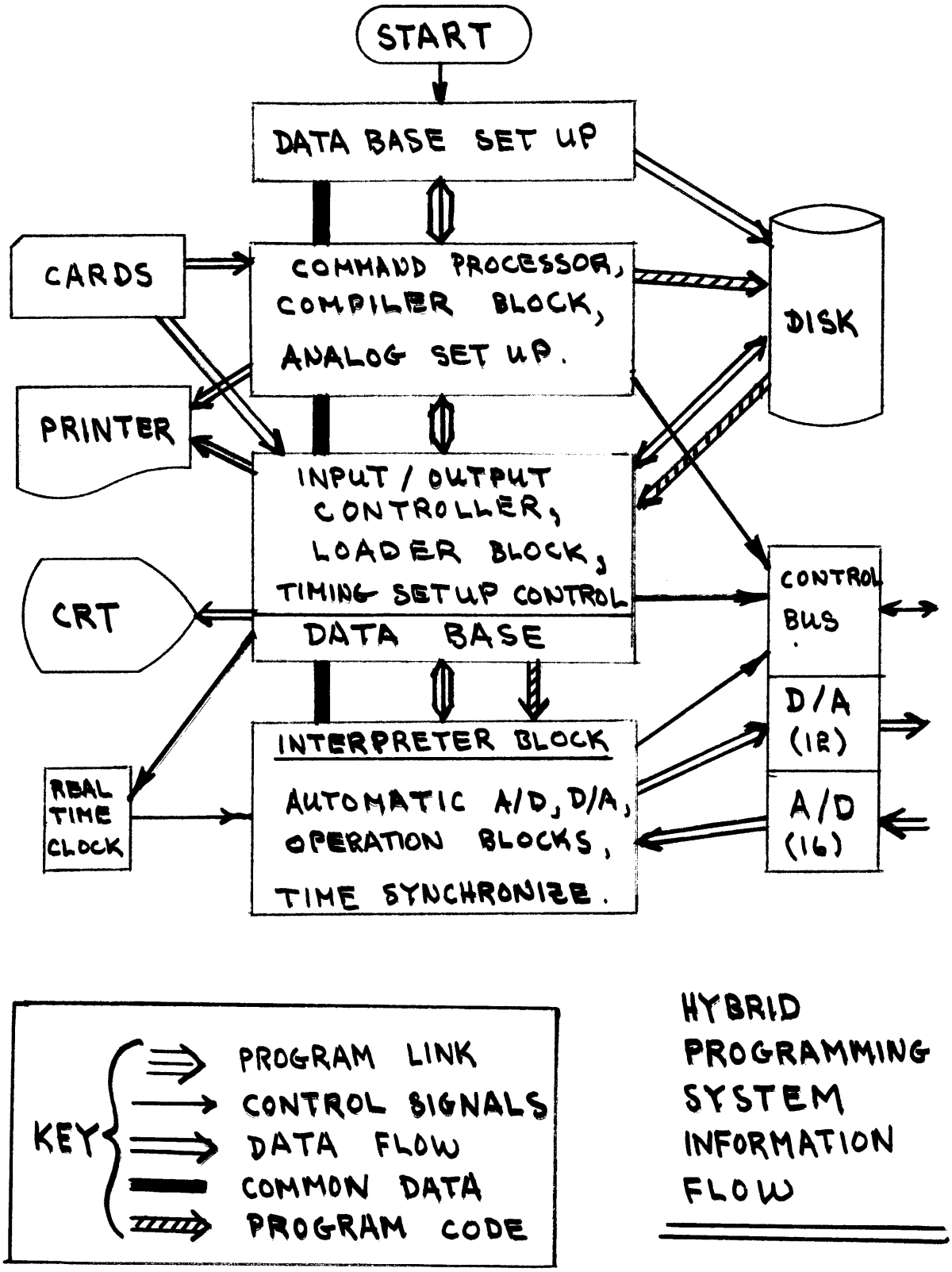

START
DATA BASE SET UP
CARDS
COMMAND PROCESSOR,
COMPILER BLOCK,
ANALOG SET UP.
DISK
PRINTER
INPUT / OUTPUT
CONTROLLER,
LOADER BLOCK,
TIMING SETUP CONTROL
CONTROL
BUS
CRT
DATA BASE
D/A
(12)
INTERPRETER BLOCK
REAL
TIME
CLOCK
AUTOMATIC A/D, D/A,
OPERATION BLOCKS,
TIME SYNCHRONIZE.
A/D
(16)
KEY
PROGRAM LINK
CONTROL SIGNALS
DATA FLOW
COMMON DATA
PROGRAM CODE
HYBRID
PROGRAMMING
SYSTEM
INFORMATION
FLOW

FIGURE 3.

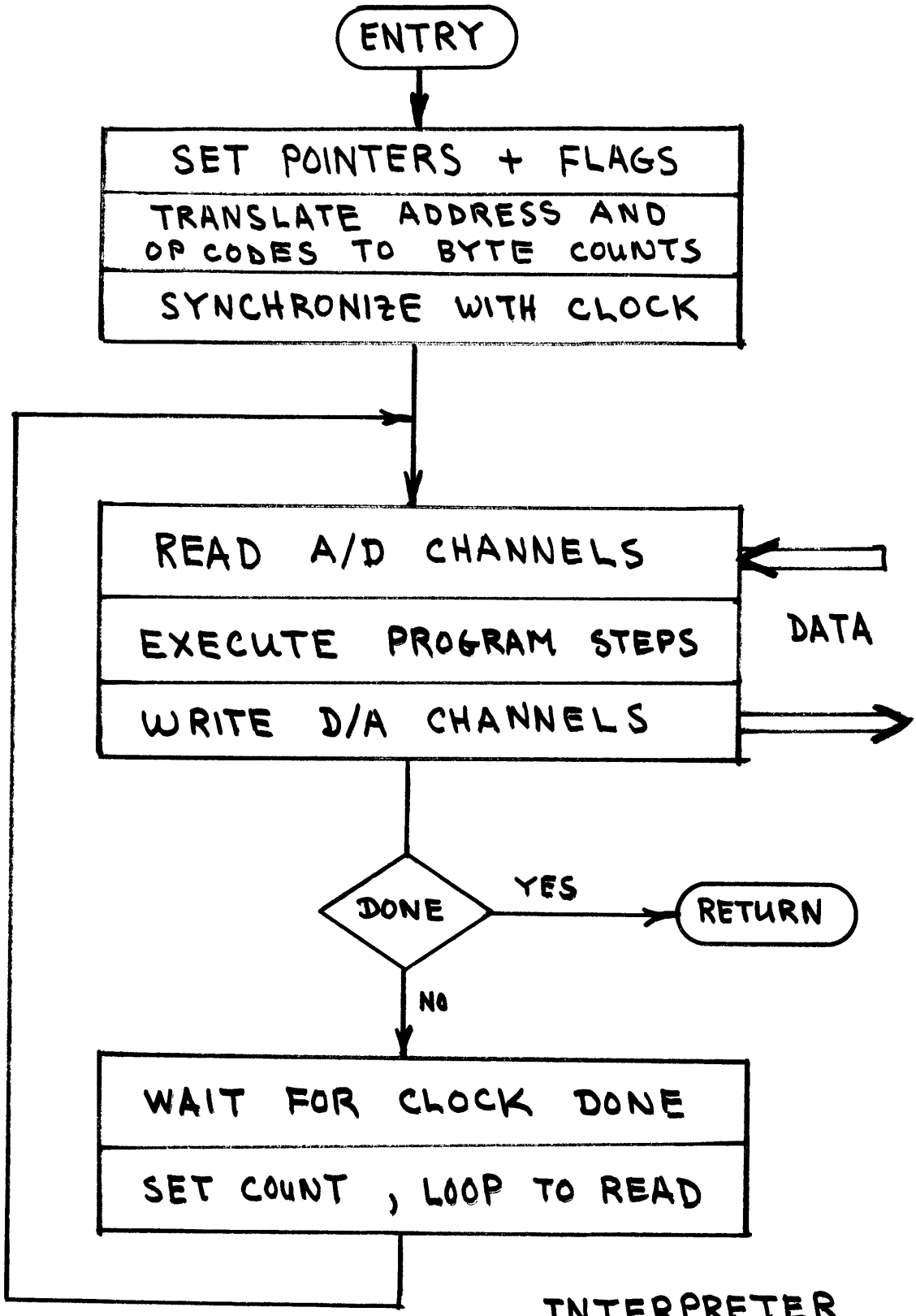


FIGURE 4.

INTERPRETER FLOW CHART

HYBRID PROGRAMMING LANGUAGE

The features included in the programming language are listed in table 2. section II. The hybrid language is a simple block-oriented system with a format similar to popular digital simulation systems such as EAI'S "HYTRAN", or IBM'S "CSMP". The major difference between these systems and the hybrid block system is the internal linkage system. The former are pure digital simulation systems, while the hybrid system allows a simulation program using analog and digital operation blocks which are linked together through the A/D, D/A interface. This allows operations such as long time delays, data storage, multi-input functions, and complex logic control, which can all be done best digitally, to become integral parts of an analog simulation.

The block nature of the system allows the user to set up a system of defined operations using simple commands and automatically link them to the analog system. The operations available to the user are listed in table 3. An example of a hybrid block program is shown in figure 5, and the hybrid program needed to create this system of blocks is shown in figure 6.

The programmer need only know a few simple rules of argument syntax and the operation codes to program any block system. The user has several data types and data structures available to him.

1) Buffers for getting data from or putting data to.
2) Delay lines of specified length which shift one entry per cycle.
3) Scaled fraction constants between $\pm$ 1.0.
4) Internal variables referenced by name.
5) Two-dimensional tables for function table lookup.
6) Analog to digital and digital to analog I/O channels.
7) Double precision variables for integrals.

One of the most important features of the system is the automatic input-output operations and data conversions done each time step. The interpreter reads all the available A/D converters into a special buffer at the start of each interpretive cycle. The program then interpretates the program, taking values of the referenced A/D channels from the buffer. References to D/A channels also refer to a special buffer. After the interpreter has executed the program for the cycle the D/A block is written out from the D/A buffer. The interpreter then waits for the external clock to finish a and the process begins again. While the program is executing, the interpreter keeps a pointer that allows sequential access to buffer entrees. This allows the user to record data into or send data from a buffer with a PUT or GET statement.

The function generator capabilities of the system are very useful in hybrid computation. These functions allow the user to store functions digitally and use them during hybrid simulations. Single input functions with any number of breakpoints can be used to generate nonlinear funtions that are difficult to generate on an analog computer. Multiple input functions with 441 values over the range of the two inputs allow nonlinear functions of two parameters to be generated during simulations by referencing the data table with a function operator.

Two function types a presently available. The first is a single input, piecewise linear table look up function. The user gives a table of input break points and output values and then references the table by name in a function operation. The value is computed by linear interpolation of the input to the break points and the output values. The second type of function available is the two input function. This function is a fixed break point, two dimensional table look up system. The user creates a table of 21 by 21 locations and inputs the function values to the table in reference to an X Y plane.

The function calculates a location in the input arguments plane and interpolates between four points to find the output.

Delay line simulation is the final operation available that is difficult or impossible to do on an analog computer. Since lumped parameter systems often require transport delays in their simulation, the digital computer gives us the ability to delay signals any amount of time required. The delay operator works by shifting the input signal through a serial shift register of length N.(N= DELAY TIME/CYCLE TIME.) As the interpreter executes the program, a pointer is recirculated through the delay line. When the pointer reaches a storage slot the delayed value is sent to the output argument and the new input value is loaded into the slot. This operation continues, slots being loaded, delayed, and sent out as long as the program is executing.

Mathematical operations are also available to do arithmetic operations with constants, variables, or A/D channels. (See table 2.) This feature frees analog amplifiers from operations such as addition, subtraction and inversion to be used as integrators or in other analog operations.

The last feature of the hybrid programming language is storage allocation and referencing. The allocation of storage, to be identified by a symbol name, is controlled by DEFINE statements. This command is followed by a specification as to the type of storage, its identifier, and any dimensioning data necessary. The system presently supports five data structures.

1) TABLE -2 dimensional data tables for functions.
2) BUFFER -1 dimensional data arrays for I/O.
3) DELAY -delay line buffers of length N.
4) VARIABLE -internal variable storage locations. (16 bits.)
5) DOUBLE -double precision variable for integrations. (32 bits.)

All the data handled by the system is in 16 bit scaled fractions for input or output to or from the user.

HYBRID OPERATIONS AND COMMANDS

I.) Operations:

ADD	(add two inputs)
SUBTRACT	(subtract two inputs)
MULTIPLY	(multiply two inputs)
DIVIDE	(divide two inputs)
FUNCF1	(one input function)
FUNCF2	(two input function)
DELAY	(delay input N cycles)
PUT	(input into buffer)
GET	(output from buffer)
INTEGRAT	(integrate input,store in output)
MOVE	(move input to output location)
INVERT	(invert input)
DEFINE	(allocate storage for processing)

II.) Commands:

*PROGRAM	(start new compilation)
*RUN	(execute program)
*LOAD	(load program from disk files)
*LIST	(print program code to printer)
*SYMBOL	(print program symbol table)
*EXEC	(link to EXECUTIVE program)
*READ	(input data to specified locations)
*PRINT	(print contents of specified arg.)
*PLOT	(plot buffer on CRT)
*SETPOT	(set servo pot)
*TIMEOP	(set external clock for cycles)
*TSCL	(set analog time scale)
*ANVAL	(read and print analog component)
*EOJ	(end of job,exit hybrid system)

Table 3.

