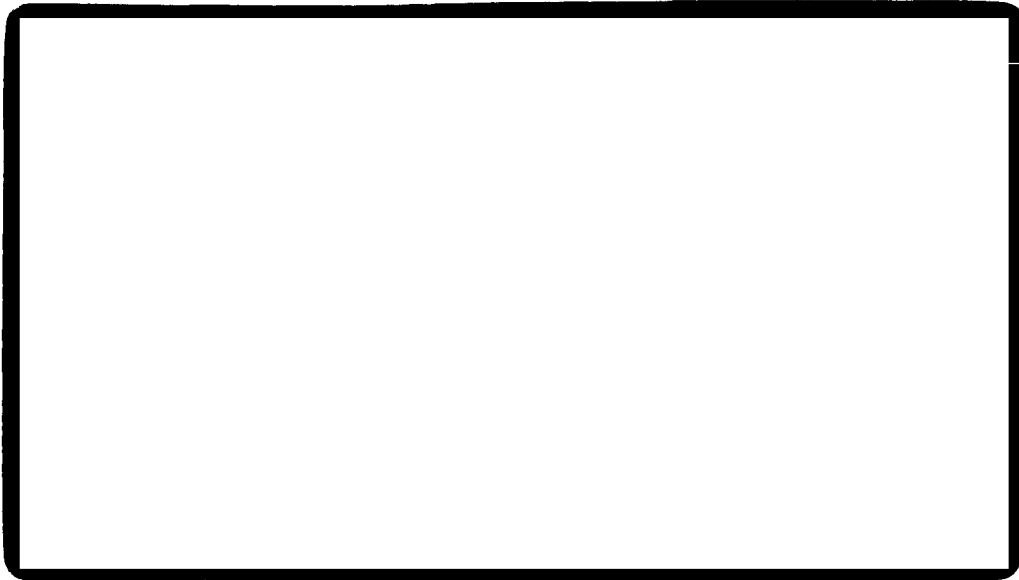
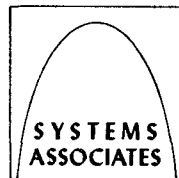


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PROGRAM USERS GUIDE (Systems Associates,
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ADVANCED COMMUNICATION SYSTEM
TIME DOMAIN MODELING TECHNIQUES

ASYSTD SOFTWARE DESCRIPTION

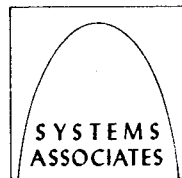
VOLUME I

PROGRAM USER'S GUIDE

August 1972

Prepared for:

Space Electronics System Division
National Aeronautics Space Administration
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Houston, Texas 77058



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PREFACE

This document describes the computer program ASYSTD, which is primarily designed to simulate the transient behavior of communications systems.

The ASYSTD program is based in part on earlier work performed for NASA MSC under Contract No. NAS9-10831, the development of the SYSTID program. The program is written in FORTRAN V for the UNIVAC 1108 computer operating under EXEC II.

The document is presented in two volumes – Volume I, Program User's Guide, and Volume II, Program Support Documentation. Program listings and detailed flow charts are under separate cover.

The analyses performed during the ASYSTD development contract are published in a series of progress reports addressing the individual tasks, which include:

- Parametric Analysis
- Optimization and Statistical Analysis
- Propagation Model Development
- Frequency to Time Domain Filter Transformations
- Orthogonal Transforms
- Bit Error Rate Measurements (EVT)
- SNR Measurements
- Distortion Measurements

SECTION 1.0

PROGRAM DESCRIPTION

ASYSTD is a system of computer routines which provides the analyst with a powerful tool for the transient simulation and analysis of complex systems — in particular, telecommunications systems, although other continuous and discrete systems can be simulated.

The unique characteristic of telecommunications systems is the large ratio between the RF carrier and baseband frequencies. Simulation of such systems would normally require prohibitive run times. However, with the techniques utilized in ASYSTD, this problem is alleviated. In particular, the RF system elements can be translated to baseband with complete retention of their RF characteristics.

The program accepts as input a topological "black box" description of a system, automatically generates the appropriate algorithms, and then proceeds to execute the simulation program. Thus the user is not necessarily required to write the algorithms in a computer language nor possess a great facility in computer programming. The system description, including both topology and element information, is supplied to the program in a free-form, user controlled engineering language which is easily learned.

ASYSTD offers the user enormous flexibility in the representation of system elements, i. e. , "black boxes". An element may be defined as:

- 1) An ASYSTD library model.
- 2) A user written, temporary ASYSTD model.

- 3) A FORTRAN arithmetic expression involving any intrinsic ASYSTD parameter, constants, variables, FORTRAN library functions, ASYSTD library functions, model output nodes (TAP's), and user supplied FORTRAN functions.

The ASYSTD model library consists of a set of computer routines, either written in FORTRAN or ASYSTD, which have been stored on a library file and cataloged in the ASYSTD directory. The user, at any time, can modify or replace the library and directory as he may choose — thus every user can easily create his own library. One unique characteristic of ASYSTD is the capability of nesting models to a level of 100 — that is, any model (or system) can reference up to 100 models, excluding itself. The nesting feature provides the user with the tools necessary to build a model library to suit his needs based upon a canonic set of models. An example might be a receiver that is used in several systems — the receiver would be a model consisting of a connection of other models.

The basic, or canonic, ASYSTD library consists mainly of a group of routines which aid in the simulation of continuous functions, that is $G(s)$. The technique applied is that of the bi-linear z -transform representation of $G(s)$. The transfer function may be defined in several ways — in terms of its poles and zeros or as one of the classical functions such as BESSEL, ELLIPTIC, etc. The sample data routines accomplish all the necessary transformations in addition to the numerical processing such as integration and differentiation. In addition, all of the FORTRAN arithmetic features are an intrinsic part of the ASYSTD library — although they do not appear in the directory.

The bi-linear transform rather than the standard z -transform is used in the representation of continuous functions because it eliminates aliasing errors, making possible the realization of commonly encountered functions whose response does not approach zero at high frequencies. Note that aliasing of the signals, however, is possible.

Another aspect of the ASYSTD model library is that it contains FORTRAN subroutines — that is, when a model (or system) is processed by

ASYSTD, the result is a FORTRAN subroutine (or main program) which is available to the user for any purpose, whether for ASYSTD or not. Thus, ASYSTD can be viewed as a FORTRAN program generator which converts a topological, non-procedural input into a procedural language-FORTRAN. Although not unique to ASYSTD, this aspect allows one to evaluate mathematical problems via ASYSTD with no concern for the Input/Output coding necessary in FORTRAN programs. That is, ASYSTD may be used as a shorthand FORTRAN system.

ASYSTD's flexibility is in part attained by designing the program to execute as a multipass processor in a batch mode of operation. The first phase reads the user input description of all models and/or a system and proceeds to formulate the corresponding FORTRAN algorithms. In this phase, the program checks for input errors such as erroneous model references, dangling nodes, etc., in which case appropriate error messages are issued. If the first phase terminates without fatal errors, the FORTRAN routines are automatically compiled and collected with the ASYSTD library to form the second phase, that of executing the simulation.

Output from the program includes plots as well as tabulated data. Conventional output is any system node or "TAP" which may be individually selected, or any variable whether intrinsic or user defined. Plots can be produced on the printer as well as a digital plotter. Printed data can be formatted, under user control, for either 8-1/2 by 11 inch pages or the full 11 by 14 inch page. Digital plotters are handled by the subroutine TMPLT, which is installation dependent.

The additional flexibility of linking to a user defined post processing routine is intrinsic to ASYSTD when utilizing the POST system identifier. This feature allows the user to access the time histories of any node, tap, or variable much the same way as the plot routines. As a matter of fact, the plot routines are indeed intrinsically named post-processors. Utility routines are available to perform any necessary input/output for the user.

The user, because of the two phase aspect, has available to him several techniques for controlling his computer runs and ensuring that the most effective use is made of the machine time. The primary means is

that of saving the results of the first phase, that is, the collected simulation package for subsequent reruns with alternate input data. Rerun would then simply entail a load-go operation. The alternate input data can be provided at execution time by use of the "DATA" identifier in the first phase.

SECTION 2.0

DATA PREPARATION

Given a description of a system or model in an engineering oriented language, ASYSTD will automatically generate the FORTRAN code required to simulate the system or model. The user, however, must reduce the system or model to an equivalent block diagram form consisting of model references, math expressions, etc., which can be interpreted by ASYSTD. The transcription of the equivalent block diagram into the input language is straightforward and easily mastered.

The initial step in using ASYSTD is to prepare the equivalent block diagram utilizing the ASYSTD library directory and FORTRAN expressions available. The model library directory currently available is given in Figure 2-1. The usage of these internal models is explained in Appendix B. The user is not in any way restricted or limited to this library — any particular function in the library can be replaced with one's own model. Thus the user's model repertoire consists of:

- 1) The invoked ASYSTD library directory.
- 2) FORTRAN math functions, including user variables, constants, etc.
- 3) Any ASYSTD model defined in the same run stream.

```

00 00 01      .
00 00 02      1
00 00 03      2 THIS ELEMENT IS THE MODEL LIBRARY DIRECTORY FOR THE SYSTID PROCESSOR.
00 00 04      3 ADDITIONS AND DELETIONS CAN BE MADE SIMPLY BY REMOVING OR ENTERING THE
00 00 05      4 DESCRIPTOR CARD, DO NOT EMBED BLANK CARDS IN THIS ELEMENT
00 00 06      .
00 00 07      5          FORMAT
00 00 08      .
00 00 09      6      A      CC      1-36      MODEL NAME, ALPHANUMERIC, LEFT ADJUST AND NO EMBEDDED
00 00 10      7          BLANKS
00 00 11      8      B      CC      41-46      THE ENTRY POINT NAME CORRESPONDING TO (A)
00 00 12      9      C      CC      50          = 1 TO INDICATE SUBROUTINE, 0 FOR A FUNCTION.
00 00 13      10     D      CC      53          = 0-9 IS THE NUMBER OF ARGUMENTS REQUIRED FOR (B)
00 00 14      11     E      CC      56          = 0-9 IS THE NUMBER OF TAPS ON THE MODEL
00 00 15      12     F      CC      60-71      OCTAL WORD REPRESENTING TYPE OF EACH TAP, I.E. THE
00 00 16      13          OCTAL WORD MADE UP FROM A 36 BIT WORD CONTAINING
00 00 17      14          A 1 FOR INPUT, 0 FOR OUTPUT IN THE BIT POSITION
00 00 18      15          OF THE TAP NUMBER STARTING FROM THE LEFTMOST BIT.
00 00 19      15     G      CC      73          PHASE INDICATOR = 1 FOR SETUP = 2 FOR RUN =3 FOR POST
00 00 20      .
00 00 21      .
00 00 22      ** THIS CARD STARTS THE LIBRARY. DO NOT REMOVE. COMMENTS ABOVE IT ONLY.
00 00 23      MODEL MODEL      DO NOT REMOVE THIS IS THE ELEMENT NAME COUNTER
00 00 24      FILTER      FILTER      1 9 0      2
00 00 25      GENRAL      GENRAL      1 9 0      2
00 00 26      GENERAL FILTER      GENRAL      1 9 0      2
00 00 27      BUTWTH      BUTWTH      1 6 0      2
00 00 28      BUTTERWORTH      BUTWTH      1 6 0      2
00 00 29      BUFUNCTION      BUTWTH      1 6 0      2
00 00 30      BESSEL      BESSEL      1 6 0      2
00 00 31      BEFUNCTION      BESSEL      1 6 0      2
00 00 32      BUTOM      BUTOM      1 7 0      2
00 00 33      BUTTERWORTH THOMPSON      BUTOM      1 7 0      2
00 00 34      BTFUNCTION      BUTOM      1 7 0      2
00 00 35      ELIPTC      ELIPTC      1 8 0      2
00 00 36      ELLIPTIC      ELIPTC      1 8 0      2
00 00 37      ELFUNCTION      ELIPTC      1 8 0      2
00 00 38      QFACT      QFACT      1 7 0      2
00 00 39      QFACTOR      QFACT      1 7 0      2
00 00 40      QUADRATICFACTOR      QFACT      1 7 0      2
00 00 41      LEADLAG      LEDLAG      1 5 0      2
00 00 42      LOOPFILTER      LEDLAG      1 5 0      2
00 00 43      LEADFUNCTION      LEADIT      1 4 0      2
00 00 44      CHEBY      CHEBY      1 7 0      2
00 00 45      CHEBYCHEV      CHEBY      1 7 0      2
00 00 46      TCHEBYCHEV      CHEBY      1 7 0      2
00 00 47      AGATE      AGATE      1 2 0      2
00 00 48      AMMODULATOR      AMMOD      1 2 0      2
00 00 49      AMMOD      AMMOD      1 2 0      2
00 00 50      AMPLITUDE DEMODULATOR      AMDEM      1 0 0      2

```

Figure 2-1. Model Library

00 00 51	AMDEM	AMDEM	1	0	0	2
00 00 52	AMPLITUDE MODULATOR SQUARE LAW	AMDESQ	1	2	0	2
00 00 53	AMDESQ	AMDESQ	1	2	0	2
00 00 54	CAL INB	CAL INB	1	1	0	2
00 00 55	CADD	CADD	1	0	0	2
00 00 56	COMPLEX ADDER	CADD	1	2	0	2
00 00 57	COMPLEX MULTIPLIER	CMULT	1	2	0	2
00 00 58	CMULT	CMULT	1	2	0	2
00 00 59	COSINE	COSINE	0	1	0	2
00 00 60	DELAY	DELAY	1	1	0	2
00 00 61	DELTA MODULATOR	DEL MOD	1	2	0	2
00 00 62	DEL MOD	DEL MOD	1	2	0	2
00 00 63	DIFFERENTIAL TOR	DIF FER	1	0	0	2
00 00 64	DIF	DIF FER	1	0	0	2
00 00 65	DIF FER	DIF FER	1	0	0	2
00 00 66	FMMODULATOR	FMMOD	1	2	0	2
00 00 67	FMMOD	FMMOD	1	2	0	2
00 00 68	FREQUENCY MODULATOR	FMD EMM	1	2	0	2
00 00 69	FMD EMM	FMD EMM	1	2	0	2
00 00 70	FMD EMM	FMD EMM	1	2	0	2
00 00 71	FMD EMM	FMD EMM	1	2	0	2
00 00 72	FMD EMM	FMD EMM	1	2	0	2
00 00 73	GNOISE	GNOISE	0	3	0	2
00 00 74	GNOIS2	GNOIS2	0	2	0	2
00 00 75	HARDLIMITER	HARD	1	0	0	2
00 00 76	HARD	HARD	1	0	0	2
00 00 77	INTEGRATOR	INTGR T	1	0	0	2
00 00 78	INTGR T	INTGR T	1	0	0	2
00 00 79	INTEGRAL WITH INITIAL CONDITIONS	INTGIC	1	1	0	2
00 00 80	INTGIC	INTGIC	1	1	0	2
00 00 81	MATCHED FILTER	MFL TER	1	1	0	2
00 00 82	MFL TER	MFL TER	1	1	0	2
00 00 83	MONOSTABLE	MONO	1	1	0	2
00 00 84	MONO	MONO	1	1	0	2
00 00 85	MULTILEVEL PCM	MLT PCM	1	2	0	2
00 00 86	MLT PCM	MLT PCM	1	2	0	2
00 00 87	NRZLBITSTREAM	NRZL	1	3	0	2
00 00 88	NRZL	NRZL	1	3	0	2
00 00 89	PHASE MODULATOR	PMMOD D	1	2	0	2
00 00 90	PMMOD	PMMOD D	1	2	0	2
00 00 91	PMMOD D	PMMOD D	1	2	0	2
00 00 92	PHASE MODULATOR	PMD EMM	1	2	0	2
00 00 93	PMD EMM	PMD EMM	1	2	0	2
00 00 94	PHASE SHIFTER	PHSHF T	1	2	0	2
00 00 95	PHSHF T	PHSHF T	1	2	0	2
00 00 96	PERIODIC TABLE FUNCTION	PTABLE	0	10	0	2
00 00 97	PTABLE	PTABLE	0	10	0	2
00 00 98	PULSE	PULSE	0	5	0	2
00 00 99	RANDOM BIT GENERATOR	RBGEN	1	1	0	2
00 01 00	RBGEN	RBGEN	1	1	0	2
00 01 01	RFAMPLITUDE MODULATOR	RAMMOD	1	3	0	2
00 01 02	RAMMOD	RAMMOD	1	3	0	2
00 01 03	RFAMDEM MODULATOR	RAMDEM	1	1	0	2
00 01 04	RAMDEM	RAMDEM	1	1	0	2
00 01 05	RFENVELOPE	RFENVE	1	1	0	2
00 01 06	RFENVE	RFENVE	1	1	0	2

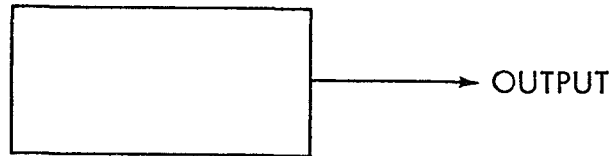
Figure 2-1. Model Library (Cont)

00 01 07	RFFMMODULATOR	RFFMOD	1	1	0	2	
00 01 08	RFMOD	RFMOD	1	1	0	2	
00 01 09	RFFREQUENCYDEMODULATOR	RFMDM	1	1	0	2	
00 01 10	RFMDM	RFMDM	1	1	0	2	
00 01 11	RFREQUENCY	RFFREQ	1	0	0	2	
00 01 12	RFFREQ	RFFREQ	1	0	0	2	
00 01 13	RFPHASEMODULATOR	RPMOD	1	1	0	2	
00 01 14	RPMOD	RPMOD	1	1	0	2	
00 01 15	RFPHASDEMODULATOR	RFPDEM	1	1	0	2	
00 01 16	RFPDEM	RFPDEM	1	1	0	2	
00 01 17	RFPHASE	RFPHAS	1	0	0	2	
00 01 18	RFPHAS	RFPHAS	1	0	0	2	
00 01 19	RFPHASESHIFTER	RFSHFT	1	2	0	2	
00 01 20	RFSHFT	RFSHFT	1	2	0	2	
00 01 21	RFLIMITER	RFLIMT	1	0	0	2	
00 01 22	RFLIMT	RFLIMT	1	0	0	2	
00 01 23	RFNOISE	RFNOIS	1	2	0	2	
00 01 24	RFNOIS	RFNOIS	1	2	0	2	
00 01 25	RFSOFTLIMITER	RFSOFT	1	2	0	2	
00 01 26	RFSOFT	RFSOFT	1	2	0	2	
00 01 27	SINE	SINE	0	1	0	2	
00 01 28	SOFTLIMITER	SOFTY	1	2	0	2	
00 01 29	SOFTY	SOFTY	1	2	0	2	
00 01 30	SPLIT	SPLIT	1	0	0	2	
00 01 31	SQ	SQ	1	1	0	2	
00 01 32	SQUAREWAVE	SQ	1	1	0	2	
00 01 33	SQUAREWAVEFREQUENCYMODULATOR	SQFMOD	1	2	0	2	
00 01 34	SQFMOD	SQFMOD	1	2	0	2	
00 01 35	SQUAREWAVEPHASEMODULATOR	SQPMOD	1	2	0	2	
00 01 36	SQPMOD	SQPMOD	1	2	0	2	
00 01 37	TABLE	TABLE	0	11	0	2	
00 01 38	TABL2	TABL2	0	11	0	2	
00 01 39	ZDEMOD	ZDEMOD	1	0	0	2	
00 01 40	ZDEMODULATOR	ZDEMOD	1	0	0	2	
00 01 41	ZEROCROSSINGDETECTOR	ZRODET	1	0	0	2	
00 01 42	ZRODET	ZRODET	1	0	0	2	
00 01 43	ATOD	ATOD	1	4	0	2	*NEW
00 01 44	DTOA	DTOA	1	4	0	2	*NEW
00 01 45	SHDTOA	SHDTOA	1	4	0	2	*NEW
00 01 46	INTLEV	INTLEV	1	2	0	2	*NEW
00 01 47	DELEAV	DELEAV	1	2	0	2	*NEW
00 01 48	FOURT	FOURT	1	2	0	2	*NEW
00 01 49	IFOURT	IFOURT	1	2	0	2	*NEW
00 01 50	HAA R	HAA R	1	3	0	2	*NEW
00 01 51	IHAAR	IHAAR	1	3	0	2	*NEW
00 01 52	HDMRD	HDMRD	1	3	0	2	*NEW
00 01 53	IHD MRD	IHD MRD	1	3	0	2	*NEW
00 01 54	OHMRD	OHMRD	1	3	0	2	*NEW
00 01 55	IOHMRD	IOHMRD	1	3	0	2	*NEW
00 01 56							
00 01 57							
00 01 58							
00 01 59							
00 01 60	\$\$\$\$\$						DO NOT REMOVE MARKS END OF LIB.
00 01 61							

Figure 2-1. Model Library (Cont)

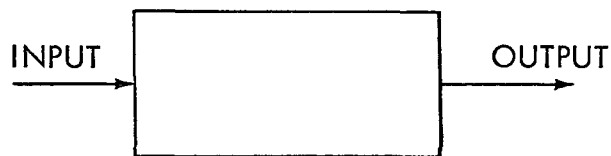
There are three basic types of ASYSTD elements (black boxes) which make up a model or system:

- Mono-node elements



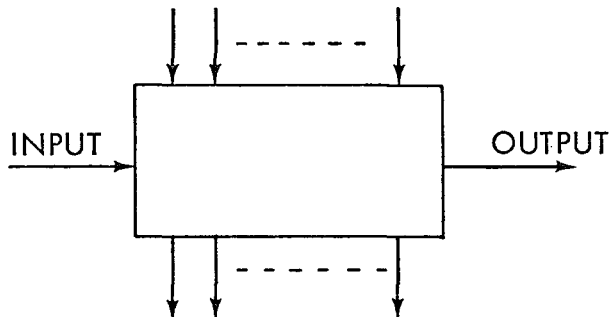
for example, a source

- Bi-node elements



for example, a filter

- Multi-node elements



for example, a mixer

The mono-node and bi-node elements are certainly the most common and most readily implemented. The multi-node element, however, may pose some problems to the inexperienced user. All elements or models have, by definition, one INPUT node and one OUTPUT node. Any other connection, be it an input or an output, is considered a "TAP". A "TAP" may be thought of in the conventional way — that is, as a point in the system or model which can be externally accessed either for observation or for insertion of a signal. There is no explicit distinction between the different types of elements since all ASYSTD topological descriptions have one input

and one output. In the case of the mono-node device, the input node serves only to satisfy the input syntax. The bi-node and multi-node distinction is even less obvious since the only requirement is that all input TAP connections to a multi-node device must be specified.