EXAMPLE BLOCK PROGRAM

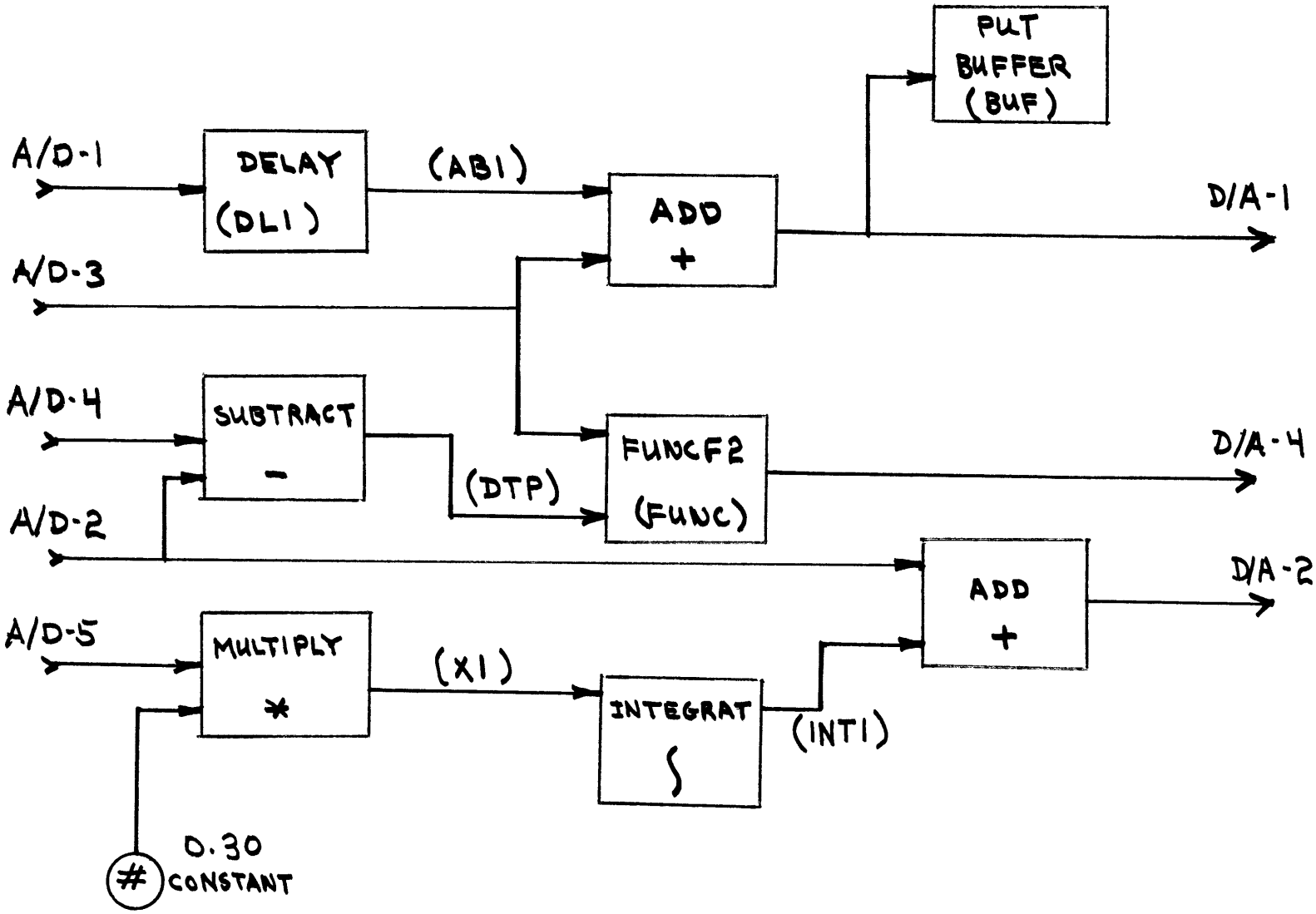


FIGURE 5.

```
/ EXAMPLE HYBOL PROGRAM
DEFINE VARIABLE AB1;
DEFINE VARIABLE DTP;
DEFINE VARIABLE X1;
DEFINE VARIABLE
DEFINE DOUBLE INT;
DEFINE TABLE FUNC(20,2);
DEFINE BUFFER BUF(200);
DEFINE DELAY DL1 10;
/ DONE STORAGE ALLOCATION,START PROGRAM CODE.
DELAY DL1,@AD01,AB1;
ADD AB1,@AD03,@DA01;
PUT @DA01,BUF;
SUBTRACT @AD04,@AD02,DTP;
FUNCF2 DTP,@AD03,@DA04;
MULTIPLY @AD05,#0.030,X1;
INTEGRAT X1,INT;
ADD @AD02,INT,@DA02;
END;
```

```
NOTE: @ADXX = A/D CHANNEL XX
      @DAXX = D/A CHANNEL XX
      # = SCALED FRACTION CONSTANT IDENTIFIER
```

FIGURE 6.

SYSTEM OPERATION

Once the user has entered the hybrid system he controls the operation of the system by a sequence of commands and program statements from a deck of computer cards. A typical run would consist of a *PROGRAM command followed by the hybrid program statements terminated with an END. The user would then input commands to set the external clock, read any required input data, and then load and run the program. After the system had finished the computation requested the user could print or plot data saved during the run, rerun the program, input a new program or any other combination of operations.

The size of a hybrid program is limited by two factors. During a simulation, the user can specify a run time of any length he requires but the number of cycles of program execution is limited to 32767maximum. The time step of this cycle is limited to the time required to execute one cycle of the program. The program cycle requires 600 microseconds plus the time required to execute one program statement, typically 15 to 50 microseconds. The second constraint is storage space required. 10000 storage locations are available to the user for tables, buffers, program,etc. Programs require 5 locations per line of code plus 32 locations for A/D and D/A buffers. The remainder of core is available for the users DEFINE allocations.

The format of commands and program statements are standardized and must be input in the expected forms.

1) *COMMAND ARG1, ARG2,...;
2) OPCODE ARG1, ARG2,...;
3) DEFINE (TYPE), ARG1, ARG2,...;
4) END;

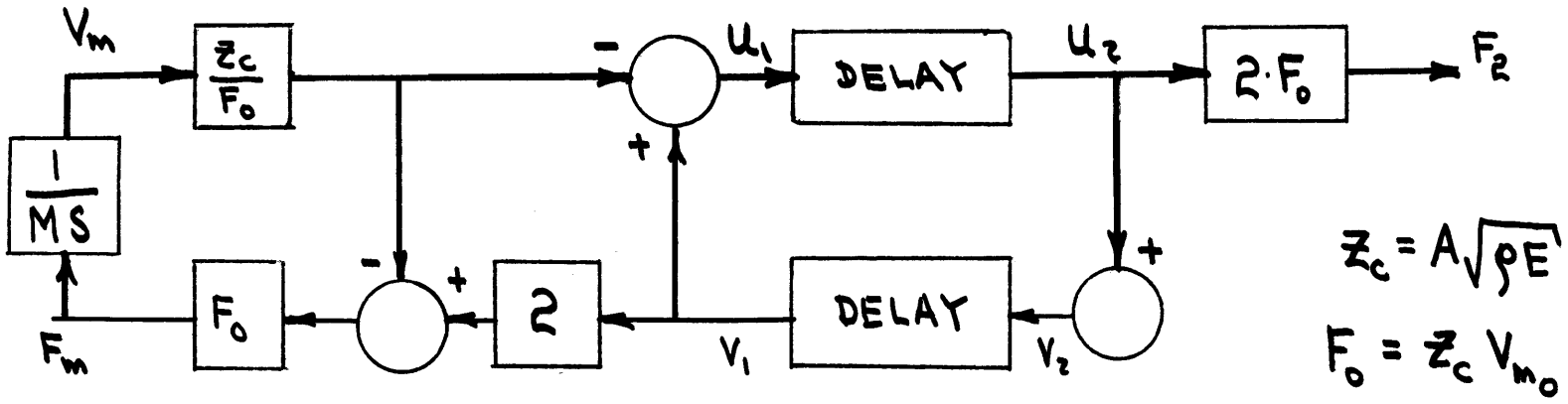
Example of programs and command input streams are shown in figures 6,9,12.

HYBRID SIMULATION TEST CASES

Two hybrid simulations test cases were run to capabilities of the hybrid programming system. The first test case is the simulation of a bar of material, steel is assumed, and its response to the impact of a force, assumed to be a hammer. The lumped parameter model of the system is shown in figure 7. The hybrid simulation model is shown in figure 8, and the hybrid program is shown in figure 9. By controlling the time scale of the analog computer and the input potentionmeter of the integrator, simulations of different bar to hammer mass ratios and bar lengths were run. Results for several cases are shown in appendix A.

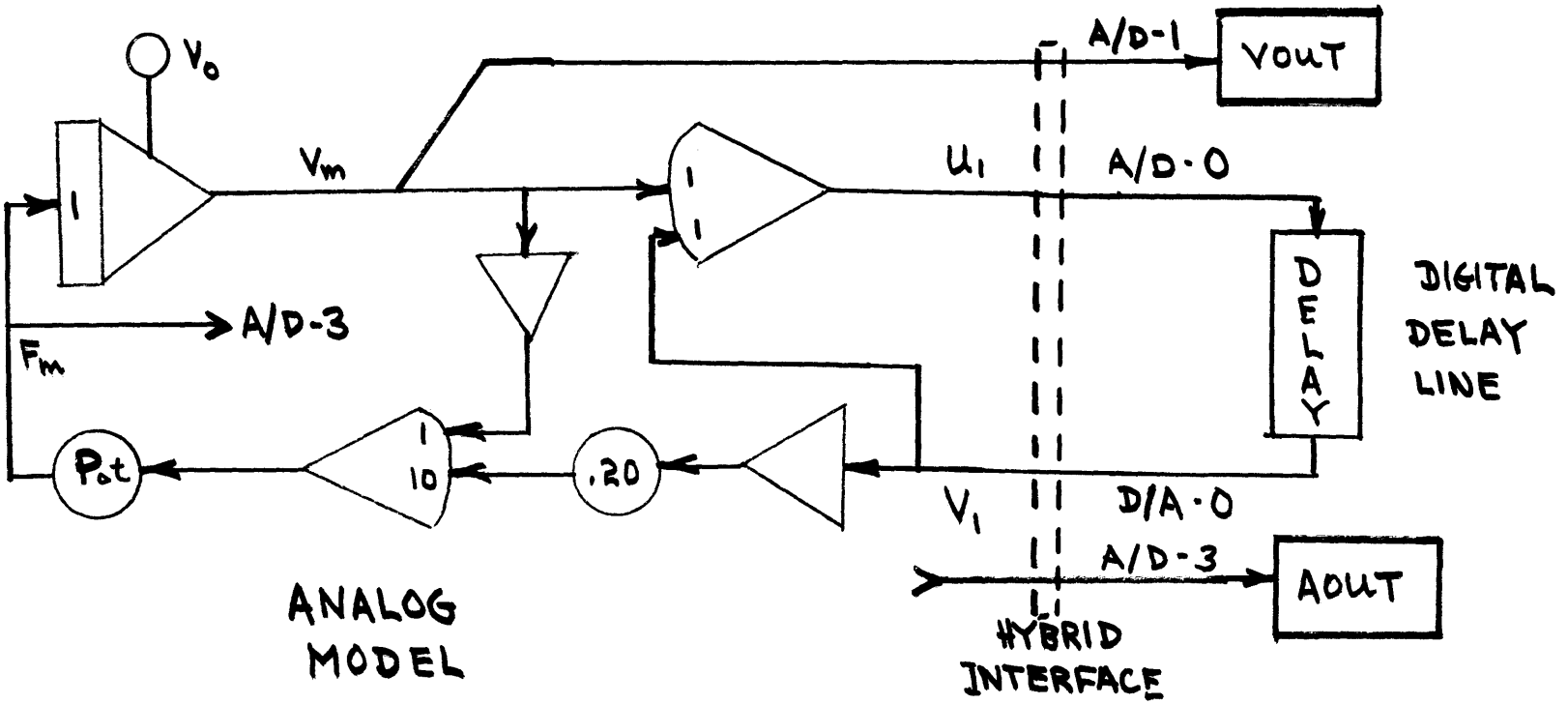
The second test was of a simplified model of a gas turbine powered ship. The system model of the ship was developed from a report on a pure digital simulation of the system run on an IBM 360. (See fig. 10.) The hybrid system model included four non linear functions and two integrations to simulate the open loop performance of the ship to fuel inputs. A block diagram of the hybrid simulation model is shown in figure 11., and the hybrid program is listed in figure 12 and 13. One test case simulation a speed change from idling to full fuel flow was run simulating 100 seconds of real time. The hybrid simulation required 10 seconds and produced results equal to the digital simulation at 30 seconds and 20% below at 100 seconds. A plot of the simulation output is shown in appendix B.

SIMULATION OF A BAR



LUMPED PARAMETER SIMULATION MODEL
OF AN ELASTIC BAR

FIGURE 7.

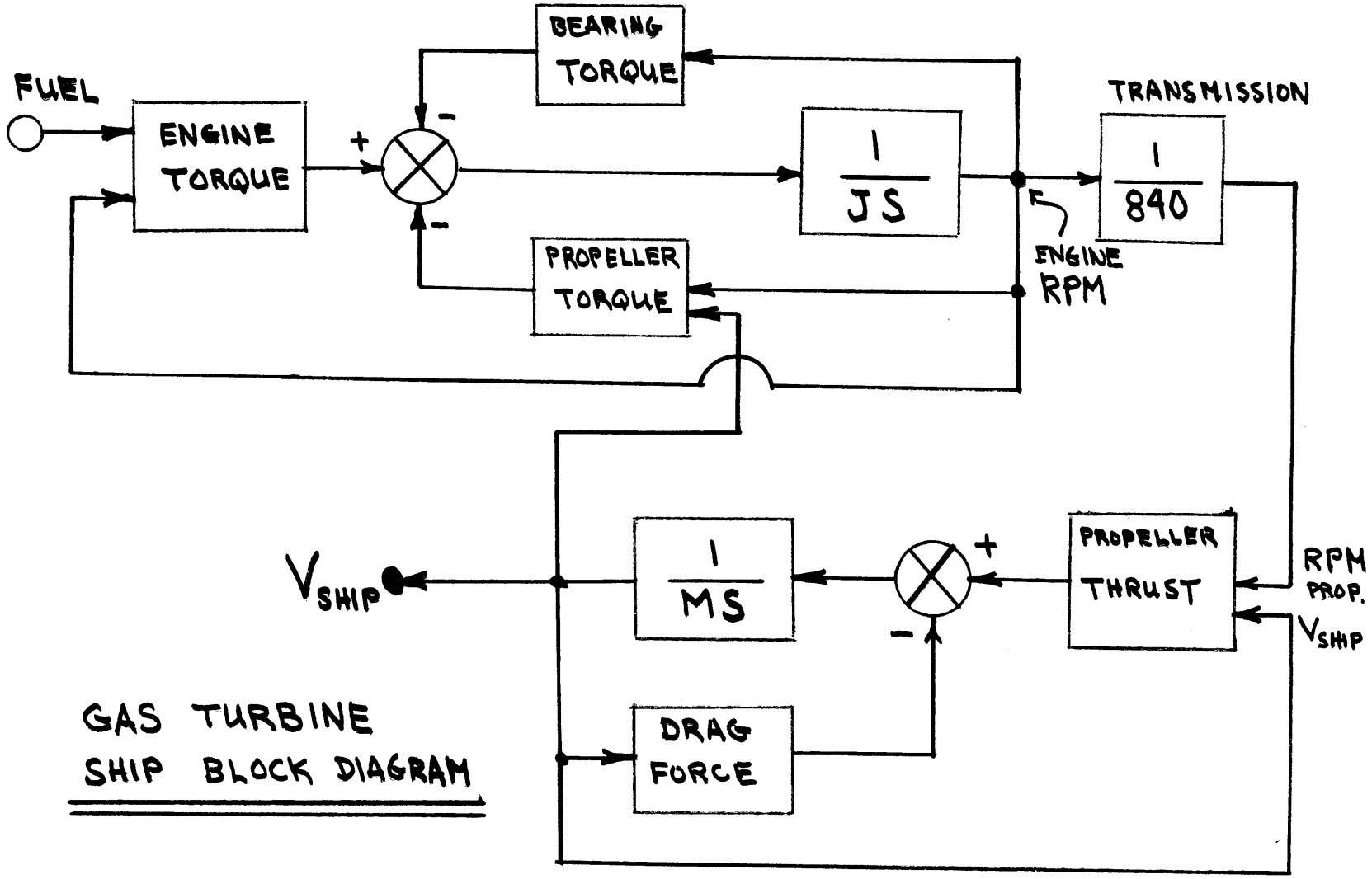


HYBRID BAR SIMULATION

FIGURE 8.

```
*PROGRAM;
/ BAR SIMULATION PROGRAM
DEFINE BUFFER VOUT(550);
DEFINE BUFFER AOUT(550);
DEFINE DELAY DEL 60;
/ DELAY SIGNAL 60 CYCLES
DELAY DEL @AD00,@DA00;
PUT @AD01,VOUT;
PUT @AD03,AOUT;
END;
/ CONTROL CARDS AND DATA
*EXEC;
*TIMEOP 10.0,0.020;
*LOAD;
*RUN;
*PLOT VOUT 200;
*PLOT AOUT 200;
*EOJ;
```

FIGURE 9.