Several rules and assumptions make up the formulation of the algorithms for simulating a system or model, and impact on the user in the following ways:

- 1) Every user defined model must have an input node named "INPUT", and an output node named "OUTPUT".
- 2) At least one path must be defined which relates OUTPUT to INPUT.
- 3) All paths must terminate at OUTPUT or at a TAP.
- 4) The value of the signal at a node is the instantaneous sum of the OUTPUT of all devices connected to the node.
- 5) The value of a TAP is the instantaneous OUTPUT of the element to which it is attached (not the output node of the element).
- 6) A TAP may be referenced external to the model in which it is defined.
- 7) Model nodes are not externally available.
- 8) TAP's maintain the status of a unique variable name and thus may be used in FORTRAN expressions, subroutine calls, output requests, etc.
- 9) Node names must be legal FORTRAN variables, i.e., no more than six alphanumeric characters, the first of which must be a letter.
- 10) TAP names are defined as TAPXXX, where XXX is a unique number less than 1000. Sequential numbering is recommended.

- 11) All variable names and expressions must be FORTRAN compatible, including integer and floating point conventions. Names beginning with the letters I through N or the letter Z are typed as integers.
- 12) Intrinsic ASYSTD variables are defined in Table 2-1, and are available to the user.
- 13) The user is cautioned against using variables which begin with the letters V or Z, as a conflict with system variables is possible.
- 14) Maximum number of continuation cards is four.
- 15) A node may not connect directly to itself.
- 16) A model name may be up to 36 characters long.
- 17) The distinctions between a model and a system are the declaration and I/O identifiers. A system is executable; a model is callable.
- 18) A TAP is externally referenced from the element field by stating the model name and the tap number. The tap number is positive for an input, negative for an output. The RNF of the statement is the LNF of the model reference.

In addition to the above, certain procedures and requirements exist as to setting up the appropriate parameter values necessary to ensure an efficient, yet cost effective simulation. These include the following:

- 1) Sampling rate should be at least 15 to 20 times that of the highest frequency of interest — which is normally the widest bandwidth, although relaxation of this approximation is certainly desirable when possible. Accuracies of less than 1 percent are easily achieved for transfer function representations with lower sampling rates. One obvious problem, particularly for low order functions, is aliasing of the input signals. Thus care must

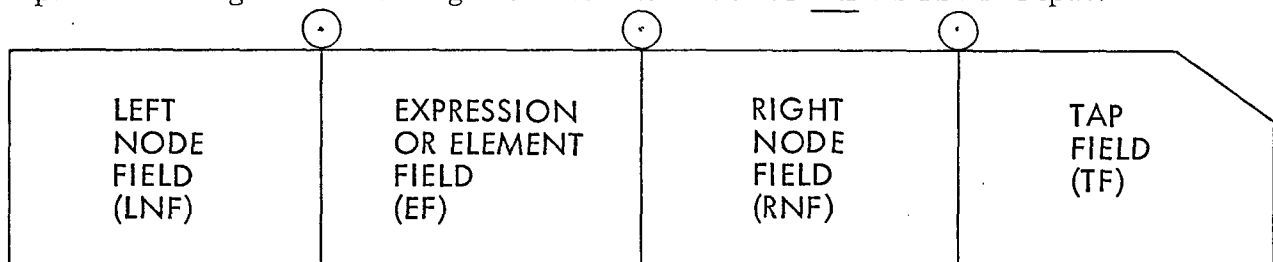
Table 2-1. Intrinsic ASYSTD Parameters

Variable	Usage
TIME (or T)	The time as kept by the Simulation Clock (unrelated to actual computer run time)
TSTART	The simulation start time (i. e. , a time bias for output labeling)
TSTOP	Simulation stop time
SETTLE	Setting time before outputting
DT	Sample time
\$	Used to denote the current signal at the input node
Z + 1	Absolute address of the first data cell available to the model (V(Z+1))
ZZ	Absolute address of the last data cell used by the model (V(ZZ))
V () or VV ()	Dynamic storage array
VIN	Address of the current real input
VIN + 1	Address of the current imaginary input
VOUT	Address of the current output
VOUT + 1	Address of the current imaginary output
PI	3.14159
TWO PI	6.28318
NPRINT	Output print interval

be taken, and in some cases, the SWAG technique is the only recourse.

- 2) All simulations require the specification of sampling time (DT) and stop time (TSTOP): Unless parameters are defined in a DATA or DEFAULT statement, ASYSTD will abort the simulation phase.
- 3) Turn on transients can be eliminated from the output by use of the intrinsic parameter SETTLE. A rule of thumb is that turn on transients should die out at approximately $5/BW$, where BW is the approximate system bandwidth.

Once the user has applied the above rules in specifying the block diagram equivalent of his system, he may assign node names and tap names where appropriate, and proceed to encode the system accordingly. The input language is fully explained in the next section; its most important aspects are introduced here. The basic problem is to represent the two-dimensional block-diagram using a series of statements. This is accomplished using the following standard format for all ASYSTD input:



where $\odot$ denotes any non-alphanumeric character delimiter (other than (7-8) and (0-8-2) punches) which serve as field separators. The Tap Field is not required.

A general element definition is exemplified by:

NODE1 < BLACK BOX > RIGHT 'TAP69

This statement says that model BLACK BOX processes the signal at NODE1 and its output is at node RIGHT. The tap TAP69 also contains the signal output by model BLACK BOX which may not be the signal at node RIGHT.

The standard card format is used for inputting the various ASYSTD identifiers and is given in Table 2-2. These identifiers are required to define whether the descriptions are for a system or model. All but DEFINE, SET, and END are illegal for a model description. The ASYSTD identifiers occupy the LNF with the appropriate data in the EF. Recall that the distinction between a model and a system is the input/output and declaration information.

An example of a model definition:

```
MODEL = EXAMPLE WITH TAPS, A, B
      INPUT = SIN ($)/TAP1 = NODE1
      NODE1 = DUMY MODEL (TAP2) = NODE2 'TAP1
      NODE2 = $$*$A/B = OUTPUT
END
```

Although this example is physically meaningless, it serves to illustrate one use of taps and is explained thusly: The signal at NODE1 equals the sine of the input signal (denoted by \$) divided by the signal output from model DUMY MODEL. (This follows from the definition of TAP1.) The signal at NODE2 is then equal to the output of DUMY MODEL, when NODE1 and TAP2 are its inputs. Note that TAP2 is an input to EXAMPLE WITH TAPS, since it was not defined in the model description. The output of EXAMPLE WITH TAPS, OUTPUT, is the signal at NODE2 squared, times A, divided by B. Here A and B are variables which must be specified by whatever model references the EXAMPLE WITH TAPS model. Also note that TAP1 is externally available for any other model reference.

Table 2-2. ASYSTD Identifiers

Identifier	Use
SYSTEM	Indicates that the deck following defines an ASYSTD system
MODEL - Name - arg 1, arg 2	Indicates that the deck which follows defines an ASYSTD model
END	Used to indicate the end of a model or system deck
DATA - Variable list	Indicates that the following values are to be read in at execution time by namelist (used only in a system) name ASYSTD
DEFAULT(T) - Variable list	Indicates the default values for DATA parameters not input through namelist
PRINT - Node or tap names	Indicates a list follows specifying output to the printer
PLOT - Node or tap names	Indicates a list follows specifying output to be plotted on the CalComp plotter
PPLOT - Node or tap names	Indicates a list follows specifying output to be plotted on the printer
POST - Routine name, node or tap names	Indicates that the following post-processing routine is to be called
PAGE	When present causes 8-1/2" x 11" compatible output
DEFINE - Variable - expression	Generates a FORTRAN define statement, which produces code to evaluate the expression
SET - Variable - expression	Generates a FORTRAN assignment statement, which gives the variable the value of the expression
VARY - Variable - parameters	Indicates the value of the variable is to be varied over a specified range

The external connection of taps between models is best illustrated in the following example:

```
MODEL - EXTERNAL TAP CONNECT, FC
INPUT < SINE (TWOPI*FC*TIME) > NODE1
      NODE1 < EXAMPLE WITH TAPS (1., 2.) > NODE2
      NODE2 < $*$ > NODE3
      NODE3 < EXAMPLE WITH TAPS +2 > NODE1
      NODE3 < 2.*$ > OUTPUT
      NODE4 < EXAMPLE WITH TAPS -1 > NODE1
      NODE4 < $ > DUMMY 'TAP09
```

In this example the signal at NODE3 is connected to input tap number two of the model named EXAMPLE WITH TAPS (as denoted in the EF and RNF of the statement). In addition, tap one of the model was externally connected to NODE4 and given the external name of TAP09, which in turn makes it available to yet another level of models.

The instructions necessary to define a system are identical to those for a model, except for the addition of the declarations and Input/Output statements. These are fully described in the next section. The entire input for similar problems is described in Section 6.0.

Several advanced techniques are available to the user in modeling any system. The principal technique is modeling directly in FORTRAN (or other compatible language) and interfacing with ASYSTD generated models. The most likely necessity for such a requirement is in RF element modeling, in which case the signals become complex. ASYSTD maintains any complex quantities but does not directly perform complex arithmetic operations. All complex RF models are, or use, models written in FORTRAN. Such an undertaking is not recommended to the novice user.

As noted above, the user may modify or replace the ASYSTD library and directory at will. This task is accomplished within the computer system executive, utilizing the file manipulation and updating features. The library directory given earlier in Figure 2-1 contains the necessary information for modifying the directory. Since each model is a subroutine, any computer system file may be designated as a library to be searched, or the EXEC temporary program file can be loaded with the desired subroutines at allocation time.

In any event, the directory serves to:

- 1) Cross reference model names and subroutine entry points.
- 2) Flag the model as a subroutine or function.
- 3) Defines the number of arguments to the routine.
- 4) Defines the number and type of each tap.
- 5) Defines the use (presently ignored) of the model.

Whenever a model is processed by ASYSTD, an entry point name is assigned to it, and any subsequent models in the same run. The assignment is made by alphabetically incrementing the least significant character of the directory entry at Line 23, i.e., if Line 23 is MODEL MODEL, then the first temporary model would have entry MODELA, the second MODELB, etc. If Line 23 was MODELX, then the first model would be MODEL Y, the second MODELZ, the third MODEMA, etc. In addition, the appropriate entries are temporarily made in the directory for defining the model for the particular run only. An example is given in Figure 2-2 where the directory entry is the first line of output. If it were desirable to add the model to the permanent library, one of two paths is available:

- 1) Rename the entry point by recompiling and updating the FORTRAN Subroutine and entering the appropriate data into the directory.
- 2) Adding the ASYSTD generated directory card into the directory and changing Line 23 to reflect the "highest" model name in the library.

Certainly, the latter is much easier, but may lead to future confusion.

NRZ
ASYSTD PROCESSOR LEVEL II
VERSION DATED 01 NOV 71 FOR THE MSC U1108 SYSTEM
THIS DECK PROCESSED ON 28 APR 72 AT 19:17:05

MODEL A 1 1 0 000000000000 2

SYSTID MODELS REFERENCED

ENTRY POINT

SQ

SQ

THIS MODEL ASSIGNED THE ENTRY POINT NAME MODEL A

```
000001      MODEL=NRZ,BR
000002          INPUT < SQ(BR/2.) > N1
000003          N1 < $*.5+.5 > OUTPUT
000004      END
```

Figure 2-2. ASYSTD Phase 1 Output for Model NRZ

SECTION 3.0

INPUT LANGUAGE

The ASYSTD input language consists of descriptive statements constructed largely from user defined names and specifications. Several key variables are used, as defined earlier in Table 2-2, in addition to names which reference defined library models. The statements for the most part define some input and output node, along with an element specification or expression relating the two. The statements can be punched in a completely free-field data card (Columns 1 through 80). Since all statements are scanned from both the left and right, field delimiters can be any non-alphanumeric character other than (7-8) and (0-2-8) punches. A statement may have up to four continuation cards, which are defined by a non-alphanumeric in Column 1. With the exception of the title on a SYSTEM card, all blanks are ignored by the processor.

As discussed in Section 2.0, the standard card format is utilized for all ASYSTD input, including the identifiers given in Table 2-2. These identifiers primarily concern themselves with initializing and controlling the execution of a system simulation. The identifier occupies the LNF and any data occupies the EF of the standard card format defined as follows:

LEFT NODE FIELD (LNF)	ELEMENT OR EXPRESSION FIELD (EF)	RIGHT NODE FIELD (RNF)	TAP FIELD (TF)
--------------------------------	--	---------------------------------	----------------------

The various identifiers are discussed below:

DATA: var₁, var₂, ..., var_n

This identifier names a list of variables which can be read in at simulation time under namelist SYSTID. Whenever this statement appears, a namelist data card must appear at execution time. The number of variables is limited only by the number one can squeeze on 5 cards. The variables must conform to FORTRAN requirements, and may be any intrinsic ASYSTD variable, e.g.,

DATA = TSTOP, DT, NPRINT, MEDIA, SAM, A

The Phase II input data for this example would be, for example:

\$SYSTID DT = 1.5 E-6, TSTOP = 10 ... \$

which is standard FORTRAN namelist input.

DEFAULT: var₁ = const, var₂ = const, ..., var_n = const

This identifier serves to load default values for any variable in the simulation, including any intrinsic ASYSTD variable. The constant values must conform to the FORTRAN rules of integer and Floating point variables or errors may occur. The number of entries is limited by the number one can squeeze on 5 cards, e.g.,

DEFAULT: DT = 1.5 E-6, TSTOP = 2.0, A = 10.,
: IOU = 3

DEFINE: variable = FORTRAN expression

This identifier generates a FORTRAN 'DEFINE' statement. 'Variable' must be a legal FORTRAN name. Whenever this name appears in the generated FORTRAN program, the FORTRAN expression is calculated using current values of any variables which may appear in the expression, and this result is used for the value of 'variable'.

END: comment

Signifies the end of a model or system description.

MODEL: model external name, arg_1 , arg_2 , ..., arg_n

This identifier instructs ASYSTD to expect a model definition only (i. e. , topological information) and to generate a subroutine.

The external name must be no more than 36 characters, with no more than 99 arguments, e. g. ,

MODEL: FM MODULATOR, BETA, FC

or

MODEL: UHF RECEIVER

PAGE: comment

This identifier, merely by being present, causes all printed output to be 8-1/2 by 11 inch compatible.

PLOT: name₁, name₂, ..., name_n

This identifier is similar to PPLOT, the exception being that here the CalComp (or SC4060) plotter is utilized, e.g.,

PLOT: TAP69, X, NODE4, OUTPUT

POST: subroutine name, name₁, name₂, ..., name_n

This identifier causes a post-processing routine named "subroutine name" to be called following the simulation. This routine is called for each occurrence of name₁, which may be nodes, taps, or variables. The call sequence generated is similar to that of the plot request, the only difference being the entry point. Utility routines are available for interfacing a user post-processor with the data time histories which are stored on drum.

PPLOT: name₁, name₂, ..., name_n

This identifier defines the data to be plotted vs. TIME following the simulation. The quantities may be nodes, taps, and variables, e.g.,

PPLOT: NODE1, TAP69, B

PRINT: name₁, name₂, name₃, ..., name_n

This identifier defines the data to be printed during the simulation. The quantities which may be printed

consist of nodes, taps, and variables. Note that TIME is automatically printed — it need not be requested, e.g.,

PRINT: NODE1, TAP69, AVAR

SET: variable = FORTRAN expression

This identifier generates a FORTRAN assignment statement which sets 'variable' equal to the value of 'FORTRAN expression'.

SYSTEM: title

This identifier instructs ASYSTD to expect other identifiers dealing with input/output, etc., and to generate a main program. The title serves to label all output (36 characters), e.g.,

SYSTEM: TRY ME SOMETIME

VARY: variable = min, max, delta

This statement generates a FORTRAN DO-LOOP which has within its range any VARY or SET statements which follow it in the ASYSTD deck as well as the program simulation. If the 'variable' name is type integer (first letter is I through N or Z), the parameters are expected to be of integer type, otherwise the variable name and parameters can be real or integer. The parameters (min, max, delta) must be constants, DEFINE variable names, or variable names which have appeared in a DATA or DEFAULT statement.

Any card which has an empty LNF (a non-alphanumeric in Column 2 or later as the first non-blank character) is treated as a comment. A comment may appear anywhere except the middle of a continued statement. Comments may be continued.

Topological input data fully utilizes the standard card format, that is:

Input node (.) expression or element (.) output node (.) Tap
assignment

where (.) is any valid delimiter as defined above. For example,

NODE1 = RF PHASE MODULATOR (BETA, FC) = NODE2
= TAP8

represents a normal statement utilizing the four fields of a standard input form.

Thus, with one format, ASYSTD input data is extremely straightforward and easily mastered.

Table 3-1 shows which statements are allowed and what order they must be placed in Systems and Models respectively.

Table 3-1. ASYSTD Identifier Hierarchy

SYSTEM	MODEL
DATA	DEFINE
DEFAULT	SET
PAGE	{ TOPOLOGICAL }
PLOT	{ INFORMATION }
POST	END
PLOT	
PRINT	
DEFINE	
VARY	
SET	
{ TOPOLOGICAL }	
{ INFORMATION }	
END	

The first card of a System is the SYSTEM card. This is followed by DATA, DEFAULT, ..., PRINT statements as appropriate in any order. Any DEFINE statements come next followed by any VARY or SET statements which are required. Topological information cards describing the System come next in any order, followed by the END card.

A MODEL card defines a Model. Any DEFINES followed by any SET statements appear next. The topological information is again followed by an END card.

SECTION 4.0

PROBLEM SUBMISSION

4.1 PROGRAM RUN PREPARATIONS

When executing the first phase of ASYSTD, the procedure PROCS/SYSTID and the element LIBARY are required along with the absolute element for the first phase (SYSTID). The LIBARY element is the model library dictionary.

The second phase requires only the library file containing all the ASYSTD library relocatable elements and the elements output to the PCF by the first phase (MAIN//SYSTID).

4.1.1 Deck Setup

The technique used by ASYSTD is to output the processed models to the PCF as elements named MODELA/SYSTID, MODELB/SYSTID, etc., in the same order as processed. When a system is processed, its element name is MAIN//SYSTID. Therefore, the user at MSC must provide the FORTRAN control card for each of the elements. The models generated in the following example are "temporary" models for this run only. That is, any system description can reference model EXAMPLE 1 during this run only. Models are permanent when the relocatable is available and an entry is made in the LIBARY element used by the first pass. Figure 4-1 is the run deck setup for the MSC UNIVAC 1108 system.

@ XOT CUR

---- LOAD THE PCF WITH SYSTID ABSOLUTE, PROCS/SYSTID, AND LIBARY

@ XOT SYSTID

MODEL: EXAMPLE ONE

.
.
.
.

END

MODEL: EXAMPLE TWO

.
.
.
.

END

MODEL: EXAMPLE THREE

.
.
.
.

END

SYSTEM. USE EXAMPLES ONE,TWO,THREE

.
.
.
.

END

@I FOR.* MODELA/SYSTID

@I FOR.* MODELB/SYSTID

@I FOR.* MODELC/SYSTID

@I FOR.* MAIN /SYSTID

@ XOT MAIN /SYSTID

\$SYSTID [NAMELIST I/O, IF SPECIFIED IN SIMULATION]

} MODELA/SYSTID
is generated in PCF

} MODELB/SYSTID

} MODELC/SYSTID

} MAIN/SYSTID

} User supplied
compiler cards

} Execute the second pass
IN SIMULATION]

Figure 4-1. Run Deck Setup for MSC 1108 Exec II System

4.1.2 Required I/O Devices

The ASYSTD program contains two phases. The first phase requires the Logical Unit assignments as follows:

Logical Unit	Device
5	Card Reader
6	Line Printer
1	Scratch Drum

Phase two requires the following I/O devices:

Logical Unit	Device
5	Card Reader
6	Line Printer
13	Drum
14	Drum

4.2 OUTPUT DESCRIPTION

4.2.1 Data Output

ASYSTD output consists of the first phase processing and the simulation or second phase output. The first phase provides output similar to the FORTRAN V compiler. Figure 4-2 is an example of the first phase output for a particular model. Annotations on the output fully explain their significance.

FIRSTIFAMP
 ASYSTD PROCESSOR LEVEL II
 VERSION DATED 01 NOV 71 FOR THE MSC U1108 SYSTEM
 THIS DECK PROCESSED ON 07 AUG 72 AT 14:25:41

MODEL A 1 3 2 400000000000 2 } LIBRARY card for
 permanent entry

SYSTID MODELS REFERENCED	ENTRY POINT
COMPLEXMULTIPLIER	CMULT
FILTER	FILTER

THIS MODEL ASSIGNED THE ENTRY POINT NAME MODEL A

TAP ORDER: 1 TAP001 2 TAP002

```

000001      MODEL=FIRST IF AMP, GAIN, SLOPE, IFUNC
000002          INPUT < COMPLEX MULTIPLIER($, TAP2) > N1
000003          N1 < FILTER(2, IFUNC, 3, 0., 6.E6, 60.E6, 1., 0., 0.) > N2
000004          N2 < FILTER(2, IFUNC, 3, 0., 6.E6, 60.E6, 1., 0., 0.) > N3
000005          N3 < FILTER(2, IFUNC, 3, 0., 6.E6, 60.E6, 1., 0., 0.) > OUTPUT
000006          INPUT < 10.**((GAIN+TAP1*SLOPE)/20.) > D1 * TAP2
000007      END
  
```

Figure 4-2. ASYSTD First Phase Output

4.2.2 Optional Output

The second phase output is completely optional under user control. The two forms of output are printed and graphical presentations, whose size is selectable as 8-1/2 by 11 inches or 11 by 14 inches (see Section 3.1). The current version provides printer plot (PTPLT), with the entry point TMPLT reserved for CalComp or SC4020 graphical routines. Examples of the output are contained in Section 6.0.

SECTION 5.0

FORTRAN INTERFACING

There are two instances in which the user may wish to write his own FORTRAN subroutines to interface with the main ASYSTD simulation. These are Models which, for some reason, are not easily or efficiently written in the ASYSTD language and post-processing routines.