GAS TURBINE SHIP BLOCK DIAGRAM

FIGURE 10.

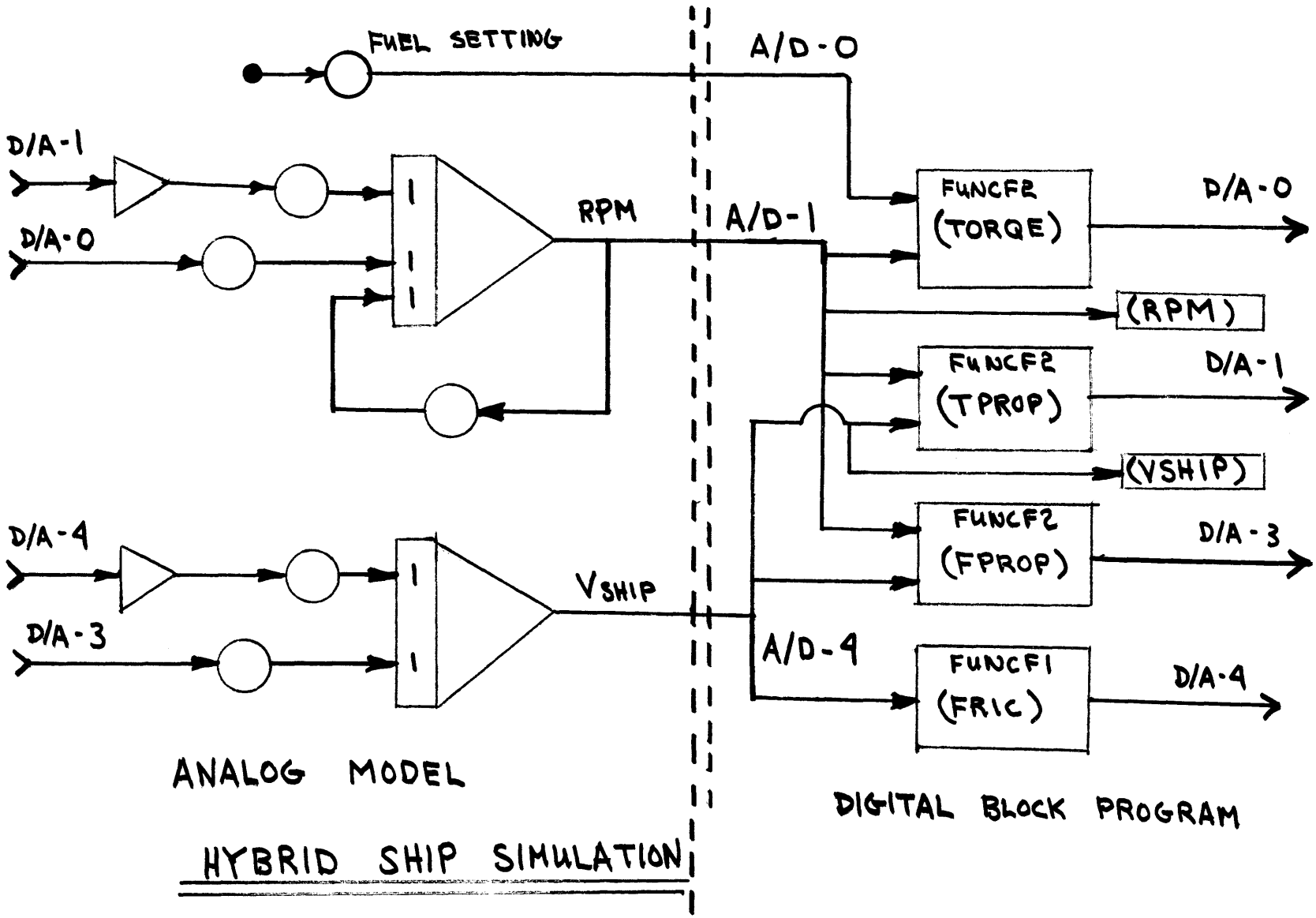

FUEL SETTING
A/D-0
D/A-1
D/A-0
RPM
A/D-1
FUNCF2
(TORQE)
D/A-0
(RPM)
FUNCF2
(TPROP)
D/A-1
(VSHIP)
FUNCF2
(FPROP)
D/A-3
D/A-4
D/A-3
VSHIP
A/D-4
FUNCF1
(FRIC)
D/A-4
ANALOG MODEL
DIGITAL BLOCK PROGRAM
HYBRID SHIP SIMULATION

FIGURE 11.

```
*PROGRAM;
/ GAS TURBINE SHIP SIMULATION PROGRAM
DEFINE TABLE TORQE(21,21);
DEFINE TABLE TPROP(21,21);
DEFINE TABLE FPROP(21,21);
DEFINE TABLE FRIC(8,2);
DEFINE VARIABLE X;
DEFINE VARIABLE Z;
DEFINE BUFFER VSHIP(1000);
DEFINE BUFFER RPM(1000);
DEFINE BUFFER BUF2(1000);
DEFINE VARIABLE Y;
DEFINE VARIABLE R;
/ FUNCTIONS FOR SIMULATION
FUNCF2 TORQE,@AD01,@AD00,@DA00;
FUNCF2 TPROP,@AD01,@AD04,@DA01;
FUNCF2 FPROP,@AD01,@AD04,@DA03;
FUNCF1 FRIC,@AD04,@DA04;
PUT @AD01,RPM;
PUT @AD04,VSHIP;
PUT @AD00,BUF2;
END;
```

FIGURE 12.

```
/ CONTROL CARDS AND DATA
*EXEC;
*READ FRIC 7,2;
DATA CARDS FOR TABLE FRIC
      •
      •
      •
*READ TORQE(21,21);
DATA CARDS FOR TABLE TORQE
      •
      •
      •
*READ FPROP(21,21);
DATA CARDS FOR TABLE FPROP
      •
      •
      •
*READ TPROP(21,21);
DATA CARDS FOR TABLE TPROP
      •
      •
      •
*TIMEOP 10.0,0.010;
*LOAD;
*RUN;
*PLOT VSHIP 200,5,1;
*PLOT BUF2 200,5,1;
*PLOT RPM 200,5;
*EOJ;
```

FIGURE 13.

CONCLUSION

From the results of tests run on system operation and of the two test cases run, I must conclude that the system fulfills the goals set for it, and provides a useful system for doing hybrid computation. The operations available to the user remove most of the difficulties presently associated with hybrid computation. Input/output, time synchronization, delay simulation, and nonlinear function generation are all available to the user without his needing to be an accomplished programmer.

The practicallity of doing hybrid computation in simulation of complex systems is apparent from the second test case. An extremely simplified model, generated from a small amount of data on ship component response was able to produce results in good agreement with a much more complicated model of a large digital computer. Using a hybrid computer system such as this can greatly increase the speed and involvement of many types of computer simulation. As digital simulation of dynamic systems becomes faster and requires less programmer experience analog simulation must move toward hybrid computer system. Hybrid systems have the flexibility and power to automate parameter optimization and statistical studies, which are very time consuming simulations to run digitally. As hybrid computer hardware and software improve simulations will be able to benefit from a system which provides the best features of digital and analog computation.

RECOMMENDATIONS

The system now exsists in a form which is flexible and provides the user with many commands. But some features which would allow better utilization of available hardware should be added. There are presently no features for testing or setting sence lines from the analog computer. The system also requires repetition of commands for multiple executions of the hybrid program. Another nonoptimal feature is the line by line non alterable execution of the program. Several features added to the compiler/interpreter system could solve some of these problems. The addition of statement labels and logical decision making operations would allow the program to control its own execution during run time. Several new function types would also improve the system. A function with hysteresis would be useful in some systems. Also the addition of a fixed break point single input function, and a variable bread point multiple input function would simplify function generation for the user.

In general a number of new operations such as transcendental functions and more complex integrator operators would be useful. The input/output operations could also be improved by providing an option for indexed operation so that data could be referenced on integral numbers of time steps. The The commands available could also be increased to provide operations such as load and run, repeat operations, and disk storage of data for later use. There are many areas where the system can be expanded and improved and in the future I plan to include most of the above recommendations.

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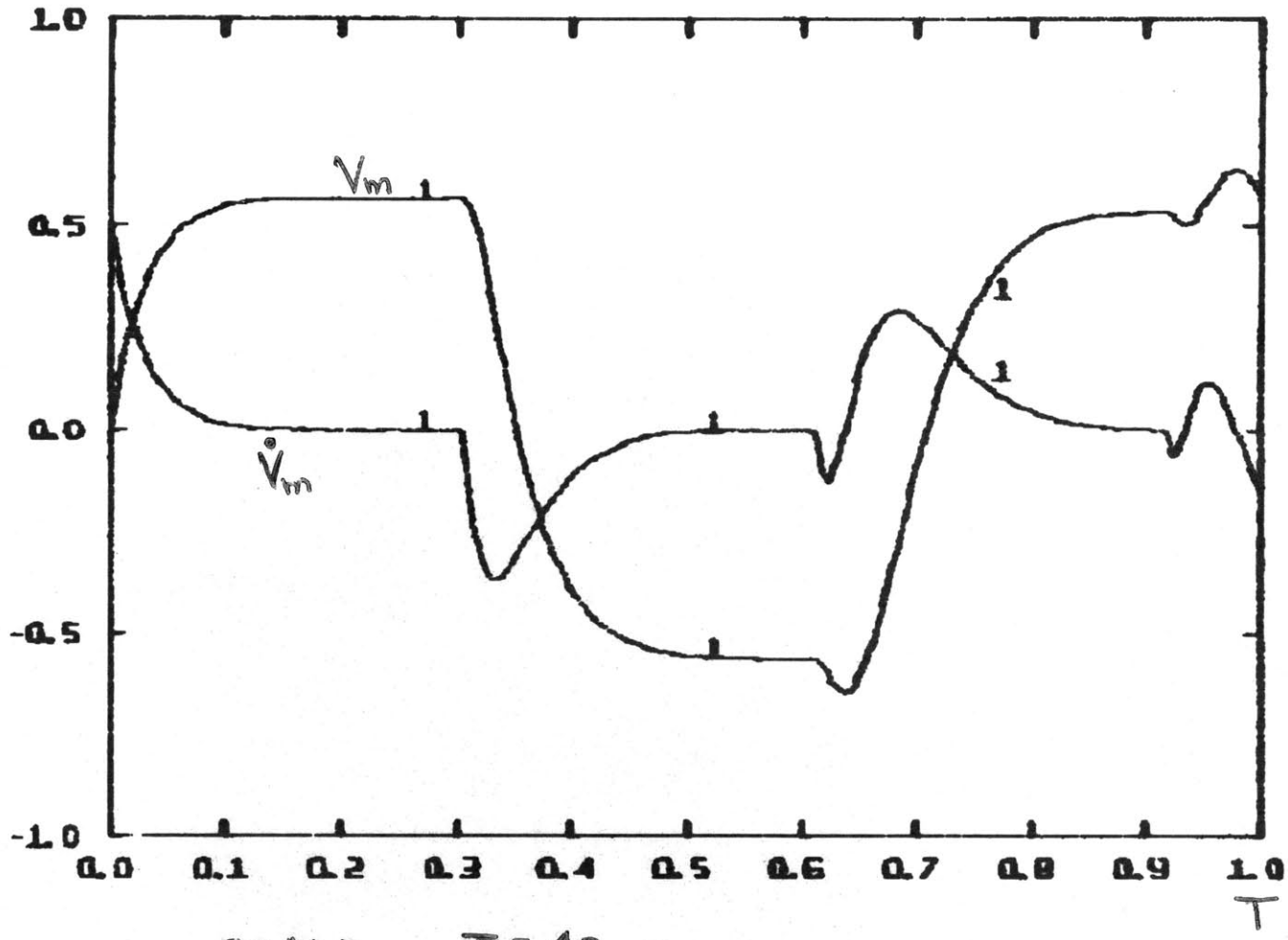
APPENDIX



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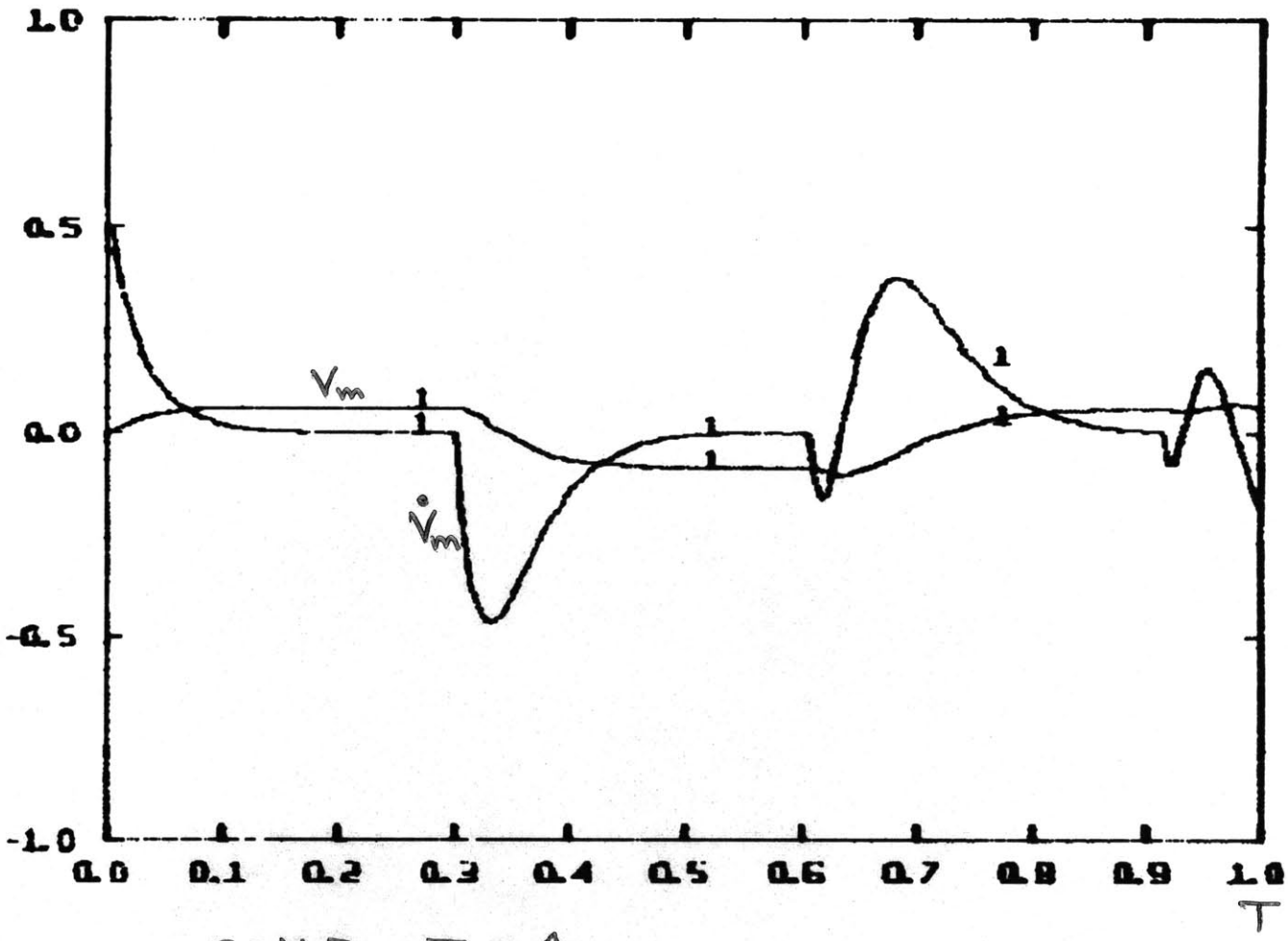

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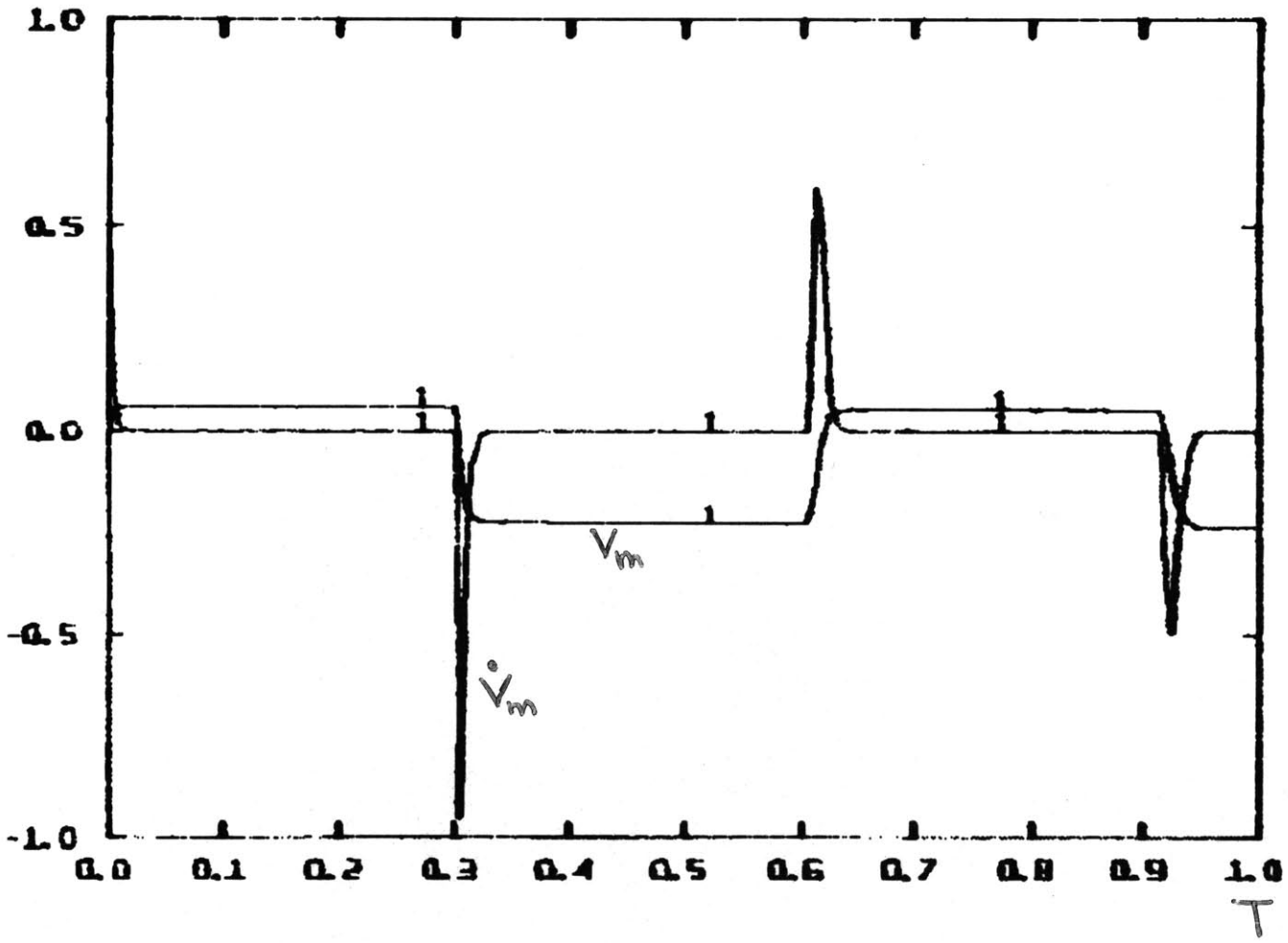

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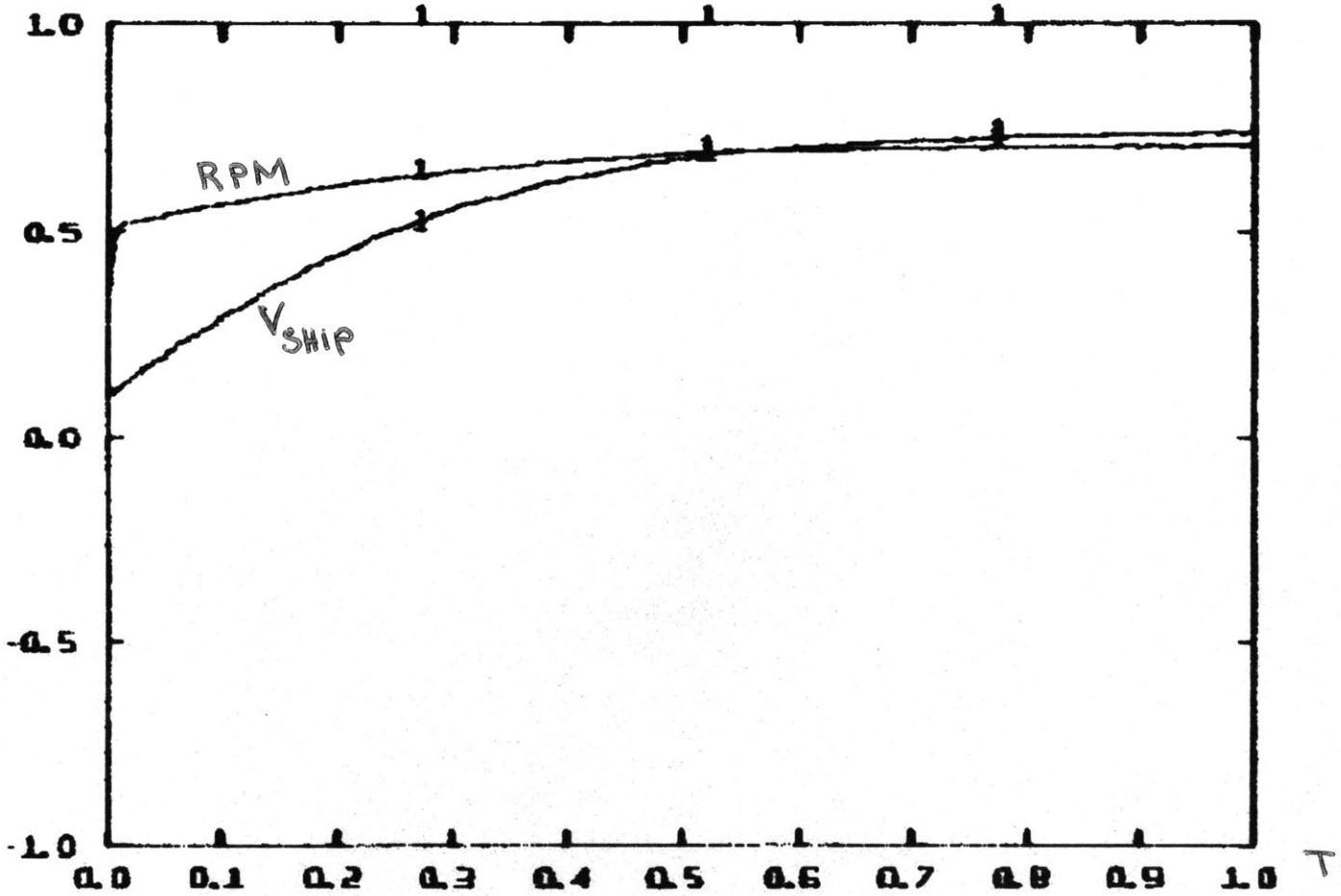
M = 8.589