5.1 FORTRAN LIBRARY MODEL PROCEDURES

An important feature of ASYSTD is its ability to reference any FORTRAN subprogram (model). However, in order for a user's FORTRAN subprogram to be re-entrant and interface correctly with any other model, it must conform to certain procedures. The characteristics of such a subprogram and then usage should be:

- Input arguments are never altered.
- Every reference to the subprogram is unique (independent).
- All local storage is considered scratch; permanent storage is only available in a common storage pool named "V".
- If a subroutine-primary input is at V(VIN) and V(VIN + 1), primary output goes to V(VOUT) and V(VOUT + 1).
- Numeric values of VIN and VOUT should be restored prior to exit.

To properly interface with any routine processed by ASYSTD, the following procedures should be followed, if applicable:

- A FORTRAN procedure named HEDFOR is available to provide compatible definition of intrinsic ASYSTD storage and variables. Use of the procedure is the FORTRAN V statement:

INCLUDE HEDFOR, LIST

When writing FORTRAN models, a current listing of this procedure is sometimes useful.

- Defining local variable Z as the last cell in the "V" pool used by the calling subroutine, and common variable ZZ the last cell to be used by this routine, set:

Z = ZZ

and

ZZ = ZZ + n

where n is the number of locations required for permanent storage in the "V" pool.

A reservation of storage space for a particular reference to this model is made, reserving cells $V(Z + 1)$ through $V(Z + n)$ for storage.

- Local variable Z is used to address the V array in the model. Common variable ZZ should not be utilized in any statement other than above, unless no other models are referenced.
- When referencing other models, VIN and VOUT should be assigned to one of the reserved cells in the "V" pool.

If a user written model is to be referenced, the user must update the ASYSTD library (element LIBRARY). This task is performed under the system executive, external to ASYSTD. See Pages 2-2 and 2-13 for instructions on making a library entry.

5.2 FORTRAN POST-PROCESSING ROUTINES

Linkage to any user post-processing routine is available through use of the ASYSTD identifier "POST". When a reference to post is made in any system description, a subroutine call is made to the user's program for every specified variable in the form:

```
CALL NAME (LABEL, NPAGE)
```

where

LABEL is the hollerith name of the variable.

NPAGE conveys the output sizing, i. e., NPAGE = 4 is 8.5 x 11 compatible output, NPAGE = 7 is standard computer size output.

For example:

The ASYSTD statements

```
POST Ø SPECTM Ø NODE1, OUTPUT
```

would generate the following two lines in the main simulation program:

```
CALL SPECTM ('NODE1', 7)
```

```
CALL SPECTM ('OUTPUT', 7)
```

The first line of the user written routine SPECTM would generally be as follows:

```
SUBROUTINE SPECTM (LABEL, NPAGE)
```

Two input parameters are required, even if the user is not concerned with output sizing.

Whenever a POST statement appears in an ASYSTD program, MAIN/SYSTID contains the following common block (all variables which begin with Z are integers):

```
COMMON/DRMHED/ZDATE(2), ZTOD(2), TSTART,  
TSTOP, VEQDT, SETTLE, ZEDIT, ZNPU, ZRESRV,  
ZUSED, ZNAMES, ZNAME (< ZNAMES >)
```

where

ZDATE = BCD of DATE, left adjusted, blank filled

ZTOD = BCD of TIME OF DAY, left adjusted,
blank filled

TSTOP	}	Self explanatory, VEQDT = DT (which appears in /COGENT/)
TSTART		
VEQDT		
SETTLE		

ZEDIT = Edit interval (if all values won't fit on
drum)

ZNPU = Number of variables saved on each
logical unit

ZRESRV = Number of words of storage reserved
for each variable to be saved

ZUSED = Number of values for each variable
 stored on drum (in some routines
 named NVAL)

ZNAMES = Number of different variables stored
 on drum

ZNAME(I),I = 1, < ZNAMES > = names of variables
 stored on drum

Inclusion of this common block in a post-processing routine allows the user access to several important variables, particularly NVAL (ZUSED), the number of values available for any particular variable stored on drum.

All retrieval of information stored on drum should be accomplished with the two subroutines DRMGET and DRMEDT.

DRMGET: Calling sequence:

CALL DRMGET (NAME, ARRAY, LENGTH, MSKIP)

where

NAME contains name of variable referenced (BCD).

ARRAY is array into which values are to be read
(dimensioned at least by LENGTH).

LENGTH is number of values to be read.

MSKIP is number of words to skip before reading.

Continuing the example, the following lines of code retrieve all values stored on drum for a particular variable, 1000 values at a time.

Example 1:

```
SUBROUTINE SPECTM (LABEL, NPAGE)
COMMON/DRMHED/DUMMY(11), NVAL
DIMENSION ARRAY (1000)

.
.
.
DO 100 MSKIP = 0, NVAL, 1000
CALL DRMGET (LABEL, ARRAY, 1000, MSKIP)

.
.
.
        Analysis of the 1000 values
        of the variable named in LABEL

.
.
.
100 CONTINUE
```

DRMEDT: Calling sequence:

```
CALL DRMEDT (NAME, NREQ, ARRAY)
```

where

NAME contains name of variable referenced (BCD).

NREQ equals number of values to be read off drum.

ARRAY is array into which values are placed
(dimensioned at least by NREQ)

Let NVAL be the twelfth word of common block /DRMHED/.
NVAL equals the number of values stored on drum for each
variable. If $NREQ \geq NVAL$, then NVAL words (all that are

on the drum) will be read into ARRAY. If NREQ < NVAL, the data on drum is edited and NREQ equally spaced values are read into ARRAY.

Example 2:

```
SUBROUTINE SPECTM (LABEL, NPAGE)
DIMENSION ARRAY (1000)
```

```
  .
  .
  .
```

```
CALL DRMEDT (LABEL, 1000, ARRAY)
```

ARRAY now contains 1000 equally spaced values
of the variable named in LABEL.

Values of TIME are not stored on drum but are computed by
DRMGET and DRMEDT when needed, saving drum I/O time.

In Example 1, assume the array TIME is dimensioned by 1000.
Then the statement:

```
CALL DRMGET ('TIME', TIME, 1000, MSKIP)
```

placed inside the DO LOOP will compute the 1000 values of time corresponding to the values in ARRAY.

Similarly, in Example 2, the statement:

```
CALL DRMEDT ('TIME', 1000, TIME)
```

would produce 1000 values of time in the array TIME such that ARRAY(I)
was the value of the variable named in LABEL at time TIME(I).

SECTION 6.0

EXAMPLES

Four example sets are presented in this section, namely:

- 1) ASYSTD simulation of an Apollo PCM/PM/PM communications link whose characteristics are given in Figure 6-1.
- 2) ASYSTD squaring loop model also defined in Figure 6-1.
- 3) ASYSTD model of sonar propagation through sea water. This example serves to illustrate evaluation of a mathematical function with ASYSTD.
- 4) ASYSTD model of FILTER response. This example serves to illustrate the DEFINE, VARY, and SET commands.

The first example consists of a temporary definition of model NRZ and use of several library models, along with some math expressions. Figure 6-2 illustrates the ASYSTD output for the run. The sequence numbers to the left of the input statements correspond to the data card number. Thus, model NRZ was defined with the first four cards of the input data deck. Following the two pages of Phase I output are the FORTRAN compilations of the resultant subroutine and main program. These two routines, along with the ASYSTD library make up the Phase II simulation program. The results of the simulation are evident following the FORTRAN routines.

A few remarks concerning this simulation are in order. Notice that following the square wave phase modulator is an RF phase modulator. At this point, we are representing the RF portion of the link at baseband.

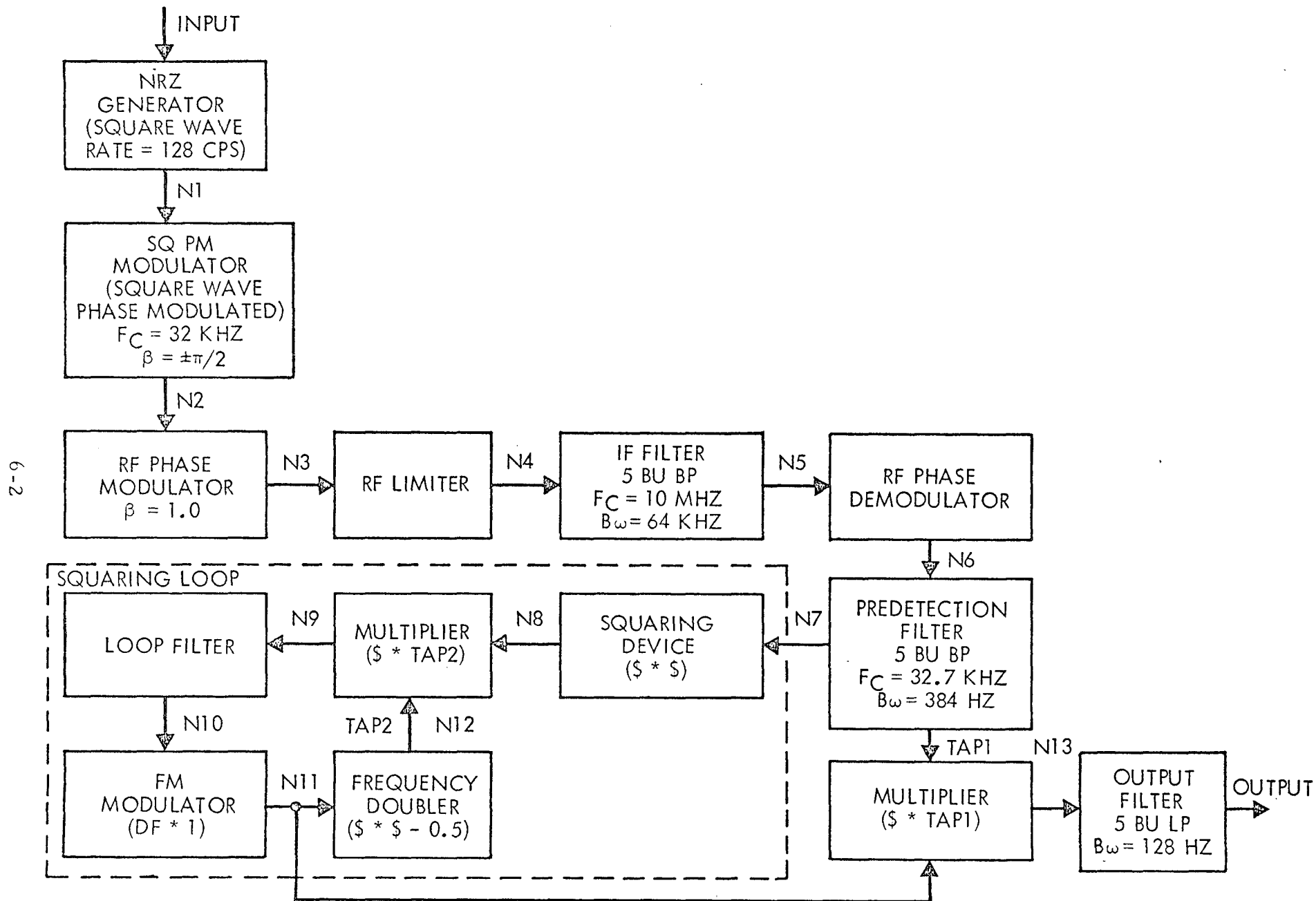


Figure 6-1. Apollo PCM/PM/PM Link Block Diagram

NRZ
 ASYSTD PROCESSOR LEVEL II
 VERSION DATED 01 NOV 71 FOR THE MSC U1108 SYSTEM
 THIS DECK PROCESSED ON 01 MAY 72 AT 16:10:25

SYSTID MODELS REFERENCED	ENTRY POINT
SQ	SQ

THIS MODEL ASSIGNED THE ENTRY POINT NAME MODEL A

```

000001      MODEL=NRZ,BR
000002      INPUT < SQ(BR/2.) > N1
000003      N1 < $.5+.5 > OUTPUT
000004      END
  
```

APOLLO PCM/PM/PM LINK
 ASYSTD PROCESSOR LEVEL II
 VERSION DATED 01 NOV 71 FOR THE MSC U1108 SYSTEM
 THIS DECK PROCESSED ON 01 MAY 72 AT 16:10:26

SYSTID MODELS REFERENCED	ENTRY POINT
NRZ	MODEL A
SQPMOD	SQPMOD
RFPHASEMODULATOR	RPMMOD
RFLIMITER	RFLIMT
BUTTERWORTH	BUTWTH
RFPHASEDEMODULATOR	RFPDEM
LOOPFILTER	LEDLAG
FMMODULATOR	FMMOD

TAP ORDER: 1 TAP001 2 TAP002

```

000005      SYSTEM . APOLLO PCM/PM/PM LINK
000006      PAGE. SMALL
000007      DEFAULT. TSTART=0.,TSTOP=.03,DT=1.5E-6,NPRINT=200
000008      DATA = DT,TSTOP,SETTLE
000009      PRINT.N1,N10,N13,OUTPUT
000010      PLOT.N1,N10,N13,OUTPUT
  
```

Figure 6-2. ASYSTD Example, Output

```

000011      INPUT < NRZ(128.) > N1
000012      N1 < SQPMOD(PI,32.768E3) > N2
000013      N2 < RF PHASE MODULATOR (1.0) > N3
000014      N3 < RF LIMITER > N4
000015      N4 < BUTTERWORTH (5,3,10.E6,64.E3,10.E6,1.) > N5
000016      N5 < RF PHASE DEMODULATOR (1.0) > N6
000017      N6 < BUTTERWORTH (5,3,32.768E3,384.,0.,1.) > N7 'TAP1
000018      N7 < $$ > N8
000019      N8 < $*TAP2 > N9
000020      N9 < LOOP FILTER (200.,1.8775994,0.,.19751719,0.) > N10
000021      N10 < FM MODULATOR (2.*PI,32.768E3) > N11
000022      N11 < $$-0.5 > N12 'TAP2
000023      N11 < $*TAP1 > N13
000024      N13 < BUTTERWORTH (2,1,0.,128.,0.,1.) > OUTPUT
000025      END

```

@ ADD ADDFIL

@I FOR,* MODEL A/SYSTID,MODEL A/SYSTID

FORTRAN V: ISD VERSION 2.2

THIS COMPILATION WAS DONE ON 01 MAY 72 AT 16:10:27

SUBROUTINE MODEL A ENTRY POINT 000065

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000077
0000	*DATA	000025
0002	*BLANK	000000
0003	COGENT	000010
0004	VSPACE	000003
0005	FLR	000014

EXTERNAL REFERENCES (BLOCK, NAME)

0006	SQ
0007	NE RR3\$

Figure 6-2. ASYSTD Example, Output (Cont)

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000044	150L	0001	000003	20L	0003	R	000002	DT	0003	R	000005	PI	0003	000003	T			
0003	R	000003	TIME	0003	R	000007	TWOPI	0004	R	000001	V	0003	I	000006	VCIN	0005	R	000002	VF
0003	I	000000	VIN	0000	I	000001	VNSAVE	0003	I	000001	VOUT	0000	I	000000	VSAVE	0004	R	000000	VSUB0
0000	I	000002	Z	0005	I	000001	ZNUMF	0003	I	000004	ZZ	0005	I	000000	Z1STF				

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```

00101  1*      SUBROUTINE  MODEL A(BR)
00101  2*      CMODEL      NRZ
00103  3*          INCLUDE MODEL1,LIST
00104  3*          IMPLICIT INTEGER (Z)
00105  3*          INTEGER VIN,VOUT,VCIN,VSAVE,VNSAVE
00106  3*          COMMON /COGENT/ VIN,VOUT,DT,TIME,ZZ,PI,VCIN,TWOPI
00107  3*          COMMON /VSPACE/ VSUB0,V(2)
00110  3*          COMMON /FLR/  Z1STF,ZNUMF,VF(5,2)
00111  3*          EQUIVALENCE (TIME,T)
00112  3*          END
00113  4*          INCLUDE MODEL2,LIST
00114  4*          Z=ZZ
00115  4*          GO TO 150
00116  4*      20  VNSAVE=VIN
00117  4*          VSAVE=VOUT
00120  4*          END
00121  5*          V(Z+1)=V(VIN)
00121  6*      C      SQ
00122  7*          VIN=Z+1
00123  8*          VOUT=Z+3
00124  9*          CALL SQ(BR/2,.)
00125  10*         V(Z+5)=V(Z+3)*.5+.5
00126  11*         VIN=VNSAVE
00127  12*         VOUT=VSAVE
00130  13*         V(VSAVE)=V(Z+5)

00131  14*      RETURN
00132  15*      150  ZZ=ZZ+      6
00133  16*          GO TO 20
00134  17*          END

```

Figure 6-2. ASYSTD Example, Output (Cont)

@I FOR,* MAIN /SYSTID,MAIN /SYSTID
 FORTRAN V: ISD VERSION 2.2
 THIS COMPILATION WAS DONE ON 01 MAY 72 AT 16:10:28

01 MAY 72 * 16:10:28.756

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000550
0000	*DATA	002131
0002	*BLANK	000000
0003	COGENT	000010
0004	VSPACE	023421
0005	FLR	030326
0006	NAME	000006
0007	INT	000001
0010	DIF	000001
0011	DRMHED	000021

EXTERNAL REFERENCES (BLOCK, NAME)

0012	DATIN
0013	PAGER
0014	MODELA
0015	SQPMOD
0016	RPMMOD
0017	RFLIMT
0020	BUTWTH
0021	RFPDEM
0022	LEDLAG
0023	FMMOD
0024	DRUMIT
0025	PTPLT
0026	NRNL\$
0027	NWNL\$
0030	NWDUS
0031	NI02\$
0032	NSTOP\$
0033	NI01\$

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000113	10L	0001	000461	100L	0000	002057	120F	0001	000513	130L	0001	000541	150L	
0001	000125	20L	0001	000544	200L	0001	000066	221G	0001	000072	226G	0001	000072	231G	
0001	000367	30L	0001	000445	363G	0000	002030	4F	0001	000404	40L	0001	000476	401G	
0001	000503	405G	0001	000033	5L	0000	002052	50F	0000	002056	60F	0003	R	000002	DT
0000	I	000001	IS	0000	I	000000	NPRINT	0003	R	000005	PI	0011	R	000007	SETTLE
0003	R	000003	TIME	0006	R	000000	TITLE	0011	R	000004	TSTART	0011	R	000005	TSTOP
0004	R	000001	V	0003	I	000006	VCIN	0000	R	000033	VDRUM	0007	R	000000	VDI2
0005	R	000002	VF	0003	I	000000	VIN	0003	I	000001	VOU	0000	R	000002	VPRINT
												0000	R	002011	VSETTL

Figure 6-2. ASYSTD Example, Output (Cont)

0004 R 000000 VSUB0	0010 R 000000 VDTD	0000 I 002012 Z	0000 I 002005 ZCOUNT	0011 I 000000 ZDATE
0000 I 002004 ZDRUM	0000 I 002003 ZEDCNT	0011 I 000010 ZEDIT	0000 I 002013 ZIOT1	0000 I 002014 ZIOT2
0011 I 000015 ZNAME	0011 I 000014 ZNAMES	0011 I 000011 ZNPU	0005 I 000001 ZNUMF	0000 I 002006 ZPRINT
0011 I 000012 ZRESRV	0011 I 000002 ZTOD	0011 I 000013 ZUSED	0003 I 000004 ZZ	0000 I 002007 Z1
0005 I 000000 Z1STF	0000 I 002010 Z2			

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```

00101 1*      INCLUDE MAIN1,LIST
00103 1*      IMPLICIT INTEGER (Z)
00104 1*      INTEGER VIN,VOUT,VCIN
00105 1*      PARAMETER VSIZE=10000,VFSIZE=2500
00106 1*      COMMON /COGENT/VIN,VOUT,DT,TIME,ZZ,PI,VCIN,TWOPI
00107 1*      COMMON /VSPACE/VSUB0,V(VSIZE)
00110 1*      COMMON /FLR/Z1STF,ZNUMF,VF(5,VFSIZE)
00111 1*      COMMON /NAME/TITLE(6)
00112 1*      COMMON /INT/VDT2 /DIF/VDTD
00113 1*      EQUIVALENCE (T,TIME)
00114 1*      DATA PI/3.1415927/, TWOPI/6.2831853/
00117 1*      DATA TSTART,SETTLE /0.,0./, NPRINT/1/
00123 1*      END
00124 2*      DATA TITLE/'APOLLO PCM/PM/PM LINK'/'
00126 3*      DATA TSTART/0./,TSTOP/.03/,DT/1.5E-6/,NPRINT/200/
00133 4*      NAMELIST/SYSTID/DT,TSTOP,SETTLE
00134 5*      PARAMETER ZPSIZE= 5
00135 6*      DIMENSION VPRINT(5,ZPSIZE)
00136 7*      DATA VPRINT(1,1)/'TIME' '/'
00140 8*      DATA VPRINT(1,2)/'N1' '/'
00142 9*      DATA VPRINT(1,3)/'N10' '/'
00144 10*     DATA VPRINT(1,4)/'N13' '/'
00146 11*     DATA VPRINT(1,5)/'OUTPUT'/'
00150 12*     PARAMETER ZDRMSZ= 250
00151 13*     DIMENSION VDRUM(ZDRMSZ,4)
00152 14*     COMMON /DRMHD/ZDATE(2),ZTOD(2),TSTART,TSTOP,VEQDT,SETTLE,
00152 15*     ZEDIT,ZNPU,ZRESRV,ZUSED,ZNAMES,ZNAME(4)
00153 16*     DATA ZNPU/ 2/, ZRESRV/131063/, ZUSED/ 0/, ZNAMES/ 4/
00160 17*     DATA ZNAME(1)/'N1' '/'
00162 18*     DATA ZNAME(2)/'N10' '/'
00164 19*     DATA ZNAME(3)/'N13' '/'
00166 20*     DATA ZNAME(4)/'OUTPUT'/'
00170 21*     READ(5,SYSTID)
00173 22*     WRITE(6,SYSTID)
00176 23*     CALL DATIN(ZDATE)
00177 24*     INCLUDE MAIN2,LIST
00200 24*     IF((TSTOP-TSTART)/DT.GT.0) GO TO 5
00202 24*     WRITE(6,4)TSTART,TSTOP,DT
00207 24*     4 FORMAT(1X,'** ERROR ** THE VALUES TSTART=',E12.6,' TSTOP=',E12.6,
00207 24*     . ' DT=',E12.6,' ARE UNREASONABLE. ')
00210 24*     STOP
00211 24*     5 ZEDIT=(TSTOP-(TSTART+SETTLE))/(DT*ZRESRV)+1
00212 24*     ZEDCNT=ZEDIT-1
00213 24*     ZDRUM=0