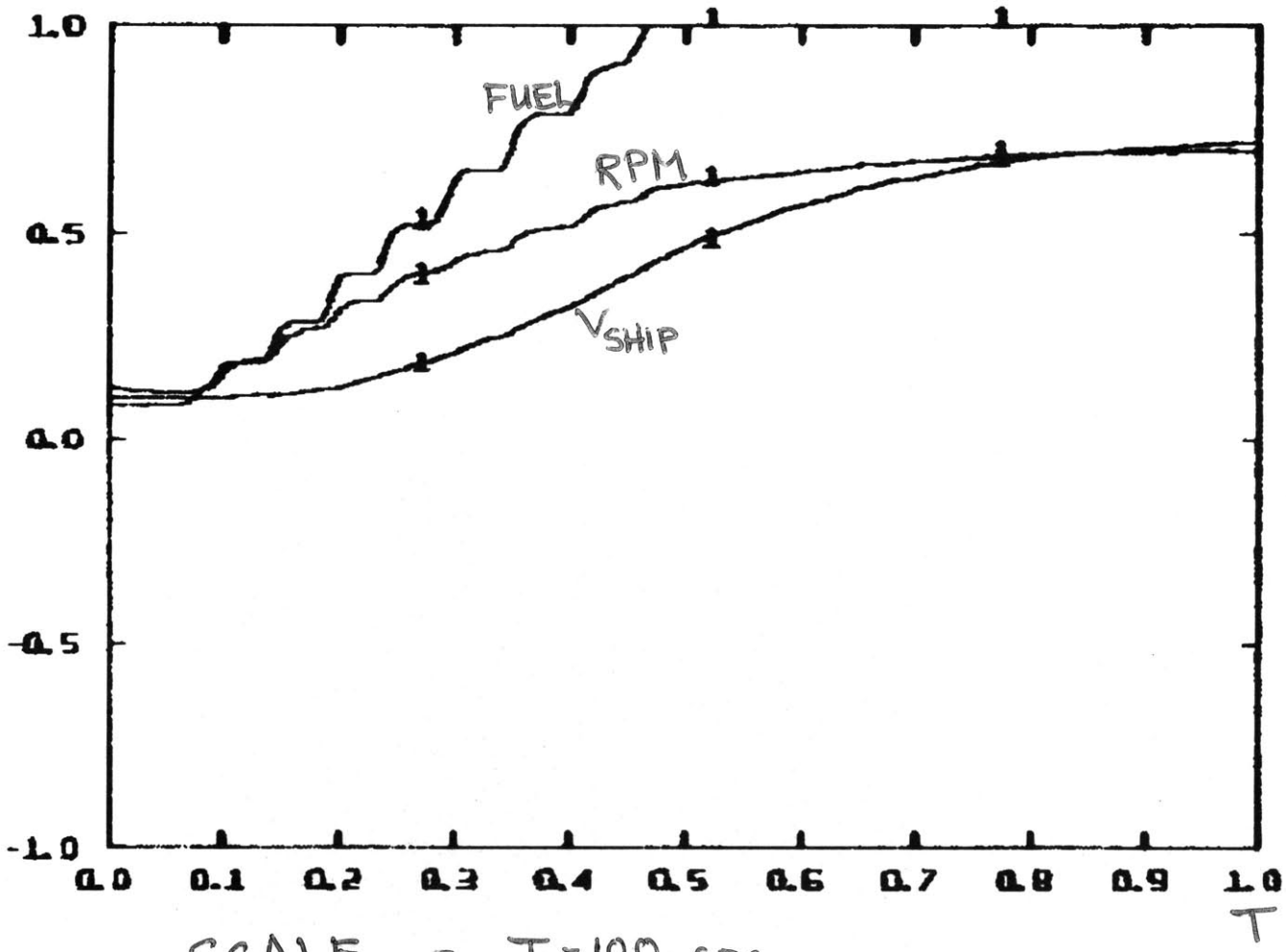
V = V_c FT/SEC



SCALE - T = 100. SEC

V_{SHIP} = 30. KNOTS

RPM = 4000. RPM ENGINE



SCALE - T = 100. SEC

FUEL = 10000. #/HR

V_{SHIP} = 30. KNOTS

RPM = 4000. RPM ENGINE

```
C MAIN COMMAND PROCESSOR AND COMPILER PROGRAM
      REAL*8 LVAR
       REAL*8 OPTEST
      REAL*8 BUFSYM,OPCODE
      REAL*8 LTAB,LBUF
      REAL*8 ARG(10)
      REAL*8 SYMTAB,CLEAR
      REAL POT
      REAL VAL
      INTEGER*2 IREC1,IREC2,LITA,LITZ,LOAD,ERRORS
      INTEGER*2 OPERCD
      INTEGER*2 COMMA,SEMICL
      INTEGER*2 EXEC,SETUP
      INTEGER*2 READ,PRINT,PLOT,RUN,EOJ,PROGRM
      REAL*8 PROGS(3)
      REAL*8 LDBL,LDEL
       INTEGER*2 LPOUND
      INTEGER*2 CARDI,IPOS,LOCCNT
      INTEGER*2 LITADC,LITDAC
      INTEGER*2 BUFFER,CARD,ERROR,OPVAL
      INTEGER*2 CORE,SYMBOL,DUMP
      INTEGER*2 PCOUNT,PSTART
      INTEGER*2 PEND
      INTEGER*2 LIST
      INTEGER*2 DATTAB
      INTEGER*2 TOPCOR
       INTEGER*2 TIMEOP,ITYPE,IPCODE
       INTEGER*2 SYMTYP
      INTEGER*2 NFILE1,NFILE2,NINP,NTYP ,NSYMAX
      INTEGER*2 OPFLAG,PFLAG,IERROR,NSYMBL,NSTMT,NOPTAB,I,J,K,IJ,KK,JJ,
     1 NARGS,NN,MM,LSAVE,NFILE
      INTEGER*2 SYMVAL,ATSIGN
      INTEGER*2 ARGVAL(10)
      INTEGER*2 CTEST,NAME
      INTEGER*2 ASTRSK,BLANK,DOLSGN
      INTEGER*2 PNUM
      INTEGER*2 ONE,THREE,ZERO
      INTEGER*2 IFLAG,NDECS,IDUMP
       INTEGER*2 ARGTYP(10)
      INTEGER*2 SETPOT,MODE,TSCALE,ANAVAL
       LOGICAL EQUAL
      DIMENSION CARD(80),X(10),OPCODE(40),OPVAL(40)
      DIMENSION SYMTAB(100),SYMVAL(100),SYMTYP(100)
C ***********************************************************
C COMMON DATA BASE AREA
      COMMON/CODES/READ,PROGRM,PRINT,PLOT,RUN,EOJ,CORE,SYMBOL,DUMP,LIST,
     1 TIMEOP,LOAD,EXEC,SETPOT,MODE,ANAVAL,TSCALE
      COMMON/CONTRL/PFLAG,NFILE1,NFILE2,TOPCOR,OPFLAG,NTYP,NINP,NSYMAX,
     1 NOPTAB,LOCCNT,NSYMBL
      COMMON/OPCOD /OPCODE,OPVAL,OPERCD,BUFSYM,ARG
```

```
      COMMON/PROGRM/PSTART,PCOUNT,PEND,NSTMT,PNUM,NDFCS,ERRORS
      COMMON/SYMBOL/SYMTAB,SYMVAL,SYMTYP
      COMMON PROGS
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C DATA INITIALIZATION
      DATA ATEST,DTEST,VTEST,STEST/'@AD ','@DA ','$   ','#   '/
      DATA   LTAB,LBUF/'TABLE   ','BUFFER  '/
      DATA OPSYMD,OPSYMY,OPSYMF/'DEFI','DELA','FUNC'/
      DATA ATSIGN/'@ '/,LPOUND/'# '/
      DATA ASTRSK,BLANK,DOLSGN/'* ',' ','$ '/
      DATA CLEAR/'         '/
      DATA LITADC,LITDAC/'AD','DA'/
      DATA LVAR/'VARIABLE'/
      DATA ETEST/';   '/
      DATA LDBL,LDEL/'DOUBLE  ','DELAY   '/
      DATA OPSYMV/'DATA'/
      DATA LITA,LITZ/'A ','Z '/
C ***********************************************************************
C FILE SPECIFICATION STATEMENTS
      DEFINE FILE 1(100,3,U,IREC1)
      DEFINE FILE 2(60,2,U,IREC2)
      DEFINE FILE 3(10000,1,U,IREC3)
C ***********************************************************************
C MARK FILE 1 WITH PROGRAM ID
      IPCODE=1
      CALL PUTMES(' $MAIN ;')
      READ(NFILE1'1)IPCODE,IERROR
      IF(IPCODE.EQ.2) GO TO 10
      IF(IPCODE.EQ.5) GO TO 11
      IPCODE=1
      WRITE(NFILE1'1)IPCODE
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C *PROGRAM OR INITIAL ENTRY,INITIALIZE FLAGS AND CLEAR TABLES
2     CONTINUE
      NFILE3=3
      NDFCS=7
      LOCCNT=33
      ERRORS=0
      NSYMBL=0
      NSTMT=1
      ERROR=0
      PFLAG=0
      IERROR=0
      PNUM=0
      PEND=0
      PCOUNT=0
      PSTART=0
C CLEAR SYMTAB
      DO 700 I=1,NSYMAX
      SYMTAB(I)=CLEAR
```

```
      SYMVAL(I)=0
      SYMTYP(I)=0
700    CONTINUE
9150   FORMAT(5X,4A2,2X,I5)
      GO TO 10
C PRINT ERROR MESSAGE
1     WRITE(NTYP,9120)IERROR,BUFSYM
9120  FORMAT(1X,'***** ERROR #',I5,' SYMBOL ERROR => ',1A8,'SKIP CARD')
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * **
       IF(IERROR.NE.10)ERRORS=ERRORS+1
10    CONTINUE
      ITYPE=0
      KK=0
      BUFSYM=CLEAR
      IERROR=0
      ONE=1
      THREE=3
      ZERO=0
        IERROR=0
      LCOUNT=LOCCNT
       IF(LOCCNT.GE.TOPCOR) GO TO 6000
C READ IN A CARD AND PROCESS
      CALL CARDIN(ARG,PFLAG,OPFLAG,IERROR)
11    CONTINUE
      IF(IERROR.NE.0) GO TO 1
      CALL MOVE(ARG(1),0,OPTEST,0,8)
C LOOK IN OPERATOR TABLE
      DO 550 K=1,NOPTAB
      IF(OPTEST.EQ.OPCODE(K)) GO TO 600
550   CONTINUE
C IF OP CODE ILLEGAL DO ERROR ROUTINE
      WRITE(NTYP,9102)OPTEST
9102   FORMAT(1X,'ILLEGAL OPERATION CODE => ',1A8)
      IERROR=4
      BUFSYM=OPTEST
      GO TO 1
600   OPERCD=OPVAL(K)
C TEST ARGS FOR TYPE
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * **
C GET ARG #
C TEST FOR IMMEADIATE
      IF(OPFLAG.EQ.1) GO TO 3000
C TEST FOR DEFINE ,FUNCTION, DELAY STATEMENTS
      OPHALF=REAL(OPTEST)
      IF(OPHALF.EQ.OPSYMD) GO TO 1000
      IF(OPHALF.EQ.OPSYMY) GO TO 1100
      IF(OPHALF.EQ.OPSYMF) GO TO 1200
C NOT TYPE STATEMENT C CHECK ARGS FOR TYPE
C @ IS AN I/O CHANNEL
C # IS A SCALED FRACTION CONSTANT
```

```
C OTHERS MUST BE DEFINED NAMES
800    CONTINUE
        NARGS=10
C PROCESS EACH ARGUMENT
        DO 801 I=1,NARGS
       ARGTYP(I)=0
801    ARGVAL(I)=0
C CHECK FOR ARG TYPE IN FIRST CHARACTER
       DO 890 IJ=2,NARGS
       CALL MOVE(ARG(IJ),0,TEST,0,3)
       IF(EQUAL(TEST,0,ATEST,0,3)) GO TO 840
       IF(EQUAL(TEST,0,DTEST,0,3)) GO TO 845
       IF(EQUAL(TEST,0,STEST,0,1)) GO TO 870
       IF(EQUAL(TEST,0,ETEST,0,1)) GO TO 895
C TEST SYMBOL TABLE
       IF(NSYMBL.EQ.0) GO TO 810
C LOOK IN SYMBOL TABLE
        DO 810 JJ=1,NSYMBL
       IF(EQUAL(ARG(IJ),0,SYMTAB(JJ),0,8)) GO TO 820
810     CONTINUE
C NOT IN SYMTAB
       WRITE(NTYP,9105) ARG(IJ)
9105    FORMAT(1X,'UNDEFINED SYMBOL => ',1A8)
       IERROR=5
       BUFSYM=ARG(IJ)
       GO TO 1
C SET ARG VALUE TO SYMBOL LOCATION
820    ARGVAL(IJ)=SYMVAL(JJ)
       ARGTYP(IJ)=SYMTYP(JJ)
       GO TO 880
C ***********************************************************************
C @ PROCESS A/D D/A CHANNEL
C GET NUMBER OF CHANNEL
840    ARGVAL(IJ)=NCFD(ARG(IJ),THREE)+1
        ARGTYP(IJ)=6
       IF((ARGVAL(IJ).LT.1).OR.(ARGVAL(IJ).GT.16)) GO TO 846
       GO TO 880
845    ARGVAL(IJ)=NCFD(ARG(IJ),THREE)+17
       ARGTYP(IJ)=7
       IF((ARGVAL(IJ).LT.17).OR.(ARGVAL(IJ).GT.32)) GO TO 846
       GO TO 880
846    IERROR=25
       WRITE(NTYP,9501)
9501    FORMAT(1X,'ILLEGAL CHANNEL CODE')
       BUFSYM=ARGVAL(IJ)
       GO TO 1
C ***********************************************************************
C SCALED FRACTION CONSTANT
870     ARGVAL(IJ)=LOCCNT
       ARGTYP(IJ)=8
```

```
C LOAD SCALED FRACTION INTO STORAGE
      NDFCS=NDFCS+1
      ITYPE=4
      MM=ISFIX(FPIN(ARG(IJ),ONE))
C WRITE SCALED FRACTION ONTO STORAGE FILE 2
      WRITE(NFILE2'NDFCS)ITYPE,LOCCNT,MM,I
      LOCCNT=LOCCNT+1
880    CONTINUE
890    CONTINUE
895   CONTINUE
900    CONTINUE
       PNUM=PNUM+6
      NSTMT=NSTMT+1
C WRITE HYBOL PROGRAM LINE ONTO STORAGE FILE
       WRITE(NFILE1'NSTMT)OPERCD,ARGVAL(2),ARGVAL(3),ARGVAL(4)
     1 ,ARGVAL(5),ZERO
      WRITE(NTYP,9988)OPERCD,ARGVAL(2),ARGVAL(3),ARGVAL(4),ARGVAL(5),IJ
9988   FORMAT(1X,8(I6,4X))
       ARGVAL(4)=0
      ARGVAL(5)=0
      GO TO 10
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * **
C DEFINE STATEMENT PROCESSOR
1000   BUFSYM=ARG(3)
      IF(NSYMBL.EQ.0) GO TO 1020
C TEST FOR CONFLICT
C LOOK IN SYMBOL TABLE FOR LOCATION
      DO 1005 I=1,NSYMBL
      IF(BUFSYM.EQ.SYMTAB(I)) GO TO 1010
1005   CONTINUE
      GO TO 1020
1010   WRITE(NTYP,9107)BUFSYM
9107   FORMAT(1X,'NAME CONFLICT => ',1A8,' PREVIOUSLY DEFINED NAME')
       IERROR=6
      GO TO 1
1020  CTEST=BLANK
      CALL BYTE(BUFSYM,0,CTEST,0)
      IF(CTEST.LT.LITA) GO TO 1025
      IF(CTEST.GT.LITZ) GO TO 1025
C PUT NEW NAME IN SYMTAB
      NSYMBL=NSYMBL+1
       IF(NSYMBL.GT.NSYMAX) GO TO 1021
      I=NSYMBL
      SYMTAB(NSYMBL)=BUFSYM
C SYMBOL VALUE IS LOCATION COUNTER
      SYMVAL(NSYMBL)=LOCCNT
      SYMTYP(I)=1
      LSAVE=LOCCNT
      LOCCNT=LOCCNT+1
      BUFSYM=ARG(2)
```

```
C TEST FOR TYPE OF DEFINE STATEMENT
      IF(BUFSYM.EQ.LVAR) GO TO 10
      IF(BUFSYM.EQ.LTAB) GO TO 1030
      IF(BUFSYM.EQ.LBUF) GO TO 1040
      IF(BUFSYM.EQ.LDBL) GO TO 1060
      IF(BUFSYM.EQ.LDEL) GO TO 1070
      WRITE(NTYP,9111)BUFSYM
9111  FORMAT(1X,'ILLEGAL TYPE SPECIFICATION IN A DEFINE =>',1A8)
      IERROR=7
      GO TO 1
1021  IERROR=29
      GO TO 1
C ***********************************************************************
C TABLE DEFINED ALLOCATE SPACE FOR N*M
C CALCULATE TABLE SIZE
1030  NN=NCFD(ARG(4),ZERO)
      SYMTYP(I)=2
      ITYPE=1
      ZERO=0
      MM=NCFD(ARG(5),ZERO)
      NN=NN*MM
      GO TO 1050
C ***********************************************************************
C BUFFER DEFINED ALLOCATE LENGTH N+1
C CALCULATE BUFFER LENGTH
1040  NN=NCFD(ARG(4),ZERO)
      ITYPE=2
      SYMTYP(I)=3
C SAVE CODE =NN
1050  LOCCNT=LOCCNT+NN
1051  NDFCS=NDFCS+1
C WRITE TYPE LENGTH LOCATION AND CODE INTO STORAGE FILE 2 FOR LOADER
      WRITE(NFILE2'NDFCS)ITYPE,LSAVE,NN,I
      GO TO 10
C IF DOUBLE PRECISION SCALED FRACTION SAVE ONE MORE HALFWORD
1060  LOCCNT=LOCCNT+1
      SYMTYP(I)=4
      GO TO 10
C ***********************************************************************
C DELAY STATEMENT ALLOCATE LENGTH AND POINTERS
1070  NN=NCFD(ARG(4),ZERO)
      SYMTYP(I)=-NN
      ITYPE=3
      ZERO=0
      I=0
      IF(EQUAL(ARG(5),0,ETEST,0,1)) GO TO 1071
      I=ICFIX(FPIN(ARG(5),ZERO))
1071  LOCCNT=LOCCNT+NN+2
      GO TO 1051
1025  WRITE(NTYP,9110)BUFSYM
```

```
9110  FORMAT(1X,'ILLEGAL NAME IN A DEFINE =>',1A8)
      IERROR=8
      GO TO 1
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * **
C DELAY STATEMENT PROCESSOR
1100   CONTINUE
      BUFSYM=ARG(2)
C LOOK IN SYMBOL TABLE
      DO 1101 I=1,NSYMBL
      IF(BUFSYM.EQ.SYMTAB(I)) GO TO 1105
1101   CONTINUE
      IERROR=20
      GO TO 1
1105   LSAVE=SYMVAL(I)
      IF(SYMTYP(I).LT.0) GO TO 1106
      IERROR=26
      GO TO 1
1106   ARG(2)=ARG(3)
      ARG(3)=ARG(4)
C SHIFT DELAY NAME TO 4 TH ARGUMENT SLOT
       ARG(4)=BUFSYM
      GO TO 800
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * **
C FUNCTION STATEMENT PROCESSOR
1200   BUFSYM=ARG(2)
      DO 1210 I=1,NSYMBL
      IF(BUFSYM.EQ.SYMTAB(I)) GO TO 1215
1210   CONTINUE
      WRITE(NTYP,9115)BUFSYM
9115  FORMAT(1X,'UNDEFINED FUNCTION NAME =>',1A8)
      IERROR=9
      GO TO 1
1215   ARG(2)=ARG(3)
      ARG(3)=ARG(4)
C SHIFT FUNCTION NAME TO LAST ARG LOCATION
      IF(EQUAL(ARG(5),0,ETEST,0,1)) GO TO 1220
      ARG(4)=ARG(5)
      ARG(5)=BUFSYM
      GO TO 800
1220   ARG(4)=BUFSYM
       GO TO 800
C **************************************************************************
C * CARD IMMEADIATE COMMAND
3000   CONTINUE
      IDUMP=0
C TEST FOR OPERATION BLOCK CODE AND BRANCH
      IF(OPERCD.EQ.PROGRM) GO TO 2
       IF(OPERCD.EQ.SYMBOL) GO TO 3600
      IF(OPERCD.EQ.EOJ) GO TO 5000
      IF(OPERCD.EQ.TSCALE) GO TO 7000
```

```
      IF(OPERCD.EQ.ANAVAL) GO TO 8000
       IF(OPERCD.EQ.SETPOT) GO TO 9000
C IF OP IN EXEC LINK TO EXEC
      IF(OPERCD.EQ.EXEC) GO TO 3001
      IF(OPERCD.EQ.LOAD) GO TO 3001
      IF(OPERCD.EQ.LIST) GO TO 3001
      IF(OPERCD.EQ.PRINT) GO TO 3001
       IF(OPERCD.EQ. PLOT) GO TO 3001
      IF(OPERCD.EQ.READ) GO TO 3001
      IF (OPERCD.EQ.RUN) GO TO 3001
      IF(OPERCD.EQ.TIMEOP) GO TO 3001
C ILLEAGAL OPERATION
      IERROR=10
       GO TO 1
C LINK TO EXEC MAIN
3001   CALL CHAIN(PROGS,2)
C ************************************************************
C SYMBOL TABLE LIST BLOCK
3600   CONTINUE
       WRITE(NTYP,9371)LOCCNT,TOPCOR
9371   FORMAT(//,' LOCATION COUNTER =',I6,' OF ',I6,/)
      WRITE(NTYP,9372)
9372  FORMAT(1X,'SYMBOL TABLE',/)
      WRITE(NTYP,9370)(SYMTAB(I),SYMVAL(I),SYMTYP(I),I=1,NSYMBL)
9370  FORMAT(4(1X,1A8,' = ',I6,' (TYPE ',I5,')'))
      GO TO 10
C ************************************************************
C MEMORY FULL FATAL ERROR
6000   CONTINUE
      WRITE(NTYP,9395)LOCCNT,TOPCOR
9395   FORMAT(1X,'MEMORY FULL, LOCATION COUNTER = ',I6,'AVAILABLE CORE=
     1',I6,' FATAL ERROR',/)
       GO TO 5000
C ************************************************************
C SET ANALOG TIME SCALE
7000    CONTINUE
      NN=NCFD(ARG(2),ZERO)
      CALL HINT
      CALL TSCL(NN)
      GO TO 10
C ************************************************************
C GET ANALOG VOLTAGE FROM SPECIFIED CHANNEL
8000   CONTINUE
      CALL MOVE(ARG(3),0,POT,0,4)
      CALL HINT
       VAL=ANVAL(POT)
      PUT,VAL
      GO TO 10
C ************************************************************
C SET SERVO POT SETTING AND DISPLAY ERROR
```

```
9000    CONTINUE
        CALL MOVE(ARG(2),0,POT,0,4)
        VAL=FPIN(ARG(3),ZERO)
         CALL HINT
        CALL SPOT(POT,VAL,IER)
        PUT,IER
        GO TO 10
C END OF JOB EXIT TO OPERATING SYSTEM
5000    CONTINUE
        WRITE(NTYP,9400)
9400    FORMAT(1X,'* * * * *  END OF JOB * * * * * *')
C END OF PROGRAM
        END
```

```
C EXEC PROGRAM,LOADER INPUT/OUTPUT,CLOCK CONTROLLER
      REAL*8 PROGS(3)
      REAL*8 LDBL,LDEL
      REAL*8 LVAR
       REAL*8 OPTEST
      REAL*8 BUFSYM,OPCODE
      REAL*8 LTAB,LBUF
      REAL*8 ARG(10)
      REAL*8 SYMTAB,CLEAR
       INTEGER*2 LOC,LOAD,ITYPE
      INTEGER*2 OPERCD,LPOUND,CARDI,IPOS,LOCCNT,LITADC,LITDAC,BUFFER,CARD,
     1D,ERROR,OPVAL,LITA,LITZ
      INTEGER*2 CORE,SYMBOL,DUMP,PCOUNT,PSTART,PEND,LIST,DATTAB,TOPCOR
      INTEGER*2 TIMEOP,ITYPE,IPCODE,SYMTYP
      INTEGER*2 COMMA,SEMICL
      INTEGER*2 READ,PRINT,PLOT,RUN,EOJ,PROGRM
      INTEGER*2 OPFLAG,PFLAG,IERROR,NSYMBL,NSTMT,NOPTAB,I,J,K,IJ,KK,JJ,
     1 NARGS,NN,MM,LSAVE,NFILE
      INTEGER*2 SYMVAL,ATSIGN
      INTEGER*2 ARGVAL(10)
      INTEGER*2 CTEST,NAME
      INTEGER*2 BUFFER(40),BFIELD(10)
      INTEGER*2 ASTRSK,BLANK,DOLSGN
      INTEGER*2 PNUM
      INTEGER*2 ERRORS
       INTEGER*2 EXEC
      INTEGER*2 ONE,THREE,ZERO
      INTEGER*2 IFLAG,NDFCS,IDUMP
       INTEGER*2 TSTEP,NCYCL,IREC1,IREC2
      INTEGER*2 LENGTH,LSAVES,ERROR,NFILE1,NFILE2,NTYP,NINP,NSYMAX
      INTEGER*2 SETPOT,MODE,ANVAL,TSCL
      REAL XPLOT,XSCL
      LOGICAL EQUAL
      DIMENSION XPLOT(200),XSCL(4)
      DIMENSION CARD(80),X(25),OPCODE(40),OPVAL(40)
      DIMENSION SYMTAB(100),SYMVAL(100),SYMTYP(100)
      DIMENSION DATTAB(10000)
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C COMMON DATA BASE AREA
      COMMON/CODES/READ,PROGRM,PRINT,PLOT,RUN,EOJ,CORE,SYMBOL,DUMP,LIST,
     1 TIMEOP,LOAD,EXEC,SETPOT,MODE,ANVAL,TSCL
      COMMON/CONTRL/PFLAG,NFILE1,NFILE2,TOPCOR,OPFLAG,NTYP,NINP,NSYMAX,
     1 NOPTAB,LOCCNT,NSYMBL
      COMMON/OPCOD /OPCODE,OPVAL,OPERCD,BUFSYM,ARG
      COMMON/PROGRM/PSTART,PCOUNT,PEND,NSTMT,PNUM,NDFCS,ERRORS
      COMMON/SYMBOL/SYMTAB,SYMVAL,SYMTYP
      COMMON PROGS
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C DATA INITIALIZATION
      DATA CLEAR/'        '/
```

```
      DATA ETEST/';   '/
C ***********************************************************************
C FILE SPECIFICATION STATEMENTS
      DEFINE FILE 1(100,3,U,IREC1)
      DEFINE FILE 2(60,2,U,IREC2)
      DEFINE FILE 3(10000,1,U,IREC3)
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C MARK FILE 1 WITH PROGRAM ID
      NFILE3=3
      IPCODE=2
      WRITE(NFILE1'1)IPCODE
      CALL PUTMES(' $EXEC ;')
C READ CORE LOAD FROM DAFILE
      READ(NFILE3'1)(DATTAB(I),I=1,TOPCOR)
      GO TO 10
1     CONTINUE
C WRITE ERROR MESSAGE AND PROBABLE SYMBOL
      WRITE(NTYP,9001)IERROR,BUFSYM
9001  FORMAT(1X,'***** ERROR #',I5,' BUFSYM =',1A8)
10     CONTINUE
C INITIALIZE FLAGS AND BUFS
       BUFSYM=CLEAR
      ERRORS=0
      ZERO=0
      IRFLAG=0
      IERROR=0
      OPFLAG=0
C READ A CARD AND PROCESS INTO ARGS AND FLAGS
      CALL CARDIN(ARG,PFLAG,OPFLAG,IERROR)
      IF(IERROR.NE.0) GO TO 1
C IF NOT IMMEADIATE OPERATION GOTO MAIN
      IF(OPFLAG.NE.1) GO TO 15
       OPTEST=ARG(1)
C LOOK IN OP CODE TABLE FOR VALUE OF OP
      DO 16 I=1,NOPTAB
       IF(OPTEST.EQ.OPCODE(I)) GO TO 17
16    CONTINUE
      IERROR=4
      GO TO 1
C ***********************************************************************
17    OPERCD=OPVAL(I)
9510    FORMAT(1X,10(1A8,2X))
C TEST AND GO TO PROPER SUBBLOCK
      IF(OPERCD.EQ.TIMEOP) GO TO 3800
      IF(OPERCD.EQ.READ) GO TO 3100
      IF(OPERCD.EQ.PRINT) GO TO 3200
      IF(OPERCD.EQ.RUN) GO TO 3400
      IF(OPERCD.EQ.LOAD) GO TO 2000
      IF(OPERCD.EQ.LIST) GO TO 2500
      IF(OPERCD.EQ.DUMP) GO TO 3500
```

```
      IF(OPERCD.EQ.PLOT) GO TO 4000
C RETURN TO MAIN IF NOT A * OPERCODE
15    IPCODE=5
C WRITE CORE LOAD TO DAFILE
      WRITE(NFILE3'1)(DATTAB(I),I=1,TOPCOR)
      WRITE(NFILE1'1)IPCODE,IERROR
       CALL CHAIN(PROGS,1)
C ***********************************************************************
C LOAD PROGRAM AND INITIALIZE DATA BASE
2000   PSTART=LOCCNT
      PCOUNT=PSTART
      DO 2010 I=2,NSTMT
      READ(NFILE1'I)DATTAB(PCOUNT),DATTAB(PCOUNT+1),DATTAB(PCOUNT+2),DATT
     1TAB(PCOUNT+3),DATTAB(PCOUNT+4),JJ
      PCOUNT=PCOUNT+5
2010   CONTINUE
      PCOUNT=PCOUNT-5
      PEND=PCOUNT
       WRITE(NTYP,9200) PSTART,PEND
9200   FORMAT(1X,'PROGRAM STARTS AT ',I5,5X,'PROGRAM ENDS AT ',I5,/)
      DO 1000 I=1,NDFCS
      READ(NFILE2'I)ITYPE,LOC,LENGTH,NN
      PUT,ITYPE,LOC,LENGTH,NN
C TABLE,BUFFER,DELAY,#,DONE
      IF(ITYPE.EQ.1) GO TO 1100
      IF(ITYPE.EQ.2) GO TO 1200
      IF(ITYPE.EQ.3) GO TO 1300
      IF(ITYPE.EQ.4) GO TO 1400
      IF(ITYPE.EQ.0) GO TO 1500
      IERROR=21
      GO TO 1
1100    DATTAB(LOC)=0
      GO TO 999
1200    DATTAB(LOC)=NN
      GO TO 999
1300   DATTAB(LOC)=LENGTH
       DATTAB(LOC+1)=1
      DATTAB(LOC+2)=NN
      GO TO 999
1400   DATTAB(LOC)=LENGTH
999   CONTINUE
1000   CONTINUE
1500   CONTINUE
      IF(PEND.LT.TOPCOR) GO TO 10
C IF CORE LOAD TOO LARGE ERROR
      WRITE(NTYP,9500)PEND,TOPCOR
9500   FORMAT(1X,'PROGRAM TOO LARGE =',I6,'AVAILABLE CORE =',I6,/)
       IERROR=35
       GO TO 1
C ***********************************************************************
```

```
C LIST PROGRAM CODE ON PRINTER
2500    CONTINUE
        DO 2020 I=PSTART,PEND,5
        WRITE(NTYP,9210)I,DATTAB(I),DATTAB(I+1),DATTAB(I+2) ,DATTAB(I+3)
       1 ,DATTAB(I+4)
9210    FORMAT(5X,I5,5X,I6,4X,I6,4X,I6,4X,I6,4X,I6)
2020    CONTINUE
        IF(ERRORS.EQ.0) GO TO 10
        WRITE(NTYP,9385)ERROR
9385    FORMAT(1X,I5,'ERRORS IN PROGRAM,RUN WILL BE SUPRESSED')
        IERROR=12
        IRFLAG=1
         GO TO 1
C ***********************************************************************
C READ OPERATION,PROCESS ARGS
C NAME LENGTH WIDTH
3100    NN=NOFD(ARG(3),ZERO)
        ZERO=0
        MM=NOFD(ARG(4),ZERO)
         BUFSYM=ARG(2)
C LOOK IN SYMBOL TABLE FOR LOCATION
        DO 3110 I=1,NSYMBL
        IF(BUFSYM.EQ.SYMTAB(I)) GO TO 3120
3110    CONTINUE
        WRITE(NTYP,9230)
9230    FORMAT(1X,'SYMBOL NOT FOUND')
        BUFSYM=ARG(2)
        IERROR=11
        GO TO 1
3120    LSAVE=SYMVAL(I)
        ITYPE=SYMTYP(I)
        IF(ITYPE.LT.0)LSAVE=LSAVE+2
        IF(ITYPE.EQ.0) LSAVE=LSAVE-1
        PUT,NN,MM
        DO 3130 I=1,NN
         READ(NINP,9050)(X(JJ),JJ=1,MM)
9050    FORMAT(10F10.5)
        DO 3125 J=1,MM
        K=LSAVE+J
        DATTAB(K)=ISFIX(X(J))
3125     CONTINUE
        LSAVE=LSAVE+MM
3130    CONTINUE
        GO TO 10
C ***********************************************************************
C PRINT OPERATION ,PROCESS ARGS
3200     BUFSYM=ARG(2)
C LOOK IN SYMBOL TABLE FOR LOCATION
        DO 3210 I=1,NSYMBL
        IF(BUFSYM.EQ.SYMTAB(I)) GO TO 3220
```

```
3210    CONTINUE
        WRITE(NTYP,9230)
        BUFSYM=ARG(2)
        GO TO 1
3220    LSAVE=SYMVAL(I)
        NN=NCFD(ARG(3),ZERO)
        MM=NN/10+1
        PUT,NN,MM
        DO 3230 I=1,MM
        DO 3225 J=1,10
        K=LSAVE+J
3225    X(J)=FLOTS(DATTAB(K))
        WRITE(NTYP,9240)(X(JJ),JJ=1,10)
9240    FORMAT(1X,10F12.5)
        LSAVE=LSAVE+10
3230    CONTINUE
        GO TO 10
C ***********************************************************************
C RUN OPERATION,INITIALIZE AND CALL INTERP
3400    CONTINUE
        IF(PSTART.EQ.PEND) GO TO 1
        CALL HINT
        CALL CVIO(0)
        CALL TC
        PAUSE 10
C LINK TO ASM INTERPRETER PHASE
        CALL INTERP(DATTAB,PSTART,NSTMT,TSTEP,NCYCL)
        CALL SP
        CALL CVIO(1)
C DONE SIMULATION,RETURN
        GO TO 10
C ***********************************************************************
C CLEAR STORAGE
3500    DO 3510 I=1,TOPCOR
3510      DATTAB(I)=0
        WRITE(NFILE3'1)(DATTAB(I),I=1,TOPCOR)
        GO TO 10
C ***********************************************************************
C CLOCK SET UP BLOCK
C WRITE OUT CLOCK VALUES AND SET CLOCK
3800    DT=FPIN(ARG(3),ZERO)
        ZERO=0
        TIME=FPIN(ARG(2),ZERO)
        NCYCL=1+IFIX(TIME/DT)
        TSTEP=ISFIX(DT)
        PUT,TIME,DT,NCYCL,TSTEP
        CALL HINT
        CALL CTSTEP(DT)
        GO TO 10
C ***********************************************************************
```

```
C PLOT BLOCK,PROCESS ARGUMENTS
C NN=# OF POINTS TO BE PLOTTED,MAX=200
4000  CONTINUE
      NN=NCFD(ARG(3),ZERO)
      IF(NN.GT.200) NN=200
      ZERO=0
4005   BUFSYM=ARG(2)
C LOOK IN SYMBOL TABLE FOR LOCATION
      DO 4010 I=1,NSYMBL
      IF(EQUAL(BUFSYM,0,SYMTAB(I),0,8)) GO TO 4020
4010   CONTINUE
      IERROR=41
      GO TO 1
4020    K=SYMVAL(I)
      MM=1
      IBOX=2
      IPLOT=1
      IF(EQUAL(ETEST,0,ARG(4),0,1)) GO TO 4021
      ZERO=0
      MM=NCFD(ARG(4),ZERO)
      IF(EQUAL(ETEST,0,ARG(5),0,1)) GO TO 4021
      IBOX=0
      IF(EQUAL(ETEST,0,ARG(6),0,1)) GO TO 4021
      IPLOT=2
4021   CONTINUE
      DO 4030 I=1,NN
      J=K+I*MM
      XPLOT(I)=FLOTS(DATTAB(J))
4030   CONTINUE
C SET SCALE FACTORS
      XSCL(1)=0.0
      XSCL(2)=1.0
      XSCL(3)=-1.0
      XSCL(4)=1.0
C PAUSE BEFORE PLOT
      PAUSE 30
      CALL PICTR(XPLOT,1,XLAB,XSCL,1,NN,0,0,IBOX,-2,1.0,IPLOT)
       CALL HINT
      GO TO 10
C END OF PROGRAM
      END
```

```
C HYBOL SETUP MAIN-INITIALIZE FILES AND PARAMETERS
      REAL*8 PNAMES(3)
      REAL*8 PROGS(3)
      REAL*8 OPCODE(40)
      REAL*8 OPC(40)
      REAL*8 ARG(10),BUFSYM,SYMTAB(100)
       INTEGER*2 ZERO
      INTEGER*2 OPVAL(40)
      INTEGER*2 SYMVAL(100),SYMTYP(100)
      IMPLICIT INTEGER*2 (A-Z)
      INTEGER*2 PFLAG,NFILE1,NFILE2,TOPCOR,IFLAG,NTYP,NINP,NSYMAX,NOPTAB
C *************************************************************
C COMMON DATA BASE AREA
      COMMON/CODES/READ,PROGRM,PRINT,PLOT,RUN,EOJ,CORE,SYMBOL,DUMP,LIST,
     1 TIMEOP,LOAD,EXEC,SETPOT,MODE,ANVAL,TSCL
      COMMON/CONTRL/PFLAG,NFILE1,NFILE2,TOPCOR,OPFLAG,NTYP,NINP,NSYMAX,
     1 NOPTAB,LOCCNT,NSYMBL
      COMMON/OPCOD /OPCODE,OPVAL,OPERCD,BUFSYM,ARG
      COMMON/PROGRM/PSTART,PCOUNT,PEND,NSTMT,PNUM,NDFCS,ERRORS
      COMMON/SYMBOL/SYMTAB,SYMVAL,SYMTYP
      COMMON PROGS
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      DATA PNAMES/'HYBOLMAN','HYBOLRUN','HYBOLSET'/
      DATA OPC/'DEFINE  ','FUNCF1  ','DELAY   ','SETPOT  ','ADD     ','SUB
     1UBTRACT','MULTIPLY','DIVIDE  ','COS     ','EXP     ','LOG     ','GET
     2ET     ','PUT     ','SENCE   ','READ    ','PRINT   ','PLOT    ','RU
     3RUN    ','END     ','SIN     ','INTEGRAT','CONVOLUT','DELAYS  ','FU
     4FUNCF2  ','MODE    ','SQRT    ','EOJ     ','PROGRAM','DUMP    ',
     5 'MOVE    ','SYMBOL  ','ANVAL   ','LIST    ','LOAD    ','RETURN  ','
     6 ','EXEC    ','TSCL    ','TIMEOP  ','FUNCHYST','        '/
C *************************************************************
C FILE SPECIFICATION STATEMENTS
C CALL DFI TO OPEN FILES
      ICART=0
      CALL DFI('HYBOLFL1 ',ICART,1,IER)
      IF(IER.NE.0) GO TO 9876
      ICART=0
      CALL DFI('HYBOLFL2 ',ICART,2,IER)
      IF(IER.NE.0) GO TO 9876
      ICART=0
       CALL DFI('DAFILE ',ICART,3,IER)
      IF(IER.NE.0) GO TO 9876
      DEFINE FILE 1(100,3,U,IREC1)
      DEFINE FILE 2(60,2,U,IREC2)
      DEFINE FILE 3(10000,1,U,IREC3)
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C DATA INITIALIZATION
      TOPCOR=10000
       ZERO=0
      IPCODE=3
```

```
      NFILE3=3
      NFILE2=2
      NFILE1=1
C CLEAR FILES 1,2,3 TO ZERO
      DO 5 I=1,100
5     WRITE(NFILE1'I)ZERO,ZERO,ZERO,ZERO,ZERO,ZERO
      DO 10 I=1,60
10      WRITE(NFILE2'I)ZERO,ZERO,ZERO,ZERO
      DO 15 I=1,TOPCOR
      WRITE(NFILE3'I)ZERO,ZERO
15    CONTINUE
C MARK FILE 1 WITH PROGRAM ID
      WRITE(NFILE1'1)IPCODE
      DO 3 I=1,3
3     PROGS(I)=PNAMES(I)
C SET UP CONTROL INFORMATION
      NTYP=5
      NINP=8
      NOPTAB=40
      NSYMAX=100
      NSYMBL=0
      LOAD=34
      TIMEOP=38
      EXEC=36
      READ=15
      PROGRM=28
      PRINT=16
      PLOT=17
      RUN=18
      EOJ=27
       CORE=32
      SYMBOL=31
      DUMP=29
      LIST=33
      SETPOT=4
      MODE=25
       TSCL=37
      ANVAL=32
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C TRANSFER DATA INTO OPCODE TABLES
      DO 2 I=1,NOPTAB
      OPCODE(I)=OPC(I)
      OPVAL(I)=I
2     CONTINUE
      OPVAL(40)=0
C SET UP PROGRAM CHAINING LINKAGE
      CALL SETCHN(PROGS,3)
C CHAIN TO HYBOL MAIN
       CALL CHAIN(PROGS,1)
C END OF PROGRAM
```

```
9876  CALL EXIT
      END
```

```
      SUBROUTINE CARDIN(ARG,PFLAG,OPFLAG,IERROR)
C SUBROUTINE TO READ,PRINT AND PROCESS A CARD.
      REAL*8 ARG(10)
      INTEGER*2 BUFFER(40),BFIELD(10)
      INTEGER*2 CARDI,CARD,LITA,LITZ,OPFLAG,IJ,I,JJ,KK,ASTRSK,BUFFER,
     1 BFIELD,CTEST,SEMICL,COMMA,IERROR,BLANK
      INTEGER*2 NINP,NTYP,K,IPOS,J,PFLAG
      INTEGER*2 PARR,PARL
      INTEGER*2 SLASH
      LOGICAL EQUAL
      DIMENSION CARD(80)
C DATA FOR CHARACTER TESTING
      DATA COMMA,SEMICL/', ',';  '/
      DATA PARR,PARL/') ','(  '/
      DATA LITA/'A '/,LITZ/'Z '/
      DATA BLANK/'   '/
      DATA ETEST/';    '/
      DATA NINP,NTYP/8,5/
      DATA ASTRSK/'* '/
      DATA SLASH/'/ '/
C ***********************************************************************
10    CONTINUE
       IERROR=0
      READ(NINP,9001)(CARD(I),I=1,80)
      WRITE(NTYP,9160) CARD
9160   FORMAT(/,1X,'INPUT CARD => ',80A1,' <=')
      PFLAG=0
      OPFLAG=0
9001  FORMAT(80A1)
C IF / COMMENT CARD JUST PRINT
      IF(EQUAL(CARD(1),0,SLASH,0,1)) GO TO 10
      DO 15 I=1,80
      CARDI=CARD(I)
C LOOK FOR A ; ( )
      IF(EQUAL(CARDI,0,ETEST,0,1)) GO TO 105
      IF(EQUAL(CARDI,0,PARR,0,1)) CARD(I)=COMMA
      IF(EQUAL(CARDI,0,PARL,0,1)) CARD(I)=COMMA
15    CONTINUE
      WRITE(NTYP,9390)
9390  FORMAT(1X,'NO SEMICOLEN TERMINATOR CHARACTER IN CARD INPUT')
      IERROR=1
       RETURN
105   CARD(I)=COMMA
      CARD(I+1)=SEMICL
      I=0
100   I=I+1
      CARDI=BLANK
      CALL BYTE(CARD(I),0,CARDI,0)
      IF(I.GT.10) IERROR=2
      IF(I.GT.10) RETURN
```

```
C TEST FOR IMMEDIATE
C SKIP BLANKS
C CHECK FOR ALPHABETIC
      IF(EQUAL(CARDI,0,ASTRSK,0,1)) GO TO 101
      IF(EQUAL(CARDI,0,BLANK,0,1)) GO TO 100
      IF(CARDI.LT.LITA) GO TO 200
      IF(CARDI.GT.LITZ) GO TO 200
      GO TO 500
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C SET * FLAG
101   OPFLAG=1
      GO TO 100
200   WRITE(NTYP,9100) I,CARDI
C ILLEGAL INPUT IN FIRST ARG
9100  FORMAT(1X,'ILLEGAL CHARACTER IN CARD COLUMN',I2,'=> ',A2)
      IERROR=3
       RETURN
C ******************************************************************************
C HAVE PROBABLE HYBOL PROGRAM CARD
C PACK OUT JUNK BYTES
500    IF(I.EQ.1) GO TO 510
      IJ=I-1
C CLEAR LEADING BLANKS
      DO 505 JJ=1,IJ
      DO 501 KK=1,79
501   CARD(KK)=CARD(KK+1)
505    CONTINUE
510   CONTINUE
      CALL PACK(CARD,80,BUFFER)
C GET FIELDS OUT
C MOVE ARGUMENT FIELDS FROM CARD TO ARRAY
      IPOS=0
      DO 520 K=1,8
      CALL FIELD(BUFFER,BFIELD,IPOS)
      CALL MOVE(BFIELD,0,ARG(K),0,8)
520   CONTINUE
C CLEAR BLANK ARGS
      DO 530 K=1,8
      CTEST=BLANK
      CALL BYTE(ARG(K),0,CTEST,0)
      IF(CTEST.NE.BLANK) GO TO 530
      DO 540 J=K,7
      ARG(J)=ARG(J+1)
540    CONTINUE
530   CONTINUE
C DONE RETURN TO CALLING PROGRAM
      RETURN
      END
```

```
 EXTRN OP,SP
 ENTRY INTERP
* HYBOL ASM INTERPRETER PHASE 2   REAL TIME PROGRAM EXEC.
* CALL INTERP(DATTAB,PSTART,NSTMT,TSTEP,NCYCL,...
* INTERPRETER ENTRY
R0 EQU 0
R1 EQU 1
R2 EQU 2
R3 EQU 3
R4 EQU 4
R5 EQU 5
R6 EQU 6
R7 EQU 7
R8 EQU 8
R9 EQU 9
R10 EQU 10
R11 EQU 11
R12 EQU 12
R13 EQU 13
R14 EQU 14
R15 EQU 15
ONE EQU 1
ZERO EQU 0
TWO EQU 2
OPNUM EQU 12
ADNUM EQU 16
DANUM EQU 12
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* SAVE REGISTERS FOR FORTRAN
INTERP STM 0,SAVEAR
 LHR R14,R15  LOAD LINKAGE ADDRESS INTO 14
 SVC 2,MESSIN
 SVC 2,SVC204  SET STATUS FOR OC
* GET ARGUMENTS INTO REGISTERS
 LH R1,2(R14)
 LH R2,4(R14)
 LH R3,6(R14)
 LH R4,8(R14)
 LH R5,10(R14)
* STORE ARGS IN SUB
* GET VALUES OF ARGUMENTS
 LH R2,0(R2)
 LH R3,0(R3)
 LH R4,0(R4)
 LH R5,0(R5)
 STH R1,TABLE
 STH R2,PSTART
 STH R3,NSTMT
 STH R4,TSTEP
 STH R5,NCYCL
```