```

Figure 6-2. ASYSTD Example, Output (Cont)

```

00214 24*      ZUSED=0
00215 24*      ZCOUNT=NPRINT-1
00216 24*      ZPRINT=1
00217 24*      VSUB0=0.0
00220 24*      DO 6 Z1=1,VSIZ
00223 24*      6 V(Z1)=0.0
00225 24*      DO 7 Z2=1,VFSIZ
00230 24*      DO 7 Z1=1,5
00233 24*      7 VF(Z1,Z2)=0.0
00236 24*      VEQDT=DT
00237 24*      VDT2=DT/2.0
00240 24*      VTDI=2.0/DT
00241 24*      TIME=ISTART-DT
00242 24*      VSETTL=ISTART+SETTLE
00243 24*      CALL PAGER
00244 24*      @.....
00244 24*      @ THE SIMULATION LOOP BEGINS HERE.  GOOD LUCK.
00244 24*      @.....
00244 24*      10 TIME=TIME+DT
00245 24*      IF(TIME.GT,ISTOP) GO TO 100
00247 24*      Z=2
00250 24*      GO TO 150
00251 24*      20 Z1STF=1
00252 24*      VIN=1
00253 24*      VOUT=2
00254 24*      END
00255 25*      ZIOT1=Z+1
00256 26*      ZIOT2=Z+2
00256 27*      C NRZ
00257 28*      VIN=Z+4
00260 29*      VOUT=Z+6
00261 30*      CALL MODEL A(128.)
00261 31*      C SQPMOD
00262 32*      VIN=Z+6
00263 33*      VOUT=Z+8
00264 34*      CALL SQPMOD(PI,32.768E3)
00264 35*      C RFPHASEMODULATOR
00265 36*      VIN=Z+8
00266 37*      VOUT=Z+10
00267 38*      CALL RPMMOD(1.0)
00267 39*      C RFLIMITER
00270 40*      VIN=Z+10
00271 41*      VOUT=Z+12
00272 42*      CALL RFLIMT
00272 43*      C BUTTERWORTH
00273 44*      VIN=Z+12
00274 45*      VOUT=Z+14
00275 46*      CALL BUTWTH(5,3,10.E6,64.E3,10.E6,1.)
00275 47*      C RFPHASEDEMULATOR
00276 48*      VIN=Z+14
00277 49*      VOUT=Z+16

```

Figure 6-2. ASYSTD Example, Output (Cont)

```

00300 50*      CALL RFPDEM(1.0)
00300 51*      C      BUTTERWORTH
00301 52*      VIN=Z+16
00302 53*      VOUT=Z+18
00303 54*      CALL BUTWTH(5,3,32.768E3,384.,0.,1.)
00304 55*      V(Z IOT1)=V(Z+18)
00305 56*      V(Z+20)=V(Z+18)*V(Z+18)
00306 57*      V(Z+22)=V(Z+20)*V(Z IOT1)
00306 58*      C      LOOPFILTER
00307 59*      VIN=Z+22
00310 60*      VOUT=Z+24
00311 61*      CALL LEDLAG(200.,1.8775994,0.,.19751719,0.)
00311 62*      C      FMMODULATOR
00312 63*      VIN=Z+24
00313 64*      VOUT=Z+26
00314 65*      CALL FMMOD(2.*PI,32.768E3)
00315 66*      V(Z+28)=V(Z+26)*V(Z IOT1)
00316 67*      V(Z+30)=V(Z+26)*V(Z+26)-0.5
00317 68*      V(Z IOT2)=V(Z+30)
00317 69*      C      BUTTERWORTH
00320 70*      VIN=Z+28
00321 71*      VOUT=Z+32
00322 72*      CALL BUTWTH(2,1,0.,128.,0.,1.)
00323 73*      IF(TIME.LT.VSETTL) GO TO 10
00325 74*      INCLUDE MAIN3,LIST
00326 74*      ZEDCNT=ZEDCNT+1
00327 74*      IF(ZEDCNT.NE.ZEDIT) GO TO 40
00331 74*      ZEDCNT=0
00332 74*      IF(ZDRUM.NE.ZDRMSZ) GO TO 30
00334 74*      CALL DRUMIT(VDRUM,ZDRMSZ,ZDRMSZ)
00335 74*      ZDRUM=0
00336 74*      30 ZDRUM=ZDRUM+1
00337 74*      END
00340 75*      VDRUM(ZDRUM,1)=V(Z+6)
00341 76*      VDRUM(ZDRUM,2)=V(Z+24)
00342 77*      VDRUM(ZDRUM,3)=V(Z+28)
00343 78*      VDRUM(ZDRUM,4)=V(Z+32)
00344 79*      40 CONTINUE
00345 80*      ZCOUNT=ZCOUNT+1
00346 81*      IF(ZCOUNT.NE.NPRINT) GO TO 10
00350 82*      ZCOUNT=0
00351 83*      ZPRINT=ZPRINT+1
00352 84*      VPRINT(ZPRINT,1)=TIME
00353 85*      VPRINT(ZPRINT,2)=V(Z+6)
00354 86*      VPRINT(ZPRINT,3)=V(Z+24)
00355 87*      VPRINT(ZPRINT,4)=V(Z+28)
00356 88*      VPRINT(ZPRINT,5)=V(Z+32)
00357 89*      IF(ZPRINT.NE.5) GO TO 10
00361 90*      WRITE(6,50)VPRINT
00367 91*      50 FORMAT( 5(6X,A6,4(4X,E12.6),/))

```

Figure 6-2. ASYSTD Example, Output (Cont)

```

00370 92*      INCLUDE MAIN5,LIST
00371 92*      WRITE(6,60)
00373 92*      60 FORMAT(//)
00374 92*      ZPRINT=1
00375 92*      GO TO 10
00376 92*      @-----
00376 92*      @ END OF SIMULATION AND OUTPUT LOOP
00376 92*      @-----
00376 92*      100 IF(ZPRINT.LT.2) GO TO 130
00400 92*      DO 110 Z2=1,ZPSIZE
00403 92*      110 WRITE(6,120)(VPRINT(Z1,Z2),Z1=1,ZPRINT)
00412 92*      120 FORMAT(6X,A6,8(4X,E12.6))
00413 92*      130 CONTINUE
00414 92*      END
00415 93*      CALL DRUMIT(VDRUM,ZDRMSZ,ZDRUM)
00416 94*      CALL PTPLT('N1',4)
00417 95*      CALL PTPLT('N10',4)
00420 96*      CALL PTPLT('N13',4)
00421 97*      CALL PTPLT('OUTPUT',4)
00422 98*      GO TO 200
00423 99*      150 ZZ= 35
00424 100*     GO TO 20
00425 101*     200 CONTINUE
00426 102*     STOP
00427 103*     END

```

\$SYSTD

```

DT      =      .15000000E-05,
TSTOP   =      .30000000E-01,
SETTLE  =      .00000000E+00,
$END

```

APOLLO PCM/PM/PM LINK

TIME	.000000	.300000-03	.599999-03	.899998-03
N1	.500000+00	.100000+01	.100000+01	.100000+01
N10	.000000	.656525-08	-.746476-07	-.152746-03
N13	.000000	.227434-04	.175139-03	.245243-03
OUTPUT	.000000	.156697-07	.168748-05	.243908-04

TIME	.120000-02	.150000-02	.180000-02	.209999-02
N1	.100000+01	.100000+01	.100000+01	.100000+01
N10	.357258-02	-.559070-04	-.526487-01	.262237+00
N13	.169327-01	.374304-02	.961061-02	.146836+00
OUTPUT	.152122-03	.597630-03	.174886-02	.417225-02

Figure 6-2. ASYSTD Example, Output (Cont)

TIME	.239999-02	.269999-02	.299998-02	.329998-02
N1	.100000+01	.100000+01	.100000+01	.100000+01
N10	.235829-03	-.732689+00	.207953+01	-.479202-02
N13	.213897-02	.571740-01	.419319+00	-.285553-01
OUTPUT	.856548-02	.156568-01	.260872-01	.402898-01

TIME	.359998-02	.389997-02	.419996-02	.449995-02
N1	.100000+01	.100000+01	.100000+01	.100000+01
N10	-.264826+01	.551619+01	-.715591-01	-.448266+01
N13	.147583+00	.691304+00	-.865632-01	.235775+00
OUTPUT	.583719-01	.800794-01	.104793+00	.131583+00

TIME	.479995-02	.509994-02	.539993-02	.569992-02
N1	.100000+01	.100000+01	.100000+01	.100000+01
N10	.753886+01	-.237658+00	-.462787+01	.683724+01
N13	.816727+00	-.143214+00	.287642+00	.786661+00
OUTPUT	.159302+00	.186727+00	.212670+00	.236107+00

TIME	.599991-02	.629990-02	.659989-02	.689988-02
N1	.100000+01	.100000+01	.100000+01	.100000+01
N10	-.431207+00	-.347788+01	.512809+01	-.616192+00
N13	-.176832+00	.310868+00	.691535+00	-.191894+00
OUTPUT	.256240+00	.272514+00	.284704+00	.292891+00

TIME	.719987-02	.749986-02	.779985-02	.809983-02
N1	.100000+01	.100000+01	.100000+01	.000000
N10	-.225543+01	.387623+01	-.871415+00	-.128855+01
N13	.330832+00	.612792+00	-.205552+00	.369509+00
OUTPUT	.297365+00	.298637+00	.297303+00	.294000+00

TIME	.839981-02	.869979-02	.899977-02	.929975-02
N1	.000000	.000000	.000000	.000000
N10	.318014+01	-.128211+01	-.251971+00	.215747+01
N13	.569352+00	-.220764+00	.411885+00	.483117+00
OUTPUT	.289434+00	.284182+00	.278610+00	.272790+00

Figure 6-2. ASYSTD Example, Output (Cont)

TIME	.959973-02	.989971-02	.101997-01	.104997-01
N1	.000000	.000000	.000000	.000000
N10	-.121934+01	.411117+00	.434535+00	-.990002-01
N13	-.190814+00	.317573+00	.217844+00	-.547896-01
OUTPUT	.266355+00	.258530+00	.248216+00	.234191+00

TIME	.107996-01	.110996-01	.113996-01	.116996-01
N1	.000000	.000000	.000000	.000000
N10	.420782-01	.190610+00	-.956791+00	.220183+01
N13	-.229144-01	-.142686+00	.126381+00	-.471236+00
OUTPUT	.215278+00	.190604+00	.159713+00	.122710+00

TIME	.119996-01	.122995-01	.125995-01	.128995-01
N1	.000000	.000000	.000000	.000000
N10	.980072+00	-.490457+01	.648092+01	.955244+00
N13	-.376862+00	.243143+00	-.764494+00	-.396353+00
OUTPUT	.803356-01	.339293-01	-.147052-01	-.635299-01

TIME	.131995-01	.134995-01	.137994-01	.140994-01
N1	.000000	.000000	.000000	.000000
N10	-.743435+01	.788194+01	.445719+00	-.684126+01
N13	.256648+00	-.812628+00	-.286450+00	.202163+00
OUTPUT	-.110463+00	-.153620+00	-.191486+00	-.223013+00

TIME	.143994-01	.146994-01	.149993-01	.152993-01
N1	.000000	.000000	.000000	.000000
N10	.662391+01	.151791+00	-.558136+01	.554226+01
N13	-.726501+00	-.167211+00	.139113+00	-.655248+00
OUTPUT	-.247648+00	-.265355+00	-.276509+00	-.281881+00

TIME	.155993-01	.158993-01	.161993-01	.164992-01
N1	.000000	.100000+01	.100000+01	.100000+01
N10	.668839-01	-.534075+01	.568418+01	.496007-01
N13	-.885654-01	.911298-01	-.660766+00	-.349722-01
OUTPUT	-.282513+00	-.279539+00	-.274107+00	-.267287+00

Figure 6-2. ASYSTD Example, Output (Cont)

TIME	.1 67 99 2- 01	.1 70 99 2- 01	.1 73 99 2- 01	.1 76 99 2- 01
N1	.1 00 00 0+ 01	.1 00 00 0+ 01	.1 00 00 0+ 01	.1 00 00 0+ 01
N1 0	- .5 52 58 7+ 01	.5 29 75 8+ 01	.4 88 09 4- 01	- .2 79 27 8+ 01
N1 3	.4 51 70 0- 01	- .6 39 16 7+ 00	.1 33 61 3- 01	- .3 99 62 3- 02
OUTPUT	- .2 59 90 6+ 00	- .2 52 39 1+ 00	- .2 44 71 1+ 00	- .2 36 33 9+ 00

TIME	.1 79 99 1- 01	.1 82 99 1- 01	.1 85 99 1- 01	.1 88 99 1- 01
N1	.1 00 00 0+ 01	.1 00 00 0+ 01	.1 00 00 0+ 01	.1 00 00 0+ 01
N1 0	.1 54 22 2+ 01	.4 83 11 0- 01	.4 80 90 1- 01	.5 58 54 3+ 00
N1 3	- .3 43 49 6+ 00	.1 73 53 6- 01	.8 74 54 6- 03	.2 03 07 8+ 00
OUTPUT	- .2 26 33 4+ 00	- .2 13 51 7+ 00	- .1 96 68 0+ 00	- .1 74 88 2+ 00

TIME	.1 91 99 1- 01	.1 94 99 0- 01	.1 97 99 0- 01	.2 00 99 0- 01
N1	.1 00 00 0+ 01	.1 00 00 0+ 01	.1 00 00 0+ 01	.1 00 00 0+ 01
N1 0	.2 96 51 1- 01	- .3 33 96 6+ 01	.5 56 42 3+ 01	- .1 97 78 0+ 00
N1 3	- .6 08 07 5- 01	.9 91 26 3- 01	.6 78 73 9+ 00	- .1 75 91 2+ 00
OUTPUT	- .1 47 56 3+ 00	- .1 14 66 9+ 00	- .7 67 38 7- 01	- .3 48 59 9- 01

TIME	.2 03 99 0- 01	.2 06 98 9- 01	.2 09 98 9- 01	.2 12 98 9- 01
N1	.1 00 00 0+ 01	.1 00 00 0+ 01	.1 00 00 0+ 01	.1 00 00 0+ 01
N1 0	- .7 23 72 9+ 01	.8 30 80 3+ 01	- .6 58 05 8+ 00	- .6 17 68 5+ 01
N1 3	.2 29 90 5+ 00	.8 46 33 4+ 00	- .2 51 54 6+ 00	.3 14 12 0+ 00
OUTPUT	.9 42 13 4- 02	.5 43 02 1- 01	.9 78 99 4- 01	.1 38 43 4+ 00

TIME	.2 15 98 9- 01	.2 18 98 9- 01	.2 21 98 8- 01	.2 24 98 8- 01
N1	.1 00 00 0+ 01	.1 00 00 0+ 01	.1 00 00 0+ 01	.1 00 00 0+ 01
N1 0	.6 26 40 1+ 01	- .1 01 77 3+ 01	- .3 24 27 8+ 01	.3 60 48 2+ 01
N1 3	.7 51 28 0+ 00	- .2 64 64 4+ 00	.3 40 92 5+ 00	.5 84 64 9+ 00
OUTPUT	.1 74 41 9+ 00	.2 04 78 7+ 00	.2 28 91 5+ 00	.2 46 65 8+ 00

TIME	.2 27 98 8- 01	.2 30 98 8- 01	.2 33 98 8- 01	.2 36 98 7- 01
N1	.1 00 00 0+ 01	.1 00 00 0+ 01	.1 00 00 0+ 01	.0 00 00 0
N1 0	- .1 24 27 8+ 01	- .1 30 01 9+ 01	.2 27 14 9+ 01	- .1 64 20 6+ 01
N1 3	- .2 50 82 6+ 00	.3 58 50 4+ 00	.4 78 41 2+ 00	- .2 47 86 6+ 00
OUTPUT	.2 58 29 2+ 00	.2 64 42 9+ 00	.2 65 96 9+ 00	.2 63 97 9+ 00

Figure 6-2. ASYSTD Example, Output (Cont)

TIME	.239 98 7- 01	.242 98 7- 01	.245 98 7- 01	.248 98 7- 01
N1	.000 00 0	.000 00 0	.000 00 0	.000 00 0
N10	- .747 02 4- 01	.174 50 0+ 01	- .223 84 0+ 01	.101 72 1+ 01
N13	.410 31 5+ 00	.435 45 6+ 00	- .248 91 5+ 00	.445 29 1+ 00
OUTPUT	.259 54 1+ 00	.253 67 3+ 00	.247 19 3+ 00	.240 56 3+ 00

TIME	.251 98 6- 01	.254 98 6- 01	.257 98 6- 01	.260 98 6- 01
N1	.000 00 0	.000 00 0	.000 00 0	.000 00 0
N10	.954 89 3+ 00	- .146 94 0+ 01	.646 72 3+ 00	.110 30 4+ 00
N13	.334 14 8+ 00	- .174 47 3+ 00	.269 22 2+ 00	.922 98 1- 01
OUTPUT	.233 78 4+ 00	.226 35 2+ 00	.217 35 9+ 00	.205 66 2+ 00

TIME	.263 98 6- 01	.266 98 5- 01	.269 98 5- 01	.272 98 5- 01
N1	.000 00 0	.000 00 0	.000 00 0	.000 00 0
N10	.487 55 1- 01	.321 83 9+ 00	.202 53 9+ 00	- .280 04 3+ 01
N13	.610 64 7- 03	- .162 65 4+ 00	- .157 07 7+ 00	.169 52 3+ 00
OUTPUT	.190 08 4+ 00	.169 68 6+ 00	.143 89 7+ 00	.112 62 0+ 00

TIME	.275 98 5- 01	.278 98 4- 01	.281 98 4- 01	.284 98 4- 01
N1	.000 00 0	.000 00 0	.000 00 0	.000 00 0
N10	.447 98 0+ 01	.389 64 7+ 00	- .808 02 6+ 01	.898 00 8+ 01
N13	- .617 99 3+ 00	- .257 48 8+ 00	.231 12 1+ 00	- .849 89 0+ 00
OUTPUT	.763 42 7- 01	.360 80 5- 01	- .671 06 8- 02	- .502 88 8- 01

TIME	.287 98 4- 01	.290 98 4- 01	.293 98 3- 01	.296 98 3- 01
N1	.000 00 0	.000 00 0	.000 00 0	.000 00 0
N10	.214 96 4+ 00	- .948 45 0+ 01	.889 69 6+ 01	.735 93 3- 01
N13	- .205 76 0+ 00	.190 19 0+ 00	- .832 55 3+ 00	- .100 17 4+ 00
OUTPUT	- .928 31 2- 01	- .132 60 0+ 00	- .168 10 3+ 00	- .198 25 4+ 00

TIME	.299 98 3- 01
N1	.000 00 0
N10	- .756 39 4+ 01
N13	.113 97 1+ 00
OUTPUT	- .222 38 8+ 00

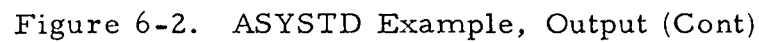
Figure 6-2. ASYSTD Example, Output (Cont)

Figure 6-2. ASYSTD Example, Output (Cont)



Figure 6-2. ASYSTD Example, Output (Cont)

6-17



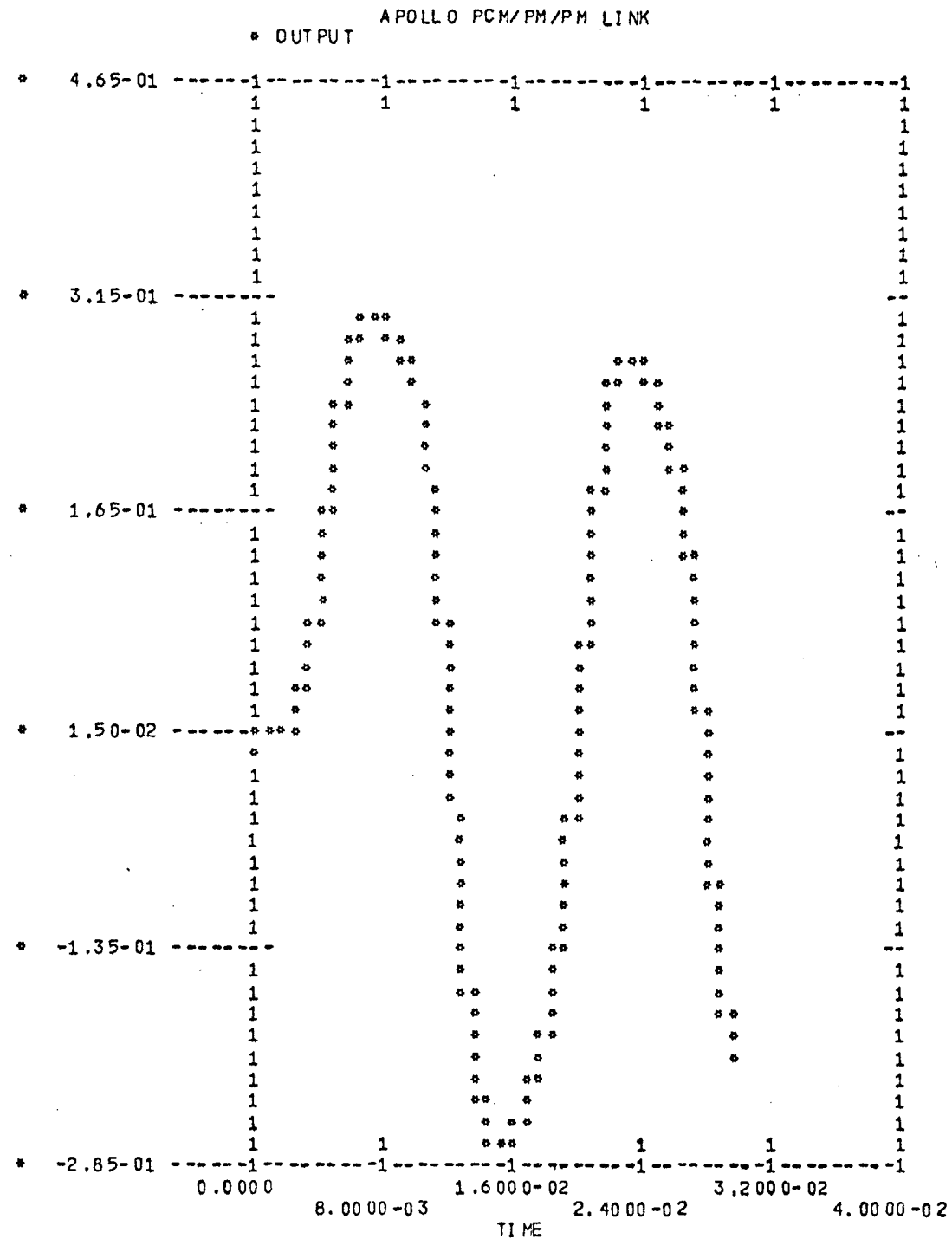


Figure 6-2. ASYSTD Example, Output (Cont)

This process is actually implemented by assuming that the input signals are analytic. This condition is met if the baseband signal spectrum is essentially zero at the carrier frequency. If this assumption is not true, a ripple in the simulation output at frequencies of approximately twice the carrier is introduced — the case if the input is a step function, for instance. In any event, the ripple is normally negligible due to the large ratio between baseband and carrier.

The second example is to illustrate the definition of a model, namely a squaring loop. Squaring loops have been utilized for deriving subcarrier phase references for detection of phase modulated signals. The topology is shown in Figure 6-1 since the elements making up the proposed model were used in the Apollo link simulation. The model utilizes a single tap for use by the multiplier. Figure 6-3 presents the Phase I ASYSTD output and resulting FORTRAN subroutine.

The third example is a model representing a sonar system propagation function. The mathematical form of the model is given by:

$$a = \frac{A f_m f^2}{f_m^2 + f^2} + B f^2 \text{ dB/meter}$$

where

f_m = Relaxation frequency (kHz) given in table below

f = Operating frequency (kHz)

A, B are curve fit coefficients for salt water given by the following

Temperature	f_m	A	B
5°C	60 kHz	6×10^{-4}	3.2×10^{-7}
15°C	100 kHz	6×10^{-4}	2.4×10^{-7}

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000074	150L	0001	000003	20L	0003	R	000002	DT	0003	R	000005	PI	0003	000003	T			
0003	R	000003	TIME	0003	R	000007	TWOPI	0004	R	000001	V	0003	I	000006	VCIN	0005	R	000002	VF
0003	I	000000	VIN	0000	I	000001	VNSAVE	0003	I	000001	VOUT	0000	I	000000	VSAVE	0004	R	000000	VSUB0
0000	I	000002	Z	0000	I	000003	ZIOT1	0005	I	000001	ZNUMF	0003	I	000004	ZZ	0005	I	000000	Z1STF

```

00101 1* SUBROUTINE MODEL A
00101 2* CMODEL SQUARING LOOP
00103 3* INCLUDE MODEL 1, LIST
00104 3* IMPLICIT INTEGER (Z)
00105 3* INTEGER VIN, VOUT, VCIN, VSAVE, VNSAVE
00106 3* COMMON /COGENT/ VIN, VOUT, DT, TIME, ZZ, PI, VCIN, TWOPI
00107 3* COMMON /VSPACE/ VSUB0, V(2)
00110 3* COMMON /FLR/ Z1STF, ZNUMF, VF(5,2)
00111 3* EQUIVALENCE (TIME, T)
00112 3* END
00113 4* INCLUDE MODEL 2, LIST
00114 4* Z=ZZ
00115 4* GO TO 150
00116 4* 20 VNSAVE=VIN
00117 4* VSAVE=VOUT
00120 4* END
00121 5* ZIOT1=Z+1
00122 6* V(Z+2)=V(VIN)
00123 7* V(Z+4)=V(Z+2)*V(Z+2)
00124 8* V(Z+6)=V(Z+4)*V(ZIOT1)
00124 9* C LOOPFILLER
00125 10* VIN=Z+6
00126 11* VOUT=Z+8
00127 12* CALL LEDLAG(200.,1.8775994,0.,.19751719,0.)

00127 13* C FMMODULATOR
00130 14* VIN=Z+8
00131 15* VOUT=Z+10
00132 16* CALL FMMOD(2.*PI,32.768E3)
00133 17* V(Z+12)=V(Z+10)*V(Z+10)-0.5
00134 18* V(ZIOT1)=V(Z+12)
00135 19* VIN=VNSAVE
00136 20* VOUT=VSAVE
00137 21* V(VSAVE)=V(Z+10)
00140 22* RETURN
00141 23* 150 ZZ=ZZ+ 13
00142 24* GO TO 20
00143 25* END

```

Figure 6-3. ASYSTD Example 2 (Cont)

Figure 6-4 is the ASYSTD output for both the model and test run which evaluates the function over a given frequency range. Note that the intrinsic variable TIME is used to represent frequency.

In the fourth example, a filter is simulated, and its response to an input signal measured for various bandwidths. The system variables DT and TSTOP are adjusted appropriately for each bandwidth (BW) considered.

The output generated by the first and last passes of this simulation are included following the FORTRAN program as shown in Figure 6-5.


```

000006      SYSTEM. SIMULATE ABSORPTION VS. FREQ AT 1 METER
000007      DEFAULT. TSTART=2., TSTOP=1000., DT=2., NPRINT=25
000008      PAGE . SMALL FOR PUBS
000009      DATA . A,B,FM
000010      PRINT. RATIO,OUTPUT
000011      PLOT. OUTPUT
000012          INPUT < 1.0 > DRIVE
000013          DRIVE < SONAR ABSORPTION(A,B,FM,TIME,1.0) > RATIO
000014          RATIO < 10.*ALOG10($) > OUTPUT
000015      END

```

@ ADD ADDF IL

```

$SYST ID
A      =      .60000000E-03,
B      =      .32000000E-06,
FM     =      .60000000E+02,
$END

```

Figure 6-4. ASYSTD Example 3 Output (Cont)

SIMULATE ABSORPTION VS, FREQ AT 1 ME

TIME	.200000+01	.520000+02	.102000+03	.152000+03
RATIO	.999991+00	.996252+00	.993099+00	.991165+00
OUTPUT	-.412234-04	-.163069-01	-.300748-01	-.385401-01

TIME	.202000+03	.252000+03	.302000+03	.352000+03
RATIO	.989432+00	.987554+00	.985413+00	.982962+00
OUTPUT	-.461386-01	-.543899-01	-.638183-01	-.746328-01

TIME	.402000+03	.452000+03	.502000+03	.552000+03
RATIO	.980183+00	.977068+00	.973613+00	.969821+00
OUTPUT	-.869288-01	-.100754+00	-.116134+00	-.133085+00

TIME	.602000+03	.652000+03	.702000+03	.752000+03
RATIO	.965692+00	.961229+00	.956437+00	.951320+00
OUTPUT	-.151615+00	-.171731+00	-.193436+00	-.216734+00

TIME	.802000+03	.852000+03	.902000+03	.952000+03
RATIO	.945883+00	.940132+00	.934072+00	.927711+00
OUTPUT	-.241625+00	-.268112+00	-.296195+00	-.325875+00

Figure 6-4. ASYSTD Example 3 Output (Cont)

SIMULATE ABSORPTION VS. FREQ AT 1 ME

* OUTPUT

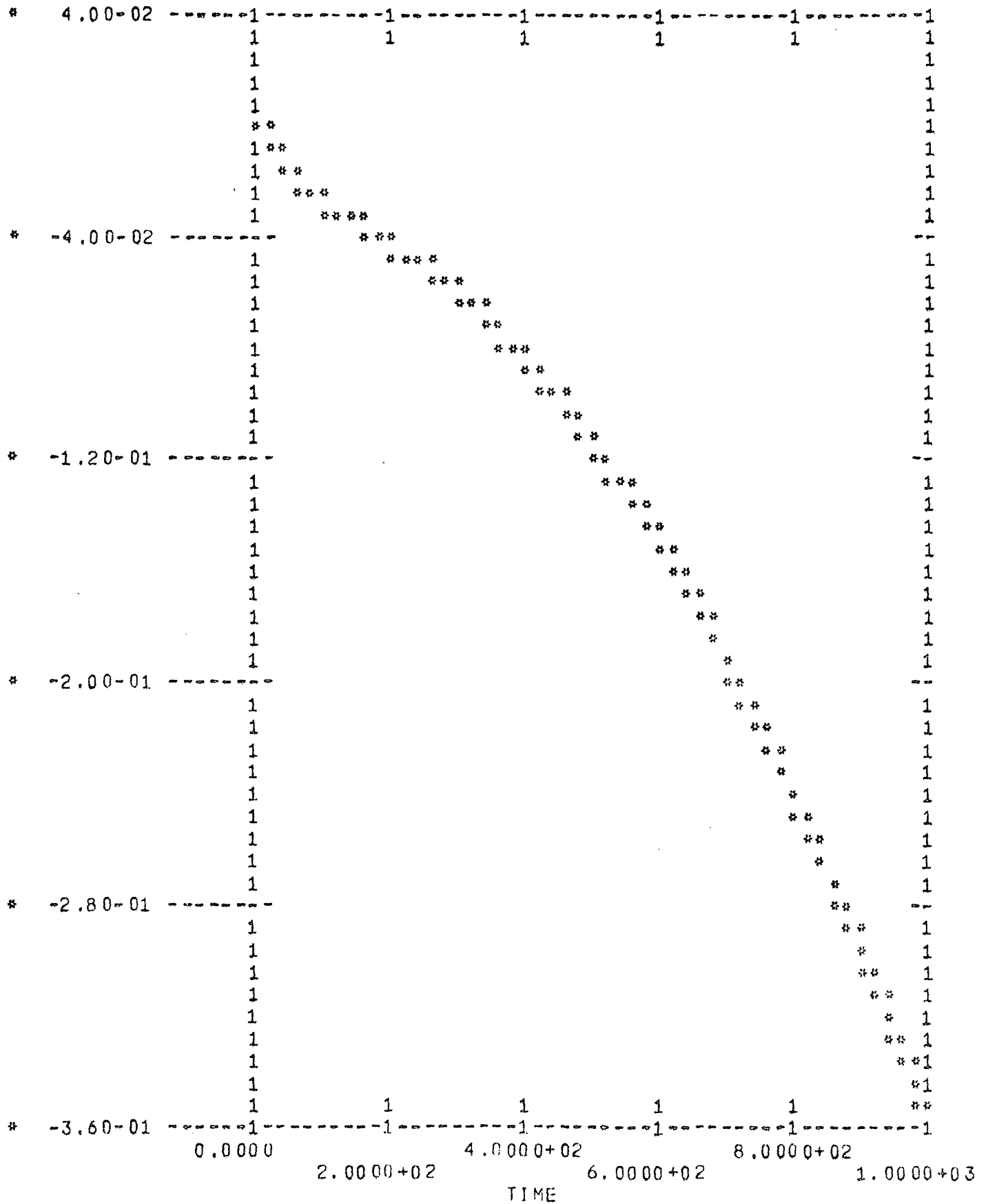


Figure 6-4. ASYSTD Example 3 Output (Cont)

TEST THE VARY/DEFINE FEATURE
 ASYSTD PROCESSOR LEVEL II
 VERSION DATED 01 NOV 71 FOR THE MSC U1108 SYSTEM
 THIS DECK PROCESSED ON 21 DEC 71 AT 15:51:34

SYSTID MODELS REFERENCED	ENTRY POINT
BUTTERWORTH	BUTWTH

```

000001 ** WARNING ** AN OUTPUT LIST CONTAINS AN ITEM WHICH IS NOT A NODE, A TAP, OR TIME,
000001 SYSTEM, TEST THE VARY/DEFINE FEATURE
000002 PRINT, OUTPUT, TESTER
000003 PAGE, SMALL
000004 PLOT, OUTPUT
000005 DEFINE, TESTER=1.+(BW-10.)/20
000006 SET: NPRINT=10
000007 VARY, BW:10.,110.,20.
000008 SET: DT=.05/BW
000009 SET: TSTOP=5/BW
000010 INPUT< 1.0 >N1
000011 N1< BUTTERWORTH(5,1.0.,BW,0.,1.) >OUTPUT
000012 END
  
```

@ ADD ADDFIL

@I FOR,* MAIN /SYSTID,MAIN /SYSTID
 UNIVAC 1108 FORTRAN V LEVEL 2206 0018 F5018S
 THIS COMPILATION WAS DONE ON 21 DEC 71 AT 15:51:35

21 DEC 71 * 15:51:35.497

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000353
0000	*DATA	002072
0002	*BLANK	000000
0003	COGENT	000010
0004	VSPACE	023421
0005	FLR	030326
0006	NAME	000006
0007	INT	000001
0010	DIF	000001
0011	DRMHED	000016

Figure 6-5. Vary/Define Feature Example

EXTERNAL REFERENCES (BLOCK, NAME)

```
0012 DATTN
0013 PAGER
0014 BUTWTH
0015 DRUMIT
0016 PTPLT
0017 NWDS
0020 NI02$
0021 NSTOPS
0022 NI01$
```

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000125	10L	0001	000275	100L	0000	0002033	120F	0001	000330	130L	0001	000342	150L
0001	000011	155G	0001	000137	20L	0001	000345	200L	0001	000100	204G	0001	000104	211G
0001	000104	214G	0001	000262	277G	0001	000213	30L	0001	000313	315G	0001	000320	321G
0000	002004	4F	0001	000222	40L	0001	000045	5L	0000	002026	50F	0000	002032	60F
0000 R	001771	BW	0003 R	000002	DT	0000 I	000001	1\$	0000 I	000000	NPRINT	0003 R	000005	PI
0011 R	000007	SETTLE	0003	000003	T	0003 R	000003	TIME	0006 R	000000	TITLE	0011 R	000004	TSTART
0011 R	000005	TSTOP	0003 R	000007	TWOPI	0004 R	000001	V	0003 I	000006	VCIN	0000 R	000021	VDRUM
0007 R	000000	VDT2	0011 R	000006	VEQDT	0005 R	000002	VF	0003 I	000000	VJN	0003 I	000001	VOUT
0000 R	000002	VPRINT	0000 R	002002	VSETTL	0004 R	000000	VSUB0	0010 R	000000	VIDT	0000 I	002003	Z
0000 I	001776	ZCOUNT	0011 I	000000	ZDATE	0000 I	001773	ZDL1	0000 I	001772	ZDL2	0000 I	001775	ZDRUM
0000 I	001774	ZEDCNT	0011 I	000010	ZEDIT	0011 I	000015	ZNAME	0011 I	000014	ZNAMES	0011 I	000011	ZNPU
0005 I	000001	ZNUMF	0000 I	001777	ZPRINT	0011 I	000012	ZRESRV	0011 I	000002	ZTOD	0011 I	000013	ZUSED
0003 I	000004	ZZ	0000 I	002000	Z1	0005 I	000000	Z1STF	0000 I	002001	Z2			

```
00101 1* INCLUDE MAIN1,LIST
00103 1* IMPLICIT INTEGER (Z)
00104 1* INTEGER VIN,VOUT,VCIN
00105 1* PARAMETER VSIZE=10000,VFSIZE=2500
00106 1* COMMON /COGENT/VIN,VOUT,DT,TIME,ZZ,PI,VCIN,TWOPI

00107 1* COMMON /VSPACE/VSUB0,V(VSIZE)
00110 1* COMMON /FLR/Z1STF,ZNUMF,VF(5,VFSIZE)
00111 1* COMMON /NAME/TITLE(6)
00112 1* COMMON /INT/VDT2 /DIF/VIDT
00113 1* EQUIVALENCE (T,TIME)
00114 1* DATA PI/3.1415927/, TWOPI/6.2831853/
00117 1* DATA TSTART,SETTLE /0.,0./, NPRINT/1/
00123 1* END
00124 2* DATA TITLE/'TEST THE VARY/DEFINE FEATURE
00126 3* PARAMETER ZPSIZE= 3
00127 4* DIMENSION VPRINT(5,ZPSIZE)
00130 5* DATA VPRINT(1,1)/'TIME '/
```

Figure 6-5. Vary/Define Feature Example (Cont)

```

00132 6* DATA VPRINT(1, 2) /'OUTPUT' /
00134 7* DATA VPRINT(1, 3) /'TESTER' /
00136 8* PARAMETER ZDRMSZ=1000
00137 9* DIMENSION VDRUM(ZDRMSZ, 1)
00140 10* COMMON /DRMHED/ ZDATE(2), ZTOD(2), TSTART, TSTOP, VEQDT, SETTLE,
00140 11* ZEDIT, ZNPU, ZRESRV, ZUSED, ZNAMES, ZNAME(1)
00141 12* DATA ZNPU/ 1/, ZRESRV/262129/, ZUSED/ 0/, ZNAMES/ 1/
00146 13* DATA ZNAME(1) /'OUTPUT' /
00150 14* DEFINE TESTER=1,+(BW-10,)/20
00151 15* CALL DATIN(ZDATE)
00152 16* NPRINT=10
00153 17* ZDL2=(110,-10,)/20,
00154 18* DO 200 ZDL1=0,ZDL2,1
00157 19* BW=10,+20,*ZDL1
00160 20* DT=.05/BW
00161 21* TSTOP=5/BW
00162 22* INCLUDE MAIN2,LIST
00163 22* IF((TSTOP-TSTART)/DT,GT,0) GO TO 5
00165 22* WRITE(6,4)TSTART,TSTOP,DT
00172 22* 4 FORMAT(1X,'** ERROR ** THE VALUES TSTART=',E12.6,' TSTOP=',E12.6,
00172 22* , ' DT=',E12.6,' ARE UNREASONABLE,')
00173 22* STOP
00174 22* 5 ZEDIT=(TSTOP-(TSTART+SETTLE))/(DT*ZRESRV)+1
00175 22* ZEDCNT=ZEDIT-1
00176 22* ZDRUM=0
00177 22* ZUSED=0
00200 22* ZCOUNT=NPRINT-1
00201 22* ZPRINT=1
00202 22* VSUB0=0,0
00203 22* DO 6 Z1=1,VSIZE
00206 22* 6 V(Z1)=0,0
00210 22* DO 7 Z2=1,VFSIZE
00213 22* DO 7 Z1=1,5
00216 22* 7 VF(Z1,Z2)=0.0
00221 22* VEQDT=DT
00222 22* VDT2=DT/2.0
00223 22* VDDT=2,0/DT
00224 22* TIME=TSTART+DT
00225 22* VSETTL=TSTART+SETTLE
00226 22* CALL PAGER
00227 22* @.....
00227 22* @ THE SIMULATION LOOP BEGINS HERE, GOOD LUCK,
00227 22* @.....
00227 22* 10 TIME=TIME+DT
00230 22* IF(TIME,GT,TSTOP) GO TO 100
00232 22* Z=2
00233 22* GO TO 150
00234 22* 20 Z1STF=1

```

Figure 6-5. Vary/Define Feature Example (Cont)

```

00235 22*      VIN=1
00236 22*      VOUT=2
00237 22*      END
00240 23*      V(Z+4)=1.0
00240 24*      C BUTTERWORTH
00241 25*      VIN=Z+4
00242 26*      VOUT=Z+6
00243 27*      CALL BUTWTH(5,1,0.,BW,0.,1,)
00244 28*      IF(TIME,LT,VSETTL) GO TO 10
00246 29*      INCLUDE MAIN3,LIST
00247 29*      ZEDCNT=ZEDCNT+1
00250 29*      IF(ZEDCNT,NE,ZEDIT) GO TO 40
00252 29*      ZEDCNT=0
00253 29*      IF(ZDRUM,NE,ZDRMSZ) GO TO 30
00255 29*      CALL DRUMIT(VDRUM,ZDRMSZ,ZDRMSZ)
00256 29*      ZDRUM=0
00257 29*      30 ZDRUM=ZDRUM+1
00260 29*      END
00261 30*      VDRUM(ZDRUM,1)=V(Z+6)
00262 31*      40 CONTINUE
00263 32*      ZCOUNT=ZCOUNT+1
00264 33*      IF(ZCOUNT,NE,NPRINT) GO TO 10
00266 34*      ZCOUNT=0
00267 35*      ZPRINT=ZPRINT+1
00270 36*      VPRINT(ZPRINT,1)=TIME
00271 37*      VPRINT(ZPRINT,2)=V(Z+6)
00272 38*      VPRINT(ZPRINT,3)=TESTER
00273 39*      IF(ZPRINT,NE,5) GO TO 10
00275 40*      WRITE(6,50) VPRINT
00303 41*      50 FORMAT(3(6X,A6,4(4X,E12,6),/))
00304 42*      INCLUDE MAIN5,LIST
00305 42*      WRITE(6,60)
00307 42*      60 FORMAT(/)
00310 42*      ZPRINT=1
00311 42*      GO TO 10
00312 42*      @-----
00312 42*      @ END OF SIMULATION AND OUTPUT LOOP
00312 42*      @-----
00312 42*      100 IF(ZPRINT,LT,2) GO TO 130
00314 42*      DO 110 Z2=1,ZPSIZE
00317 42*      110 WRITE(6,120)(VPRINT(Z1,Z2),Z1=1,ZPRINT)
00326 42*      120 FORMAT(6X,A6,8(4X,E12,6))
00327 42*      130 CONTINUE
00330 42*      END
00331 43*      CALL DRUMIT(VDRUM,ZDRMSZ,ZDRUM)
00332 44*      CALL PTPLT('OUTPUT',4)
00333 45*      GO TO 200
00334 46*      150 ZZ= 9
00335 47*      GO TO 20
00336 48*      200 CONTINUE
00340 49*      STOP
00341 50*      END

```

END OF UNIVAC 1108 FORTRAN V COMPILATION, 0 *DIAGNOSTIC* MESSAGE(S)

Figure 6-5. Vary/Define Feature Example (Cont)

TEST THE VARY/DEFINE FEATURE

TIME	,0 00 00 0	,5 00 00 0-01	,1 00 00 0+00	,1 50 00 0+00
OUTPUT	,5 97 95 8-04	,4 34 82 8+00	,1 12 98 4+01	,9 54 79 0+00
TESTER	,1 00 00 0+01	,1 00 00 0+01	,1 00 00 0+01	,1 00 00 0+01

TIME	,2 00 00 0+00	,2 50 00 0+00	,3 00 00 0+00	,3 50 00 0+00
OUTPUT	,1 01 65 0+01	,9 94 12 7+00	,1 00 20 2+01	,9 99 33 3+00
TESTER	,1 00 00 0+01	,1 00 00 0+01	,1 00 00 0+01	,1 00 00 0+01