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* CONVERT ARGUMENT ARRAY INDEX VALUES INTO BYTE ADDRESSES
* CODE TO TRANSLATE IDEXES INTO ACTUAL BYTE ADDRESSES
* GET PROGRAM OFFSET
 LHR R5,R1
 LHR R6,R3  REG 6 = LINES OF CODE IN PROG
* BYTE OFFSET=(I-1)*2
 SIS R2,1
 AHR R2,R2
 AHR R1,R2
 STH R1,PROGAD
* PSTART = PSTART OFFSET PLUA ADDRESS OF DATTAB
* DO ALL CONVERSION ON 3 ARGS AT ONCE
GETADD LH R2,2(R1)
 LH R3,4(R1)
 LH R4,6(R1)
 LH R9,0(R1)  LOAD OP CODE
 LH R10,8(R1)
* CHANGE TO BYTES
* ADD=(I-1)*2+A(DATTAB)
 SIS R2,1
 SIS R3,1
 SIS R4,1
 SIS R10,1
 AHR R2,R2
 AHR R3,R3
 AHR R4,R4
 AHR R10,R10
* ADD A(DATTAB)
 AHR R2,R5
 AHR R3,R5
 AHR R4,R5
 AHR R10,R5
* STORE IN OLD LOC
 STH R2,2(R1)
 STH R3,4(R1)
 STH R4,6(R1)
 STH R10,8(R1)
 XHR R8,R8 LOAD A 0 INTO 8
COMPAR LH R7,OPCODE+2(R8)  LOAD ADDRESS OF OP BLOCK
 CLH R9,OPCODE(R8) COMPARE OPCDE TO TABLE
 BE FOUND  FOUND OPCODE
 AIS R8,4 INCREMENT TO NEXT OP CODE
 BS COMPAR TEXT NEXT
FOUND STH R7,0(R1)  SAVE OP ADD IN OP CODE LOCATION
* TEST IF DONE
 SIS R6,1
 BZS CONTNU  GO TO INTERPRETER SECTION IF DONE ADDRESS CONVERSION
* INCREMENT AND DO NEXT LINE
 AIS R1,10
```