TIME	,4 00 00 0+00	,4 50 00 0+00	,5 00 00 0+00
OUTPUT	,1 00 02 1+01	,9 99 94 0+00	,1 00 00 2+01
TESTER	,1 00 00 0+01	,1 00 00 0+01	,1 00 00 0+01

Figure 6-5. Vary/Define Feature Example (Cont)

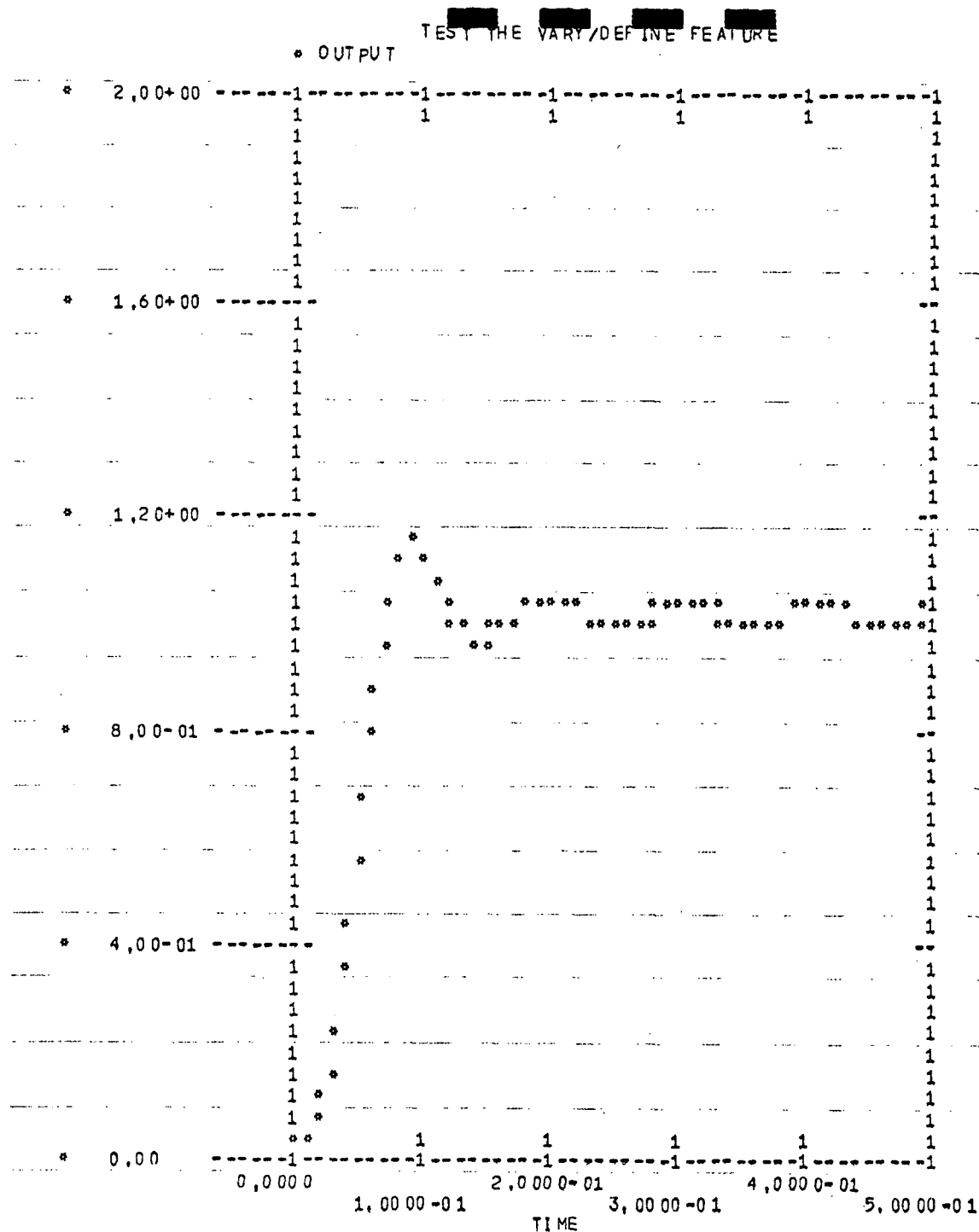


Figure 6-5. Vary/Define Feature Example (Cont)

TEST THE VARY/DEFINE FEATURE

TIME	,000000	,454545-02	,909091-02	,136364-01
OUTPUT	,597958+04	,434828+00	,112984+01	,954790+00
TESTER	,600000+01	,600000+01	,600000+01	,600000+01

TIME	,181818-01	,227273-01	,272727-01	,318182-01
OUTPUT	,101650+01	,994127+00	,100202+01	,999333+00
TESTER	,600000+01	,600000+01	,600000+01	,600000+01

TIME	,363636-01	,409091-01	,454545-01
OUTPUT	,100021+01	,999939+00	,100002+01
TESTER	,600000+01	,600000+01	,600000+01

Figure 6-5. Vary/Define Feature Example (Cont)

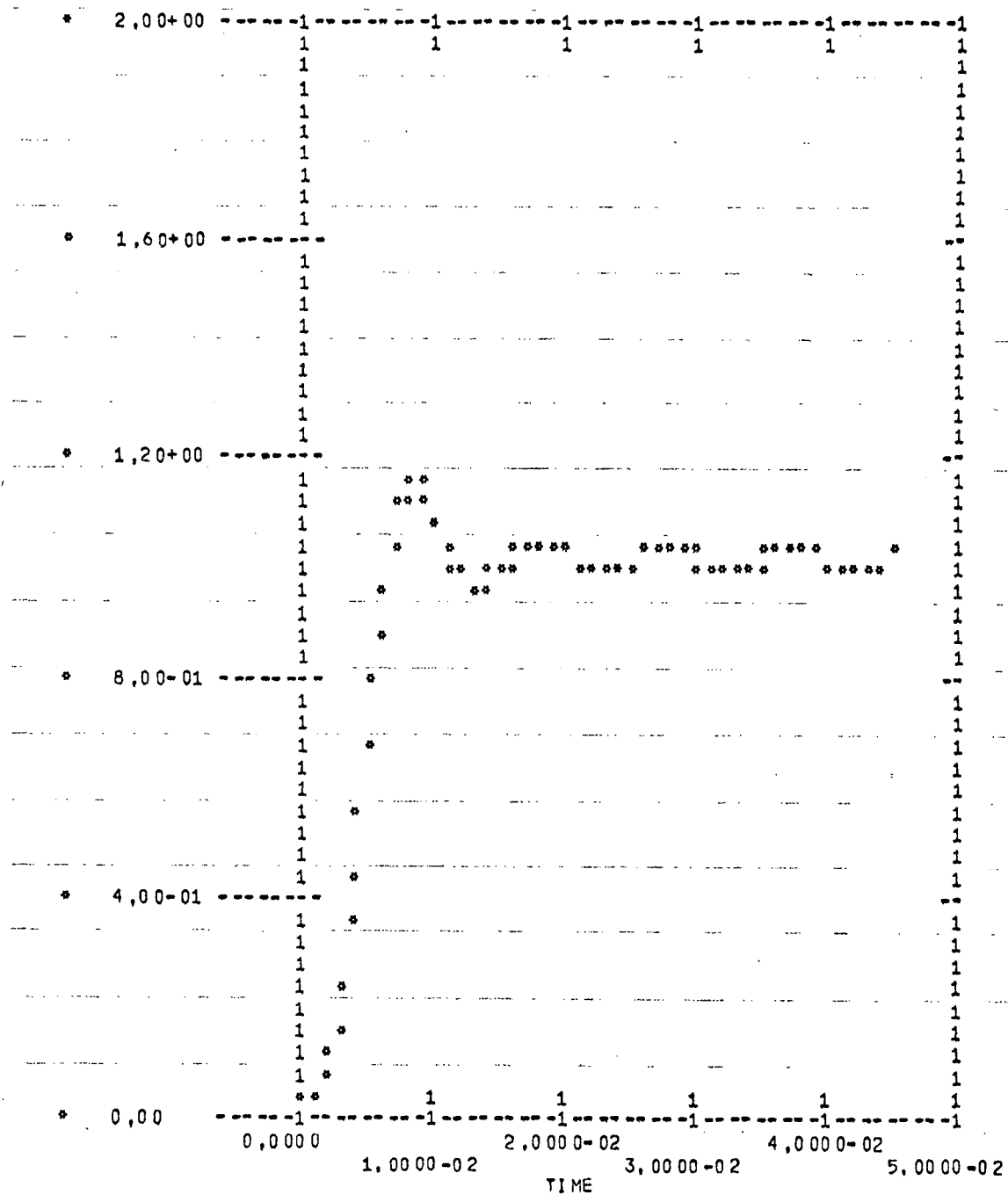


Figure 6-5. Vary/Define Feature Example (Cont)

APPENDIX A
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APPENDIX B

ASYSTD LIBRARY DESCRIPTIONS

The ASYSTD library consists of a collection of models developed by both Systems Associates, Inc. and NASA MSC, Space Electronics Division. The following material describes the use of the models. The descriptions are grouped under various identifiers, an index of which follows. Several blank Library forms have been included for future use.

Signal Generators

- Gaussian Noise
- Pulse Generator
- Square Wave Generator
- Table Generators
- Periodic Table Generator
- Transcendental Function Generators

Modulators

- Amplitude Modulators
- Frequency Modulators (Sine Wave)
- Frequency Modulator (Square Wave)
- Phase Modulators (Sine Wave)
- Phase Modulator (Square Wave)
- Delta Modulator

Demodulator

- Amplitude Demodulators
- Phase Demodulators
- Frequency Demodulators
- Frequency Demodulator with Feedback

Filters

- General Filter Model
- Butterworth
- Chebychev
- Bessel
- Butterworth-Thompson
- Elliptic
- Quadratic
- Lead Lag Function
- Lead Function
- Matched Filter

Limiters

- Soft Limiters
- Hard Limiters
- RF Soft Limiter
- RF Hard Limiter

Transforms

- Fourier Transform (FFT) (and Inverse)
- Haar Transform (and Inverse)
- Hadamard Transform (and Inverse)
- Ordered Hadamard Transform (and Inverse)

Coders

- Analog-to-Digital
- Digital-to-Analog
- Sample Hold Digital-to-Analog
- Multi-Level PCM

Math

- Complex Adder
- Complex Multiply
- Differentiator
- Integral with Initial Conditions
- Integral

Miscellaneous

- Interleaver
- De-Interleaver
- Time Delay
- Phase Shifter
- Signal Split
- Time Latch
- Zero Crossing Detector



MODEL	GROUP ID	PAGE	DATE
GAUSSIAN NOISE GENERATOR	Sig. Gen.	1	April, 1972
LIBRARY MODEL NAMES			
GNOISE			

DESCRIPTION

This function provides noise modeling capability, providing the SNR and ENB of the generator are defined.

USAGE

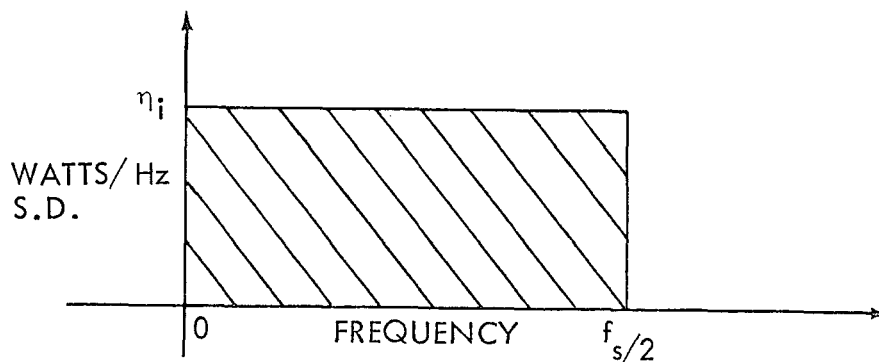
N1 < GNOISE (SNR, ENB, ISTART) > N2

where: SNR is the signal-to-noise ratio desired in ENB (equivalent noise bandwidth) assuming a 1 watt signal level.

ISTART is a positive integer (>0) for initializing the random number generator.

DETAILED DESCRIPTION

WHITE GAUSSION:





ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
GAUSSIAN NOISE GENERATOR	Sig. Gen.	2	April, 1972

where

$$f_s = \frac{1}{DT} = \frac{1}{\text{sampling rate}}$$

$$\sigma_i^2 = \frac{\eta_i f_s}{2} = \frac{\eta_i}{2DT}$$

or

$$\boxed{\eta_i = 2\sigma_i^2 DT} \quad (\text{Watts/Hz})$$

$$N_o = \eta_i * ENB = 2\sigma_i^2 DT * ENB \quad (\text{watts})$$

where ENB = equivalent noise bandwidth under consideration.

For a given SNR in bandwidth, BW:

$$\frac{S}{N_o} = 10^{\text{SNR}/10}$$

where

$$S = \text{signal power in BW} \quad (\text{watts})$$

or

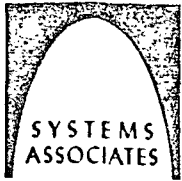
$$N_o = S * 10^{-\text{SNR}/10} = 2\sigma_i^2 DT * ENB$$

or

$$\boxed{\sigma_i = \sqrt{S / \sqrt{10^{\text{SNR}/10} * 2DT * ENB}}}$$

APPLICATION

This model is a function and may be used in expressions.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
GAUSSIAN NOISE TWO	Sig. Gen.	1	April, 1972

LIBRARY MODEL NAMES

GNOIS2

DESCRIPTION

This model provides noise modeling capability, providing the spectral density desired.

USAGE

N1 <GNØIS2 (ETA, ISTART)> N2

where: ETA is the desired spectral density (watts/Hz)

ISTART is a positive integer (>0) for initializing the random number generator

DETAILED DESCRIPTION

See "Gaussian Noise Generator"

$$ETA = 10^{\frac{1}{SNR/10} * ENB}$$

APPLICATION

This model is a function and may be used in expressions.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
PULSE GENERATOR	Sig. Gen.	1	April, 1972
LIBRARY MODEL NAMES			
PULSE			

DESCRIPTION

This model produces a periodic output of pulses of the shape described below.

USAGE

N1 < PULSE(RATE, TD, TR, TL, TF) > N2

where: RATE = frequency of output

TD = delay time

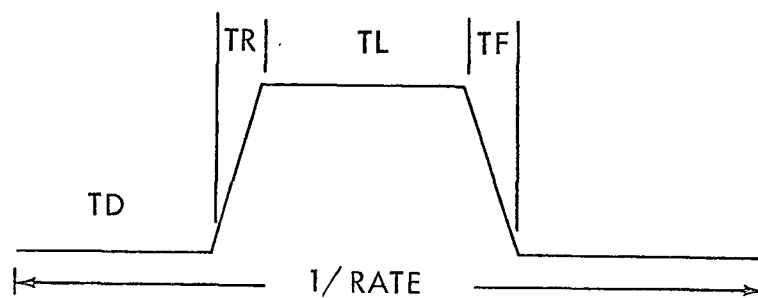
TR = rise time

TL = level time

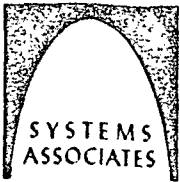
TF = fall time

OUTPUT

The maximum value is plus one and the minimum value is zero.

APPLICATION

This model is a function and may be used in expressions.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
SQUARE WAVE GENERATOR	Sig. Gen.	1	April, 1972
LIBRARY MODEL NAMES			
SQ SQUARE WAVE			

USAGE

N1 < SQ(RATE) > N2

where: RATE = frequency of the square wave output
at node N2

OUTPUT

A square wave of period $1/\text{RATE}$ whose maximum value is plus one and whose minimum value is minus one.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
TABLE	Sig. Gen.	1	April, 1972

LIBRARY MODEL NAMES

TABLE

DESCRIPTION

This function provides a piece-wise linear function for modeling both driving functions and non-linearities.

USAGE

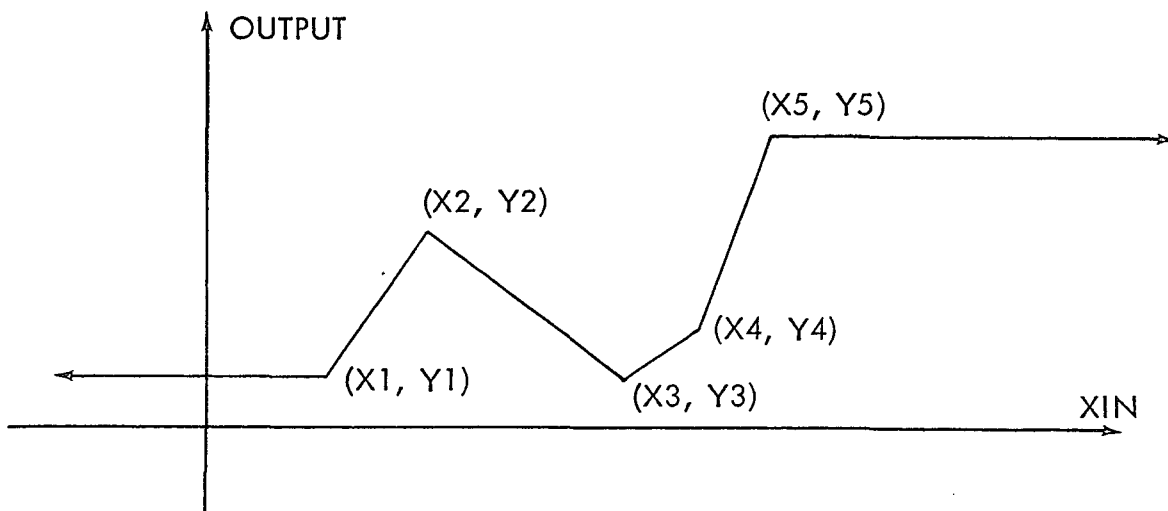
N1 < TABLE (XIN, X1, Y1, X2, Y2, X3, Y3, X4, Y4, X5, Y5 > N2

where: XIN = independent variable

$\left. \begin{array}{l} X1, Y1 \\ \vdots \\ X5, Y5 \end{array} \right\}$

Five point pairs describing the function
(Note: Out-of-range values assume the end point values)

OUTPUT (Example)





ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
TABLE	Sig. Gen.	2	April, 1972

APPLICATION

This model is a function and may be used in expressions.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
PERIODIC TABLE FUNCTION	Sig. Gen.	1	April, 1972
LIBRARY MODEL NAMES			
PERIODIC TABLE FUNCTION PTABLE			

DESCRIPTION

This model provides the periodic function capability. The output is periodic with period $T5$.

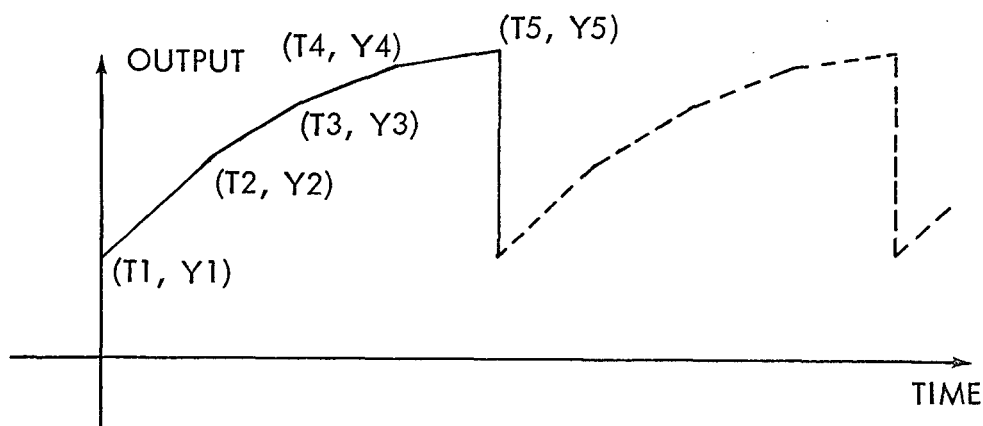
USAGE

$N1 < PTABLE (T1, Y1, T2, Y2, T3, Y3, T4, Y4, T5, Y5) > N2$

where: $\left. \begin{matrix} T1, Y1 \\ \vdots \\ T5, Y5 \end{matrix} \right\}$ Five point-pairs describing the function

and $T5 =$ Period of the function

OUTPUT (Example



In this example $T1=0$; if $T1 \neq 0$, the output is set to $Y1$ for $0 \leq \text{TIME} \leq T1$

APPLICATION

This model is a function and may be used in expressions.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
TABL2	Sig. Gen.	1	April, 1972
LIBRARY MODEL NAMES			
TABL2			

DESCRIPTION

This function provides a piece-wise linear function for modeling both driving functions and non-linearities, and provides zero output levels for out of range conditions.

USAGE

N1 <TABL2 (XIN,X1,Y1,X2,Y2,X3,Y3,X4,Y4,X5,Y5) > N2

where: XIN = independent variable

$\left. \begin{array}{l} X1, Y1 \\ \vdots \\ X5, Y5 \end{array} \right\}$ five point pairs describing the function

OUTPUT

This model is the same as model "TABLE" except out-of-range values ($XIN < X1$ or $XIN \geq X5$) yield an output of zero.

APPLICATION

This model is a function and may be used in expressions.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
TRANSCENDENTAL FUNCTIONS	Sig. Gen.	1	April, 1972

LIBRARY MODEL NAMES

SIN	SINE
COS	COSINE
TAN	TANGNT

DESCRIPTION

These elements are FORTRAN transcendental functions or utilize FORTRAN functions.

USAGE (Example)

N1 < SIN (\$) > N2

N2 is set to the trigonometric sine of N1

SIN (x)	} x in radians	SINE (y)	} y in cycles
COS (x)		COSINE (y)	
TAN (x)		TANGNT (y)	

APPLICATION

These elements are functions and may be used in expressions.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
AMPLITUDE MODULATOR	Modulator	1	April, 1972
LIBRARY MODEL NAMES			
AM MODULATOR AMMOD			

DESCRIPTION

The Linear Amplitude Modulator provides classical modulation capability to the ASYSTD user. This element is the baseband model.

USAGE

N1 <AMMOD(BETA,FC)> N2

where: BETA = Modulation Index (ratio)

FC = Carrier frequency

OUTPUT

Let INPUT(t) be the real input to the model (value at node N1) and Vo(t) be the real output of the model, then

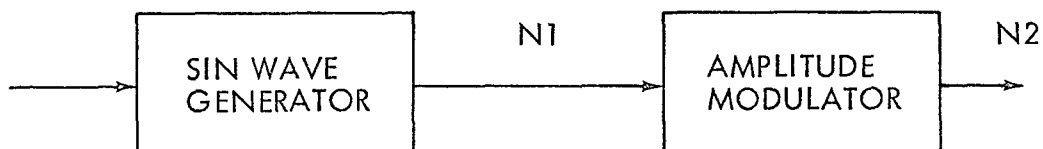
$$V_o(t) = (1.0 + \text{BETA} \cdot \text{INPUT}(t)) \cdot \cos(2\pi \text{FC} \cdot \text{Time})$$

RESTRICTIONS

$\text{BETA} \cdot \text{INPUT}(t) \leq 1.0$ for no over-modulation.

APPLICATION

An example of using the model in a system is as follows:



INPUT < SINE (T) > N1

N1 <AMMOD (1.0, 100 E3)> N2



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
RF AMPLITUDE MODULATOR	Modulator	1	April, 1972

LIBRARY MODEL NAMES

RF AMPLITUDE MODULATOR
RAMMOD

DESCRIPTION

The Linear Amplitude Modulator provides classical modulation capability to the ASYSTD user. The output of this model is a complex baseband signal which represents the modulated carrier in the baseband.

USAGE

N1 < RAMMOD (BETA, PHI, MODE) > N2

where: BETA = Modulation Index (ratio)

PHI = Instantaneous Phase Jitter

MODE = 1.0 for Double Sideband (DSB)

MODE = 0.0 for Double Sideband-Suppressed Carrier

OUTPUT

Let $i(t)$ be the real input to the model (node N1),

then: $V_o(t) = [MODE + BETA * i(t)] e^{j(\omega_c t + PHI)}$

translating $V_o(t)$ to baseband:

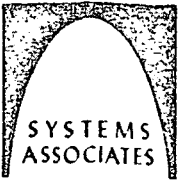
$$V_o'(t) = V_o(t) e^{-j\omega_c t}$$

or $V_o'(t) = [MODE + BETA * i(t)] e^{jPHI} = V_r(t) + jV_i(t)$

where: $V_o'(t)$ is the complex baseband output signal at N2

with $V_r(t) = [MODE + BETA * i(t)] \cos(PHI)$

$$V_i(t) = [MODE + BETA * i(t)] \sin(PHI)$$



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
RF AMPLITUDE MODULATOR	Modulator	2	April, 1972

RESTRICTIONS

$|\text{BETA} * i(t)| \leq 1.0$ for no over-modulation

APPLICATION

This model is used in place of the amplitude modulator when carrier translation is required.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
LINEAR FREQUENCY MODULATOR	Modulator	1	April, 1972

LIBRARY MODEL NAMES

FM MODULATOR
FMMOD

DESCRIPTION

The Linear Frequency Modulator Model provides a classical model for this type of angle modulation. The carrier output magnitude is defined as unity.

USAGE

N1 < FMMOD(DF, FC) > N2

where: DF = frequency deviation (Hz) of the carrier per unit input

FC = carrier frequency

OUTPUT

Let the signal at N1 at time T be $i(t)$.

Let the signal at N2 at time T be $V_o(t)$.

then:
$$V_o(t) = \text{SINE}\left(FC * t + DF * \int_{TSTART}^t i(\tau) d\tau\right)$$

NOTE: The arguments of the SINE function is in Hz.

APPLICATION

FMMOD is for use when no carrier translation is required in the simulation.



MODEL	GROUP ID	PAGE	DATE
RF LINEAR FREQUENCY MODULATOR	Modulator	1	April, 1972

LIBRARY MODEL NAMES

RF FM MODULATOR
RFMMOD

DESCRIPTION

The Linear Frequency Modulator model provides a classical model for this type of angle modulation. The carrier output magnitude is defined as unity.

USAGE

N1 < RFMMOD(DF) > N2

where: DF = frequency deviation (Hz) of the carrier per unit input.

OUTPUT

Let $i(t)$ be the real input to the model (node N1), then for the ideal FM modulator

$$V_o(t) = e^{j(\omega_c t + \beta \int_0^t i(t) dt)}$$

where: $\beta = Z \pi DF$

translating $V_o(t)$ to baseband:

$$V_o'(t) = V_o(t) e^{-j\omega_c t}$$

or

$$V_o'(t) = e^{j\beta \int_0^t i(t) dt} = V_r(t) + jV_j(t)$$

where: $V_o'(t)$ is the complex baseband output signal at N2

with: $V_r(t) = \cos(\beta \int_0^t i(t) dt)$

$$V_j(t) = \sin(\beta \int_0^t i(t) dt)$$

APPLICATION

This model is used in place of the FREQUENCY MODULATOR model when carrier translation is required in the simulation.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
SQUARE WAVE FREQUENCY MODULATOR	Modulators	1	
LIBRARY MODEL NAMES			
SQUARES WAVE FREQUENCY MODULATOR SQFMOD			

DESCRIPTION

The Square Wave Frequency Modulator provides a model for this type of angle modulation with ideal limiting.

USAGE

N1 < SQFMOD(DF, FC) > N2

where: DF = frequency deviation (cycles) of the carrier
per unit input

FC = carrier frequency

OUTPUT

Let the signal at N1 at time T be INP(T).

Let the signal at N2 at time T be OUT(T).

Then:
$$F(T) = \text{SINE}\left(FC \cdot T + DF \cdot \int_{T_{\text{START}}}^T \text{INP}(t) dt\right)$$
 [linear frequency modulation]

NOTE: The arguments of the SINE function is in cycles

OUT(T) = +1 when F(T) ≥ 0

OUT(T) = -1 when F(T) < 0



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
LINEAR PHASE MODULATOR	Modulator	1	April, 1972
LIBRARY MODEL NAMES			
PHASE MODULATOR PMMODD PMMOD			

DESCRIPTION

The Linear Phase Modulator provides a classical model for this type of angle modulation. The carrier output level is defined as unity.

USAGE

N1 < PMMOD(BETA, TC) > N2

where: BETA = Phase (Radians) deviation per unit input

FC = Carrier frequency (Hz)

NOTE: Modulation Index = $BETA * Input_{max}$

OUTPUT

Let the signal at N1 at time T be $i(t)$
Let the signal at N2 at time T be $Vo(t)$

then: $Vo(t) = \sin(2\pi * FC * t + BETA * i(t))$

APPLICATION

This model is for use when no carrier translation is required in the simulation.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
RF LINEAR PHASE MODULATOR	Modulator	1	April, 1972
LIBRARY MODEL NAMES			
RF PHASE MODULATOR RPMMOD			

DESCRIPTION

The Liner Phase Modulator provides a classical model for this type of angle modulation. The output is the complex baseband signal.

USAGE

N1 < RPMMOD(BETA) > N2

where: BETA = Phase (Radians) deviation per unit input

OUTPUT

Let $i(t)$ be the real input to the model, then:

$$V_o(t) = e^{j \{ \omega_c t + \beta \cdot i(t) \}}$$

translating $V_o(t)$ to baseband:

$$V_o'(t) = V_o(t) e^{-j \omega_c t}$$

or

$$V_o'(t) = e^{j \beta \cdot i(t)} = V_r(t) + j V_j(t)$$

where: $V_o'(t)$ is the complex baseband output signal at N2

with $V_r(t) = \cos(\beta \cdot i(t))$

$$V_j(t) = \sin(\beta \cdot i(t))$$

APPLICATION

This model is used in place of the FM MODULATOR model when carrier translation is required in the simulation.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
SQUARE WAVE PHASE MODULATOR	Modulator	1	April, 1972

LIBRARY MODEL NAMES

SQUARE WAVE PHASE MODULATOR
SQPMOD

DESCRIPTION

The Square Wave Phase Modulator provides a model for this type of angle modulation with ideal limiting.

USAGE

N1 < SQPMOD(BETA, FC) > N2

where: BETA = Phase (Radians) deviation per unit input

FC = Carrier frequency

NOTE: Modulation Index = $BETA * Input_{max}$

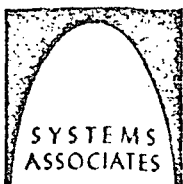
OUTPUT

Let the signal at N1 at time T be INP(T).
Let the signal at N2 at time T be OUT(T).

$F(T) = \sin(2\pi * FC * T + BETA * INP(T))$ [linear phase modulation]

OUT(T) = +1 when $F(T) \geq 0$

OUT(T) = -1 when $F(T) < 0$



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
DELTA MODULATION	Modulator	1	April, 1972
LIBRARY MODEL NAMES			
DELTA MODULATOR DELMOD			

DESCRIPTION

Delta modulation is a coded modulation system nearly as efficient as PCM, requires more bandwidth than PCM, but has much simpler circuitry. These advantages make delta modulation quite attractive as a standard model. The output waveform magnitude is defined as ± 1 .

USAGE

N1 <DELMOD(PW,PPS)> N2

where: PW = Pulse width (unit time)

PPS = Pulse repetition rate (pulses/unit time)

OUTPUT

In a delta modulation system, only the changes in signal amplitude from sample to sample are output. The process consists of utilizing a pulse generator (clock), one shot multi-vibrator, an integrator, and a difference circuit.

$$\text{let } e_{(t)} = \text{input}_{(t)} - \int \text{Output}_{(t)} dt$$

$$\text{where output}_{(t)} = \text{Sign}(e_{(t)}) * \delta(t)$$

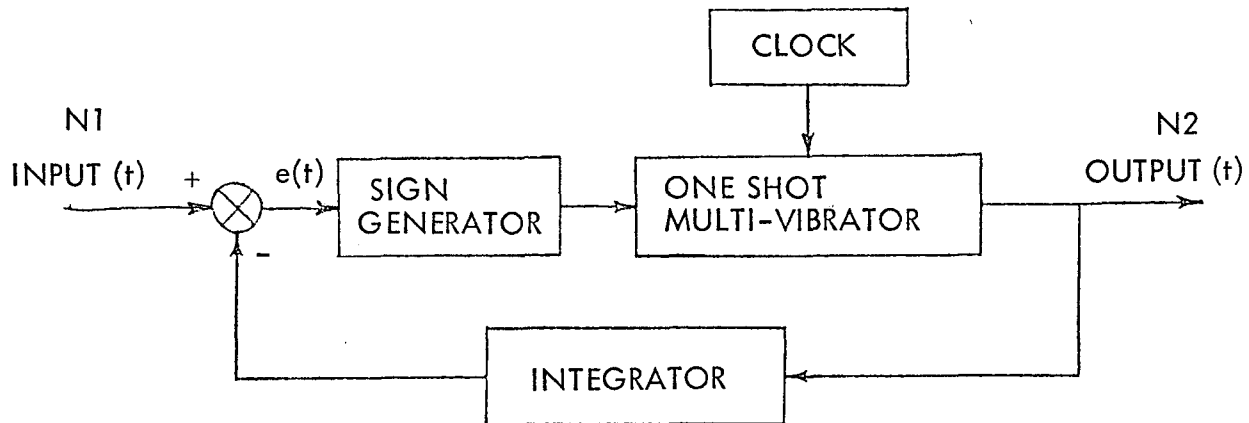
where $\delta(t)$ is a finite pulse of width PW

The above process is clocked at a repetition rate of PPS

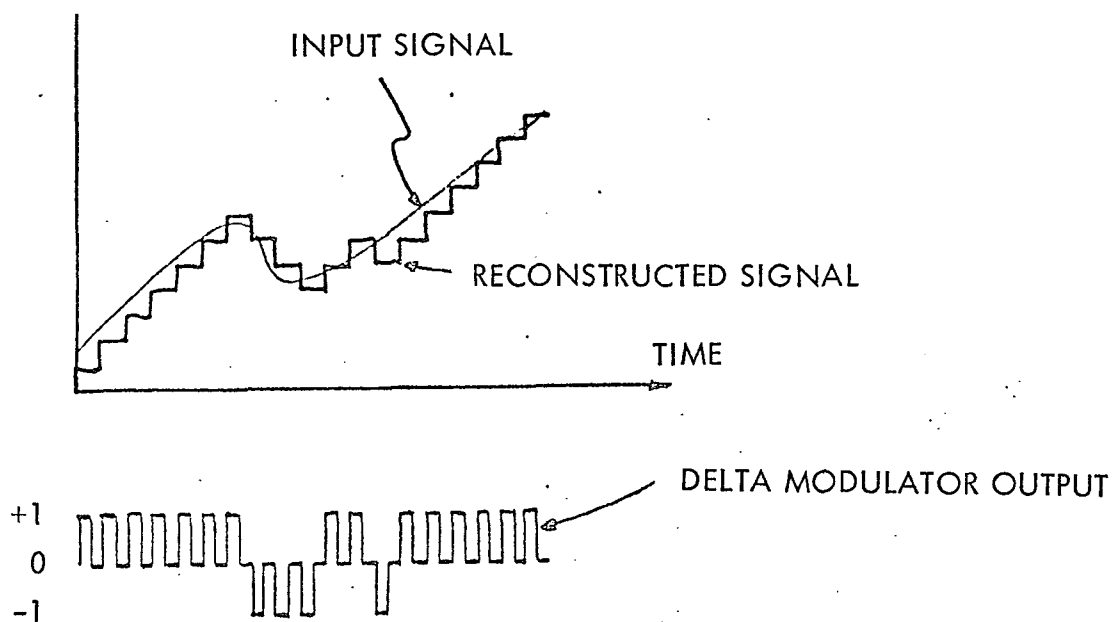


ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
DELTA MODULATION	Modulator	2	April, 1972



EXAMPLE:



The width of the pulses in the Delta Modulator output is PW. There is one positive or negative pulse every 1/PPS. The input signal and the signal which can be reconstructed from the Delta Modulator output have the same scale. Each step is 1/PPS wide and PW high.



MODEL	GROUP ID	PAGE	DATE
DELTA MODULATION	Modulator	3	April, 1972

RESTRICTIONS

In general, the delta modulator cannot follow the input signal whenever:

$$\left| \frac{d}{dt} \text{input}(t) \right| > PW * PPS$$

To prevent overload, PW and PPS should be adjusted so that:

$$\left| \frac{d}{dt} \text{input}(t) \right|_{\max} \leq PW * PPS$$

which is usually satisfied if:

$$A\omega \leq PW * PPS$$

where: A = Peak value of input

ω = Maximum frequency of input

If PW and PPS cannot be adjusted to meet this condition (note $PWS \leq 1/PPS$), then the input to the delta modulator must be properly scaled.

In the case where:

$$\left| \frac{d}{dt} \text{input}(t) \right|_{\max} < < PW * PPS$$

PW may be decreased or the input signal scaled to provide more information in the delta modulator output.

APPLICATION

The delta modulator is normally used in pulse coding an audio signal for subsequent transmission via a modulated carrier. As such, this model will be mainly used in generating a baseband signal.

REFERENCE

For a description of delta modulation and a bibliography, see:
H. R. SCHINDLER, "Delta Modulation",
IEEE SPECTRUM, October 1970, pp. 69-78



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
AMPLITUDE DEMODULATOR	Demod.	1	April, 1972

LIBRARY MODEL NAMES

AMPLITUDE DEMODULATOR
AMDEM

DESCRIPTION

This linear Amplitude Demodulator provides a rudimentary model for use in the ASYSTD library. The basic model is a full wave rectifier followed by a user selected filter function chosen for the particular application.

USAGE

N1 < AMDEM > N2

NOTE: N2 must be the input to a filter.

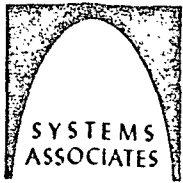
OUTPUT

The output signal at N2 is simply the absolute value of the signal at N1

$$N2(T) = |N1(T)|$$

APPLICATION

This model is for use in the baseband region. Its output must be fed through an averaging filter to eliminate the carrier.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
RF AMPLITUDE DEMODULATOR	Demod.	1	April, 1972
LIBRARY MODEL NAMES			
RF AM DEMODULATOR RAMDEM			

DESCRIPTION

This model is a rudimentary Amplitude Demodulator for use in modeling in the RF region.

USAGE

N1 < RAMDEM(GAIN) > N2

where: GAIN = Amplification of the model
(typically 1/BETA, see
RF AMPLITUDE MODULATOR)

OUTPUT

Let X be the complex signal at N1

$$X = X_r + jX_i$$

$$|X| = (X_r^2 + X_i^2)^{1/2}$$

Let Y be the output at N2

$$Y = \text{GAIN} * (|X| - 1.)$$

APPLICATION

This model should be followed with a user selected filter for accurate simulation.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
PHASE DEMODULATOR	Demod.	1	April, 1972
LIBRARY MODEL NAMES			
PHASE DEMODULATOR PMDEMM			

DESCRIPTION

This Phase Demodulator simply takes the integral of an FM demodulator output.

USAGE

N1 < PMDEMM(DV, FC) > N2

where: FC = Center Frequency

DV = Output Magnitude per Unit Phase Deviation
(Volts/Radians)

OUTPUT

The Phase Demodulator output is given by $DV * \int FMDEMOD(t) dt$
where FMDEMOD(t) is the output of an FMDEMOD with a
sensitivity of 1v/radian.

APPLICATION

This model is to be used with external filtering.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
RF PHASE DEMODULATOR	Demod.	1	April, 1972
LIBRARY MODEL NAMES			
RF PHASE DEMODULATOR RFPDEM			

DESCRIPTION

This model represents an ideal wide band phase demodulator.

USAGE

N1 < RFPDEM(DV) > N2

where: DV = Output Magnitude per Unit Phase Deviation
(Volts/Radians)

OUTPUT

Let the complex input at N1 be $X = X_r + jX_i$

Then the output of this model is $DV * \tan^{-1} \left(\frac{X_i}{X_r} \right)$

APPLICATION

This model is to be used with external filtering.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
FREQUENCY DEMODULATOR WITH FEEDBACK	Demod.	1	April, 1972
LIBRARY MODEL NAMES			
FMFB			

DESCRIPTION

The Frequency Demodulator with Feedback Model (FMFB) provides an alternate demodulation process capability. The basic model consists of a multiplier, IF filter, FM discriminator (FMDEMOD) and a Voltage Controlled Oscillator (FMMOD). The RF filter and post-detection low pass filter are external to the model.

USAGE

N1 < (FMFB (NIF, NTYPE, AR, EM, BIF, FIF, GAIN, FC, DV, DF)) > N2

where: NIF -IF Filter Order (≤ 10)

NTYPE -Type of Filter Function:

- = 1 for Butterworth
- = 2 for Chebyshev
- = 3 for Bessel
- = 4 for Butterworth-Thomson
- = 5 for Elliptic

AR -Amplitude Ripple (dB)

EM -M-Factor for Butterworth-Thomson
Stop Band Ratio for Elliptic (if positive)
Modular Angle (Degrees) for Elliptic
(if negative)

BIF -IF Filter Bandwidth

GAIN -Detector Gain + VCO Amp Gain

FIF -IF Frequency



MODEL	GROUP ID	PAGE	DATE
FREQUENCY DEMODULATOR WITH FEEDBACK	Demod.	2	April, 1972

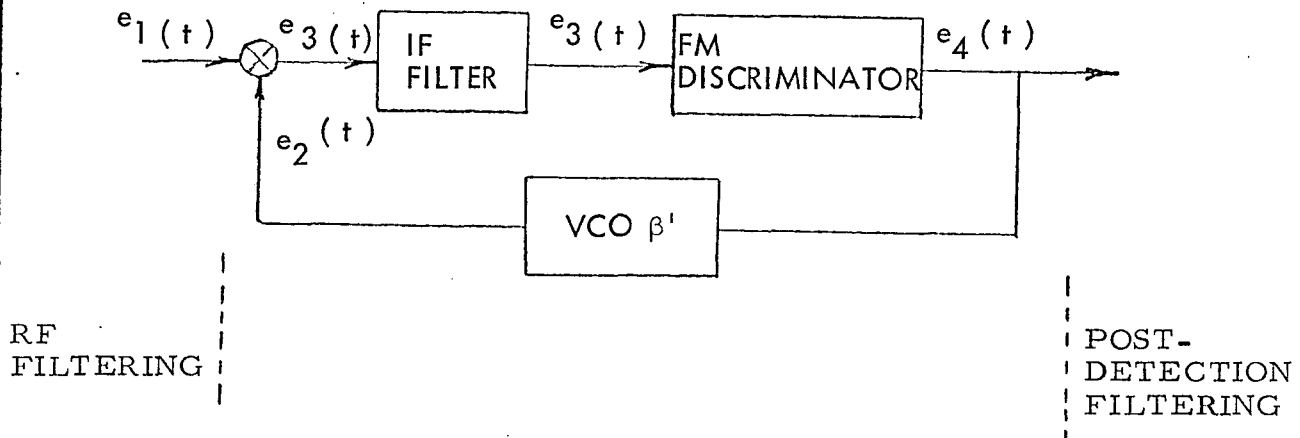
FC - Carrier Frequency

DV - FM Discriminator Constant (Volts/Hz)

DF - VCO Deviation (e.g., Hz/Volts)

NOTE: N1 is the output of an RF filter and N2 is the input to a low pass filter.

DETAILED DESCRIPTION



Let

$$e_1(t) = A(t) \cos (\omega_c t + \phi_i(t))$$

and

$$e_2(t) = -B \sin (\omega_{VCO} t + \theta(t))$$

where

$$\phi_i(t) = \beta \int S(t)$$

$$\theta(t) = \beta' \int e_4(t)$$

and

$$e_3'(t) = \frac{A(t)B}{2} \left\{ \begin{aligned} &\sin [\omega_{IF} t + \phi_i(t) - \theta(t)] \\ &-\sin [(\omega_{IF} + \omega_c) t + \phi(t) + \theta(t)] \end{aligned} \right\}$$



MODEL	GROUP ID	PAGE	DATE
FREQUENCY DEMODULATOR WITH FEEDBACK	Demod.	3	April, 1972

assuming the IF filter passes only the first term

$$e_3'(t) = \frac{A(t)B}{2} \sin(\omega_{IF}t + \phi_i(t) - \theta(t))$$

the output of the FM discriminator is ideally

$$e_4(t) = \frac{d}{dt} [\phi_i(t) - \theta(t)] DV = DV [\beta S(t) - \beta' e_4(t)]$$

$$e_4(t) = DV \frac{\beta}{1 + \beta'} S(t)$$

APPLICATION

The FMFB demodulator utilizes a tracking principle to achieve good SNR performance.



MODEL	GROUP ID	PAGE	DATE
FILTER	Filter	1	April, 1972
LIBRARY MODEL NAMES			
FILTER			

DESCRIPTION

The modeling of filters, or continuous functions relies on several computer routines previously developed by SAI which perform the various functions described in Appendices A and C. For ease in their use, an interface routine is written called FILTER, with several entry points as is explained below.