```
 B GETADD
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* START INTERPRETER
CONTNU EQU *
 LH R12,NCYCL
 LIS R10,1  LOAD FIRST TIME STEP VALUE INTO 10
* STOP AND WAIT FOR CLOCK TO RESET
 LHI R1,X'68'    LOAD CLOCK ADDRESS INTO 1
CWAIT SSR R1,R2 SENCE CLOCK STATUS
 BNCS CWAIT LOOP UNTIL CLOCK RESTETS
 LHI 3,X'0047'
 LHI 2,X'0400'
 LHI 1,X'00A0'
 OCR 1,3
 WHR 1,2
CYCLDN EQU *
 LH R13,PROGAD  LOAD PROGRAD START ADDRESS
 SIS R13,10
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* READ IN DATA FROM A/D BLOCK
* CODE TO READ A BLOCK OF A/D CONVERTERS
READAD LH R1,TABLE  LOAD A(DATTAB) INTO R1
 LHI R2,ADNUM LOAD NUM OF A/DS
 LHI R3,X'84'  LOAD OPCODE TO READ IN ADC AND INCREMENT MUX
 LHI R5,X'A4'  LOAD A HEX A4
 LHI R6,X'A0' LOAD A HEX A0
 XHR 7,7 ZERO REG 7
READY OCR R6,R5  SEND AN A4 TO DEVICE A0
 WHR R6,R7  SEND CHANNEL NUMBER
 LIS R9,10 LOAD A 10 AND COUNT DOWN TO WAIT 10 MICROSECS
RWAIT SIS R9,1  WAIT FOR 20 MICROSECONDS
 BNMS RWAIT
READ OCR R6,R3 SEND AN 84 TO THE INTERFACE
 RHR R6,R8  READ SCALED FRACTION INTO R8
 NHI R8,X'FFC0'
 STH R8,0(R1) SAVE VALUE IN DATTAB
 AIS R1,2 INCREMENT ADDRESS
 AIS R7,1 INCREMENT CHANNEL #
 SIS R2,1  SUBTRACT FROM LOOP COUNTER
 BNZ READ
* DONE READING BLOCK OF A/D IN
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
TEST EQU *
* GET OP CODE,ARG1,ARG2,ARG3
* 9 INSTRUCTION OVERHEAD PER SET
 AIS R13,10
 LH R1,0(R13)
 LH R2,2(R13)
 LH R3,4(R13)
 LH R4,6(R13)
```

```
 LH R5,8(R13)
 STH R2,ARG2  SAVE ADDRESSES
 STH R3,ARG3   BECAUSE SOME OPS NEED THEM
 LH R2,0(R2)  GET VALUES OF ARGS FOR IMMEADIATES
 LH R3,0(R3)
 BR R1 BRANCH TO OP CODE BLOCK
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* INTERNAL ARGUMENT STORAGE LOCATIONS
A3VAL DC X'A300'
SVC204 DC X'0004'
 DC X'4000'
TABLE DC X'0'
PSTART DC X'0'
NSTMT DC X'0'
PROGAD DC X'0'
TSTEP DC X'0'
SVCONE DC X'0001'
ERROR DC X'0'
ERRORS DC X'0'
LINE DC X'0'
NCYCL DC X'0'
ARG2 DC X'0'
ARG3 DC X'0'
A2VAL DC X'4200'
MASKAD DC X'FFC0'
LOST DC X'0'
SAVEAR DS 32
* SVC 2 MESSAGE BLOCKS
MESSIN DC 7
 DC 10
 DC C' ENTER INT'
MESSS DC 7
 DC 6
 DC C' DO OP'
MESSI DC 7
 DC 10
 DC C' READ ADCS'
MESSR DC 7
 DC 10
 DC C' WRITE DAS'
MESSCL DC 7
 DC 10
 DC C' CHECK CLK'
* OPCODE AND BLOCK ADDRESS TABLE
OPCODE DC 5
 DC A(ADDOP)
 DC 6
 DC A(SUBOP)
 DC 7
 DC A(MULTOP)
```

```
 DC 12
 DC A(GETOP)
 DC 13
 DC A(PUTOP)
 DC 8
 DC A(DIVOOP)
 DC 3
 DC A(DELAY)
 DC 19
 DC A(ENDOPS)
 DC 21
 DC A(INTGRT)
 DC 23
 DC A(DELAYS)
 DC 22
 DC A(CONVLT)
 DC 2
 DC A(FUNC1)
 DC 24
 DC A(FUNCF2)
 DC 30
 DC A(MOVEOP)
 DC Ø
 DC A(ENDOPS)
 DC 40
 DC A(INVERT)
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* ADD TWO SCALED FRACTIONS
ADDOP AHR R2,R3
 STH R2,Ø(4)
 B TEST
* SUBTRACT TWO SCALED FRACTIONS
SUBOP SHR R2,R3
 STH R2,Ø(4)
 B TEST
* MULTIPLY TWO SCALED FRACTIONS
MULTOP LHR R9,R2
 MHR R8,R3 MULTIPY BY SF
 SLA R8,1
 STH R8,Ø(4) SAVE RESULT IN OUTPUT ARG LOC
 B TEST
* DIVIDE TWO SCALED FRACTIONS
DIVDOP LHR R8,R2
 SHR R9,R9
 SRA R8,1
 DHR R8,R3 DIVIDE BY SF
 STH R9,Ø(4)
 B TEST
INVERT LH R3,ARG3  GET LOC BACK
 XHR R1,R1  CLEAR REG 1 TO Ø
```

```
 SHR R1,R2     SUBTRACT VAL FROM ZERO
 STH R1,0(R3)   SEND VAL OUT
 B TEST
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* PUT VALUE INTO BUFFER(NCYCL)
PUTOP LH R3,ARG3
 LHR R4,R10   GET TSTEP #
 AHR R4,R4
 AHR R4,R3
 STH R2,0(4) PUT VALUE IN BUFFER
 B TEST
* GET VALUE FROM BUFFER(NCYCL)
GETOP LH R3,ARG3
 LH R2,ARG2
 LHR R4,R10
 AHR R4,R4
 AHR R4,R3
 LH R3,0(R4)
 STH R3,0(2)
 B TEST
MOVEOP LH R3,ARG3  GET ADDRESS OF 3 BACK
 STH R2,0(R3)  MOVE VAL TO LOC OF 3
 B TEST
DELAYS EQU *
 B TEST
CONVLT EQU *
 B TEST
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
ERROR1 LIS R7,1
 SVC 2,MESSAG
 B TEST
MESSAG DC 7
 DC 10
 DC C'ILLEGAL OP'
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* DELAY LINE - SIMPLE TYPE
* DELAY SUBROUTINE
DELAY LH R5,0(R4) REG 5 IS LENGTH NN
 LH R6,2(R4)
 LH R3,ARG3  GET LOC BACK
 CLHR R6,R5 COMPARE PNT TO NN
 BNPS PNTROK  IF PNT SMALL ENOUGH GO TO OK
 LIS R6,ONE
PNTROK LHR R7,R6    SAVE PNT IN REG 7
 AHR R6,R6
 AHR R6,R4   ADD DISPLACEMENT FOR DATTAB
 AHI R6,4  ADD 4 FOR OFFSET
 LH R8,0(R6)   GET DELAYED VALUE
 STH R8,0(R3)  GET VAL DELAYED THEN PUT AT OP LOC
 STH R2,0(R6) PUT NEW VALUE IN OLD SLOT
```

```
 AIS R7,1
 STH R7,2(R4)  SAVE PNT+1 IN PNT
 B TEST
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* ONE DIMENSIONAL TABLE LOOKUP
FUNC1 LH R3,ARG3
 AIS R4,2  INCREMENT PNT TO DATA
FCOMP CH R2,0(R4)  COMPARE X WITH X(I) IN TABLE
 BE FEQUAL X HIT TABLE EXACT
 BMS FUNC00  IF X LT POINT OK
 AIS R4,4  INCREMENT TO NEXT ADDRESS
 BS FCOMP
FUNC00 SIS R4,4  SET 4 FOR X(I)
 LH R5,0(R4)  LOAD X(I) IN 5
 LH R6,2(R4) R6=Y(I)
 LH R7,4(R4) R7=X(I+1)
 LH R9,6(R4)  R9=Y(I+1)
 SHR R9,R6  R9=Y(I+1)-Y(I)
 SHR R7,R5  R7=X(I+1)-X(I)
 SHR R2,R5 R2=X-X(I)
 MHR R8,R9 R9=R9*(X-X(I)) RESULT IN R8
 DHR R8,R7  R8=R8/X(I+1-X(I) RESULT IN R9
 AHR R9,R6  R9=R9+Y(2)
 STH R9,0(R3)  PUT AT OUT LOC
 B TEST DONE SO RETURN
FEQUAL LH R2,2(R4)  GET Y(I)
 STH R2,0(R3)  PUT AT OUT LOC
 B TEST
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
V3276 DC 3276
FORTY2 DC 42
TEN DC 10
TWENTY DC 20
* 2 INPUT FUNCTION TABLE LOOK UP
FUNCF2 LHR R1,R5  SAVE TABLE ADDRESS IN 1
 LHR R0,R4  SAVE OUTPUT LOC IN 0
 LHR R5,R2  PUT X IN 5
 LHR R7,R3  PUT Y IN 7
 MH R4,TWENTY
 MH R6,TWENTY
 LHR R8,R4
 LHR R9,R6
 AIS R4,11 I=I+11
 AHR R4,R4 I=I*2
* R5 NOW HAS COLUMN BYTE OFFSET
 AIS R6,10  J=J+10
 LHR R7,R6 PUT OVER FOR *
 MH R6,FORTY2    J=J*42
* R7 NOW HAS ROW OFFSET BYTES
* XIYJ=LOC+ROW+COL
```

```
 AHR R4,R1  ADD TABLE LOC
 LHR R1,R2 PUT OUTPUT LOC IN 1
 AHR R4,R7 ADD ROW OFFSET
* R5 NOW POINTS TO XIYJ VALUE LOCATION
 LHR R11,R4  SAVE LOC IN 11
 LHR R7,R8  PUT # INTO 7
 MH R6,V3276  *BY .1 BUT NOT A SCALED FRAC
 MH R8,V3276  *BY.1
 SHR R2,R7  R2=DELTA X
 SHR R3,R9  R3=DELTA Y
* CALCULATE FAKE END PNTS AND CENTER
 LH R5,2(11) LOAD XI+1,YJ
 SH R5,0(11) -XI,YJ
 MHR R4,R2  S.F. * DELTA X DIFF
 DH R4,V3276  S.F. / BY .1
 AH R5,0(11) + XI,YJ
 LHR R8,R5 SAVE IN 8
 LH R5,44(11) LOAD XI+1,YJ+1
 SH R5,42(11) - XI,YJ+1
 MHR R4,R2  * BY DELTA X S.F.
 DH R4,V3276 S.F./.1
 AH R5,42(11) + XI,YJ+1
 SHR R5,R8  DELTA Z = Z(I+1)-Z(2)
 MHR R4,R3  S.F. * DELTA Y
 DH R4,V3276  S.F. /.1
 AHR R5,R8 Z=Z(I)+DELTA Z
 STH R5,0(R1)  PUT AT OUTPUT LOC
 B TEST
* INTEGRATOR BLOCK
INTGRT LH R3,ARG3 GET ADDRESS
 LHR R9,R2  SET  UP FOR MULTIPLY
 SHR R8,R8  CLEAR R8 TO ZERO
 MH R8,TSTEP  INPUT*DT
 SLA R8,1 SHIFT OUT EXTRA BIT
 AH R9,2(3)
 ACH R8,0(3)  ADD TEMP TO OLD INTEGRAL
 STH R8,0(3)
 STH R9,2(3)  STORE NEW INTEGRAL IN OLD LOCATION
 B TEST DONE RETURN
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
ENDOPS EQU *
* WRITE OUT DATA INTO D/A BLOCK
* OUTPUT D/A BLOCK
 LHI R1,X'A0' LOAD A HEX A0
 LH R2,TABLE
 AHI R2,32  SET STARTING ADDRESS OF INPUT BUFFER
 XHR R3,R3 ZERO 3
 LHI R4,DANUM
 XHR R5,R5 ZERO 5
 LHI R6,X'80'  LOAD A  INC AND SEND COMMAND CODE
```

```
 OC R1,A2VAL      SEND AN A2
 WHR R1,R5   PUT IN RESET JAM MODE
 OCR R1,R1  SET CHANNEL VALUE
 WHR R1,R5 WRITE  FIRST ADDRESS
WRITDA OCR R1,R6  SEND SET COMM
 WH R1,0(R2)  SEND VALUE
 AIS R2,2 NEW ADD
 SIS R4,1  DECREMENT LOOP
 BNZS WRITDA
 OC R1,A3VAL SEND AN A3 TO INTERFACE FOR TRANSFER COMMAND
 WHR R1,R5  SEND JUNK
* DONE WRITING BLOCK
 AIS R10,1  ADD A ONE TO 10 TO COUNT STEPS DONE
 SIS R12,1 SUBTRACT 1 FROM 12 TO SET CC FOR DONE
 BZ DONE IF CC ZERO FINISHED RUN
 LHI R2,X'68' LOAD CLOCK ADDRESS INTO 2
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* CODE TO SENCE CLOCK STATUS
 SSR R2,R4  SENCE STATUS OF CLOCK PUT IN 4
 BCS CHIT  MISSED PULSE,TOO LONG A PROGRAM
 BNPS CHIT  CLOCK NOT RUNNING
CLOOP SSR R2,R4  TEST CLOCK STATUS
 BNCS CLOOP LOOP IF NOT DONE COUNTING DOWN
 B CYCLDN  RETURN AND RESTART PROGRAM IF NOT DONE
CHIT SVC 2,MESS2  PUT OUT CLOCK ERROR MESSAGE
 B CYCLDN
MESS2 DC 7
 DC 10
 DC C'CLOCK LOST'
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* ON INTERUPT CHECK IF FINISHES PROG OK
* FINISHED RUNNING PROGRAM
DONE LH R1,ERRORS
 BAL 15,SP
 DC 2
 LM R0,SAVEAR  RETURN REGISTERS FOR FORTRAN
 AH R15,0(R15) GET RETURN ADDRESS
 BR R15
  END
```