When utilizing any Filter model in a simulation of an RF link, translation of the filter to the baseband region is necessary for efficient simulation. The translation parameters are reflected in the reference to the Filter model.

DETAILED DESCRIPTION

The detailed description for generating the various filter functions in the s domain is described in Appendix A. Once the function of s is known, the bilinear z transform is derived. In order to reduce round-off errors, the function is represented by second degree sections, or quadratic factors. The bilinear z-transform converts a factor of s to a factor of the same degree in z, that is:

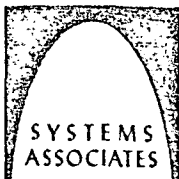
$$\frac{O(s)}{I(s)} = \frac{a_2 s^2 + a_1 s + a_0}{b_2 s^2 + b_1 s + b_0} \left| \frac{F_2 z^{-2} + F_1 z^{-1} + F_0}{D_2 z^{-2} + D_1 z^{-1} + D_0} \right| = \frac{O(z)}{I(z)}$$

NOTE: D_0 is normalized to entry

z^{-1} is a unit delay

The difference equation for one of the quadratic factors will then be:

$$O(t) = F_2 I(t - 2DT) + F_1 I(t - DT) + F_0 I(t) \\ - D_2 O(t - 2DT) - D_1 O(t - DT)$$



MODEL	GROUP ID	PAGE	DATE
FILTER	Filter	2	April, 1972

where: DT is the sampling time.

If the filter is not being translated, the quadratic factors are cascaded. However, when translating the filter (described in Appendix A), both real and imaginary coefficients of s result and the function is represented by parallel quadratic factors. The representation of the function as a sum of terms rather than a product eliminates the necessity of computing the roots of a polynomial in determining $K_r(s)$ and $K_i(s)$, (see Appendix A).

When using a translated filter, the run time can be reduced significantly in trade for exact representation of the filter. Reduction of approximately one-fourth is realized by using an equivalent low pass function; or one-half by assuming symmetry of the filter (i.e., $K_i(s) = 0$). This is accomplished when referencing one of the functions as described below.

USAGE

N1 <FILTER(NP,IF,IG,FX,BW,FC,AMP,AR,EM)> N2

All variables must be included whether they are applicable or not.

where: NP = filter order
IG = filter geometry
= 1 for Low Pass
= 2 for High Pass
= 3 for Band Pass
= 4 for Band Stop
AR = amplitude ripple (dB)
EM = M-factor for Butterworth-Thomson or stop-band ratio (>0) or modulator angle (<0) for Elliptic functions
FX = arithmetic center frequency
BW = bandwidth
FC = translation frequency (i.e., translate such that FC becomes zero)
AMP = voltage gain at FX



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
FILTER	Filter	3	April, 1972

IF = filter function
= 1 for Butterworth
= 2 for Chebyshev
= 3 for Bessel
= 4 for Butterworth-Thomson
= 5 for Elliptic

Alternate references to filters are as follows:

BUTTERWORTH (NP, IG, FX, BW, FC, AMP)

CHEBYSHEV (NP, IG, FX, BW, FC, AMP, AR)

BESSEL (NP, IG, FX, BW, FC, AMP)

BUTTERWORTH THOMSON (NP, IG, FX, BW, FC, -
AMP, EM)

ELLIPTIC (NP, IG, FX, BW, FC, AMP, AR, EM)

Special Cases:

a) A model is available to characterize a filter from frequency response data (see GENERAL FILTER).

b) QFACTOR (AMP, A1, A2, A3, A4, A5, A6)

used to describe:

$$\text{AMP} * \frac{A1s^2 + A2s + A3}{A4s^2 + A5s + A6}$$

c) LEADLAG (AMP, F1, F2, F3, F4)

used to describe:

$$\text{AMP} * \frac{\left(\frac{s}{2F1} + 1\right)\left(\frac{s}{2F2} + 1\right)}{\left(\frac{s}{2F3} + 1\right)\left(\frac{s}{2F4} + 1\right)}$$



MODEL	GROUP ID	PAGE	DATE
FILTER	Filter	4	April, 1972

if:

F2 = 0 then one zero is eliminated

F1 = 0 then both zeros are eliminated

F4 = 0 then one pole is eliminated

F3 = 0 then both poles are eliminated

d) LEAD FUNCTION (AMP, F1, F2, F3)

used to describe:

$$\text{AMP} * \frac{\left(\frac{s}{2 F1} + 1\right) \left(\frac{s}{2 F2} + 1\right)}{\left(s \frac{s}{2 F3} + 1\right)}$$

and is otherwise the same as the LEADLAG function.

APPLICATIONS AND RESTRICTIONS

When utilizing the above function, any time FC > 0, an RF filter is referenced (i. e., complex inputs and outputs) rather than a baseband filter (i. e., real inputs and outputs). The following table describes the conditions set up by FC and FX.

FC	FX	IG	Result
0	-	-	Baseband filter simulation
>0	>0	3	RF translated filter
>0	<0	3	Symmetric translated filter (Q = ∞)
>0	0	7	Equivalent low pass function



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
BUTTERWORTH FILTER	Filter	1	April, 1972

LIBRARY MODEL NAMES

BUTTERWORTH
BUTWTH
BUFUNCTION

DESCRIPTION

For a description of Butterworth filters, see Appendix C, Section C.2.2.

USAGE

N1 < BUTTERWORTH(NP, IG, FX, BW, FC, AMP) > N2

NP = filter order

IG = filter geometry

= 1 for Low Pass

= 2 for High Pass

= 3 for Band Pass

= 4 for Band Stop

FX = arithmetic center frequency

BW = bandwidth

FC = translation frequency (i.e., translate such that FC becomes zero)

AMP = voltage gain at FX

APPLICATION

For applications and restrictions in using this model, see the discussion on the model FILTER.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
CHEBYSHEV FILTER	Filter	1	April, 1972
LIBRARY MODEL NAMES			
CHEBYSHEV CHEBY TCHEBYCHEFF			

DESCRIPTION

For a description of Chebyshev filters, see Appendix C, Section C.2.3.

USAGE

N1 <CHEBYSHEV(NP,IG,FX,BW,FC,AMP,AR) > N2

where: NP = filter order

IG = filter geometry

= 1 for Low Pass

= 2 for High Pass

= 3 for Band Pass

= 4 for Band Stop

AR = amplitude ripple (dB)

FX = arithmetic center frequency

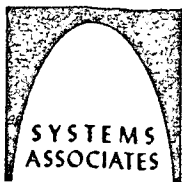
BW = bandwidth

FC = translation frequency (i.e., translate such that FC becomes zero)

AMP = voltage gain at FX

APPLICATION

For applications and restrictions in using this model, see the discussion on the model FILTER.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
BESSEL FILTER	Filter	1	April, 1972

LIBRARY MODEL NAMES

BESSEL
BE FUNCTION

DESCRIPTION

For a description of Bessel filters, see Appendix C, Section C.2.4.

USAGE

N1 <BESSEL(NP,IG,FX,BW,FC,AMP)> N2

NP = filter order

IG = filter geometry

= 1 for Low Pass

= 2 for High Pass

= 3 for Band Pass

= 4 for Band Stop

FX = arithmetic center frequency

BW = bandwidth

FC = translation frequency (i.e., translate such that FC becomes zero)

AMP = voltage gain at FX

APPLICATION

For applications and restrictions in using this model, see the discussion on the model FILTER.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
BUTTERWORTH THOMSON FILTER	Filter	1	April, 1972

LIBRARY MODEL NAMES

BUTTERWORTH THOMSON
BT FUNCTION
BUTOM

DESCRIPTION

For a description of Butterworth Thomson filters, see
Appendix C, Section C.2.5.

USAGE

N1<BUTTERWORTH THOMSON(NP,IG,FX,BW,FC,AMP,EM)>N2

NP = filter order

IG = filter geometry

= 1 for Low Pass

= 2 for High Pass

= 3 for Band Pass

= 4 for Band Stop

FX = arithmetic center frequency

BW = bandwidth

FC = translation frequency (i.e., translate such
that FC becomes zero)

AMP = voltage gain at FX

EM = M-factor

APPLICATION

For applications and restrictions in using this model,
see the discussion on the model FILTER.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
ELLIPTIC FUNCTION FILTER	Filter	1	April, 1972
LIBRARY MODEL NAMES			
ELLIPTIC ELIPTC EL FUNCTION			

DESCRIPTION

For a description of Elliptic Function Filters, see Appendix C, Section C.2.6.

USAGE

N1 < ELLIPTIC(NP, IG, FX, BW, FC, AMP, AR, EM) > N2

where: NP = filter order

IG = filter geometry

= 1 for Low Pass

= 2 for High Pass

= 3 for Band Pass

= 4 for Band Stop

FX = arithmetic center frequency

BW = bandwidth

FC = translation frequency (i.e., translate such that FC becomes zero)

AMP = voltage gain at FX

AR = amplitude ripple (dB)

EM = stop-band ratio if positive modular angle if negative

APPLICATION

For applications and restrictions in using this model, see the discussion on the model FILTER.



MODEL	GROUP ID	PAGE	DATE
GENERAL FILTER	Filter	1	April, 1972
LIBRARY MODEL NAMES			
GENERAL FILTER GENRAL			

DESCRIPTION

The General Filter model determines an arbitrary element transfer function by the complex curve fitting method. The procedure is entirely analogous to familiar curve fitting techniques except that the quantities involved are complex numbers. It requires an assumption on the part of the user as to the number of poles and zeros which characterize the transfer function of the element in question. From an appropriate number of representative amplitude and phase response samples over the frequency range of interest, the values of these complex poles and zeros which characterize the element transfer function may then be determined.

DETAILED DESCRIPTION

(See also Appendix C)

A generalized element transfer function $H(s)$ is customarily written in the form:

$$H(s) = \frac{A \prod_{i=1}^{NZ} (s - Z_i)}{\prod_{i=1}^{NP} (s - P_i)} \quad (1)$$

where: $s = j\omega$, complex frequency

$P_i =$ complex pole ($s + j\omega_i$)

$Z_i =$ complex zero ($s + j\omega_i$)

$NP =$ number of poles (also filter order)

$NZ =$ number of zeros

$A =$ multiplicative real constant

The poles and zeros are always either complex conjugate pairs or single real values.



MODEL	GROUP ID	PAGE	DATE
GENERAL FILTER	Filter	2	April, 1972

For each response sample at frequency ω_k the poles and zeros are related to the empirically determined amplitude and phase through

$$\frac{A \prod_{i=1}^{NZ} (j\omega_k - Z_i)}{\prod_{i=1}^{NP} (j\omega_k - P_i)} = \alpha_k + j\beta_k \quad (2)$$

where

$$\text{Magnitude response} = \sqrt{\alpha^2 + \beta^2}$$

$$\text{Phase response} = \tan^{-1} \beta/\alpha$$

Hence, for each response sample point, the right side of Equation (2) is determined and the left side is a complex expression in the P_i 's and Z_i 's. If the form of $H(s)$ is assumed by specifying the number of poles and zeros, the P_i 's, Z_i 's, and A are determined by the set of $NP+NZ+1$ such complex equations which result from the substitution of corresponding phase and amplitude response samples at a like number of frequencies. The actual solution of this system of complex linear equations is effected by standard library subroutines.

USAGE

N1 <GENRAL(NP,NZ,IDB,FC,IG,BW,AMP)> N2

where: NP = assumed number of poles

NZ = assumed number of zeros

IDB = 1 if response amplitude data is to be in dB

= 0 if response amplitude data is normalized to 1.0

FC = translation frequency (i.e., translate such that FC becomes zero)



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
GENERAL FILTER	Filter	3	April, 1972

IG = filter geometry
= 1 for Low Pass
= 2 for High Pass
= 3 for Band Pass
= 4 for Band Stop

BW = bandwidth

AMP = voltage gain (ratio) midway between the upper
and lower cutoff frequencies

INPUT

The number of frequency response data points should equal
 $NP + NZ + 1$.

Input frequency response data is read in through the subroutine
POLZER, one card per response data point, in the order:
Frequency (Hz), Amplitude (dB or relative magnitude), Phase
(degrees). The input data format is (1PE15.4, OP2F15.4).
An input data set for a general 3rd order filter with two zeros
($NP + NZ + 1 = 6$) is as follows:

FREQUENCY	AMPLITUDE	PHASE
1.4320-05	.0000	-10.3210
4.7750-05	-.0030	-34.9240
1.0980-04	-.4420	-87.3390
1.6710-04	-3.6820	-141.9130
2.8970-04	-15.7100	157.0050
3.3740-04	-19.6160	146.5060



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
QUADRATIC FACTOR	Filter	1	April, 1972

LIBRARY MODEL NAMES

QFACT
QFACTOR
QUADRATIC FACTOR

DESCRIPTION

This model is used to describe the transfer function:

$$H(s) = \text{AMP} * \frac{A1s^2 + A2s + A3}{A4s^2 + A5s + A6}$$

(see Appendix C, Section C.1)

USAGE

N1 <QFACTOR(AMP, A1, A2, A3, A4, A5, A6)> N2

where: AMP = amplification constant

A1-A6 = constants specifying the transfer function



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
LEAD LAG	Filter	1	April, 1972
LIBRARY MODEL NAMES			
LEAD LAG LOOP FILTER			

DESCRIPTION

This model is used to describe the transfer function:

$$H(s) = \text{AMP} * \frac{\left(\frac{s}{2 F1} + 1\right)\left(\frac{s}{2 F2} + 1\right)}{\left(\frac{s}{2 F3} + 1\right)\left(\frac{s}{2 F4} + 1\right)}$$

(see Appendix C, Section C.1)

USAGE

N1 <LEADLAG(AMP, F1, F2, F3, F4)> N2

where: AMP = amplification constant

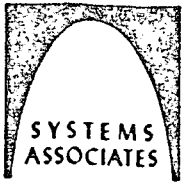
F1-F4 = constants specifying the transfer function, and if:

F2 = 0 then one zero is eliminated

F1 = 0 then both zeros are eliminated

F4 = 0 then one pole is eliminated

F3 = 0 then both poles are eliminated



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
LEAD FUNCTION	Filter	1	April, 1972
LIBRARY MODEL NAMES			
LEAD FUNCTION			

DESCRIPTION

This model is used to describe the transfer function

$$H(s) = \text{AMP} * \frac{\left(\frac{s}{2 F1} + 1\right) \left(\frac{s}{2 F2} + 1\right)}{\left(s \frac{s}{2 F3} + 1\right)}$$

(see Appendix C, Section C.1)

USAGE

N1 <LEAD FUNCTION(AMP, F1, F2, F3)> N2

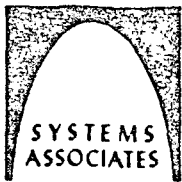
where: AMP = amplification constant

F1-F3 = constants specifying the transfer function,
and if:

F2 = 0 then one zero is eliminated

F1 = 0 then both zeros are eliminated

F3 = 0 the pole is eliminated



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
MATCHED FILTER	Filter	1	April, 1972
LIBRARY MODEL NAMES			
MATCHED FILTER MFLTER			

DESCRIPTION

The Matched Filter model is a simple integrate and dump routine clocked to the Bit Time.

USAGE

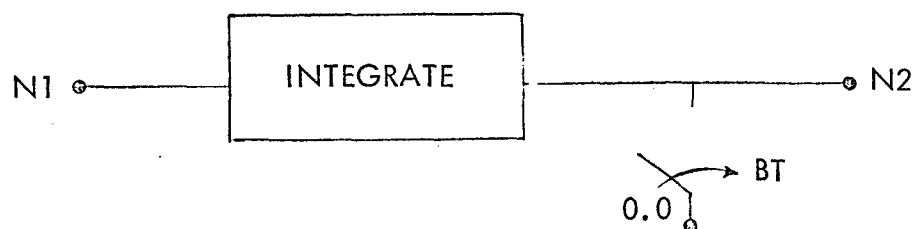
N1 <MFLTER(BT)> N2

where: BT = bit time

OUTPUT

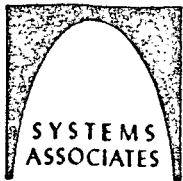
The output at N2 is the trapezoidal approximation of the integral of the signal at N1. Every BT, this integral is reset to zero.

BLOCK DIAGRAM



RESTRICTIONS

The integrate-Dump process is asynchronous and starts at time equal to zero, requiring the user's discretion in its use.



ASYSTD LIBRARY

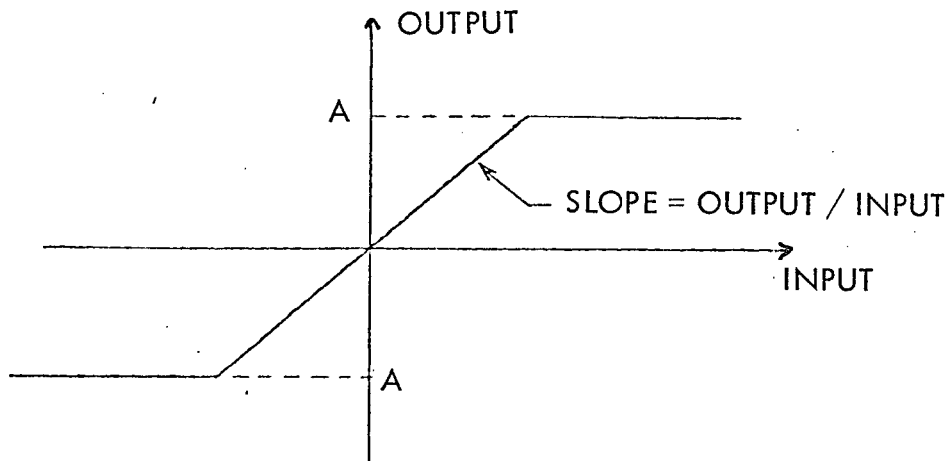
MODEL	GROUP ID	PAGE	DATE
SOFT LIMITER	Limiter	1	April, 1972
LIBRARY MODEL NAMES			
SOFT LIMITER SOFTY			

USAGE

N1 <SOFTY(A,SLOPE)> N2

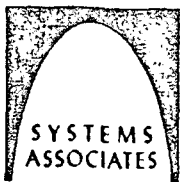
where: A = maximum amplitude of output
SLOPE = slope of transition limit

OUTPUT



APPLICATION

This element is for use in baseband modeling.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
HARD LIMITER	Limiter	1	April, 1972

LIBRARY MODEL NAMES

HARD LIMITER
HARD

USAGE

N1 <HARD> N2

OUTPUT

The absolute value of the output at N2 is 1. The sign of the output is the same as the input at N1.

APPLICATION

This element is for use in baseband modeling.



MODEL	GROUP ID	PAGE	DATE
RF SOFT LIMITER	Limiter	1	April, 1972
LIBRARY MODEL NAMES			
RF SOFT LIMITER RFSOFT			

USAGE

N1 <RFSOFT(A,SLOPE)> N2

where: A = maximum amplitude of output
SLOPE = slope of transition limit

OUTPUT

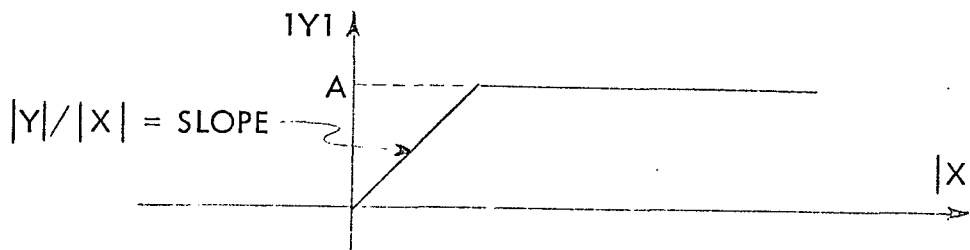
Let $X = X_r + jX_i$ be the complex signal at N1
and Let $Y = Y_r + jY_i$ be the complex signal at N2

$$|X| = (X_r^2 + X_i^2)^{1/2} = \text{magnitude of } X$$

$$\phi(X) = \tan^{-1} (X_i/X_r) = \text{phase of } X$$

Then the output at N2 is such that:

- 1) $\phi(Y) = \phi(X)$
- 2) $|Y| = F(|X|)$ as described by the graph below:



APPLICATION

This element is for modeling in the RF region.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
RF HARD LIMITER	Limiter	1	April, 1972
LIBRARY MODEL NAMES			
RF LIMITER RFLIMIT			

USAGE

N1 <RF LIMITER> N2

OUTPUT

Assume the input at N1 is described by:

$$X = X_r + jX_i = [X_r^2 + X_i^2]^{1/2} e^{j \tan^{-1} (X_i/X_r)}$$

then the output at N2 is:

$$Y = Y_r + jY_i = C e^{j \tan^{-1} (Y_i/Y_r)}$$

where:

$$Y_r = \frac{CX_r}{[X_r^2 + X_i^2]^{1/2}}$$

$$Y_i = \frac{CX_i}{[X_r^2 + X_i^2]^{1/2}}$$

In this model $C = 1$.

In other words, the phase of the signal is maintained but the magnitude is set to 1.

APPLICATION

The element is for use in modeling in the RF region.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
FOURIER TRANSFORM	Transforms	1	April, 1972
LIBRARY MODEL NAMES			
FOURT FOURIER	IFOURT INVERSE FOURIER		

DESCRIPTION

This model samples an input signal and calculates the Discrete Fourier Transform of these samples. Its output is the coefficients of this transform. IFOURT performs the inverse transform, reconstructing the input signal to FOURS.

USAGE

N1 <FOURT(N, TW)> N2
or
N1 <IFOURT(N, TW)> N2

where: N = number of samples per transform

TW = time window per transform

NOTE: Although N can be any positive integer, the transform is much faster if all the prime factors of N are 2, 3 or 5.

NOTE: The actual time window used is the multiple of N*DT nearest TW.

OUTPUT

Each TW, this model takes N samples of the input at N1, and calculates the Discrete Fourier Transform (or the inverse of the transform). The output of the model during this TW is the N transformed values produced during the previous TW.

NOTE: The input and the output of this model are complex.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
FOURIER TRANSFORM	Transforms	2	April, 1972

REFERENCE

For a discussion of this transform, see COMSAT Laboratories, "Orthogonal Transform Feasibility Study, Final Report", Contract NAS9-11240, November 1971, Section 3.2.

APPLICATION

The models INTLEV and DELEAV have been provided to deal with the complex inputs and outputs of this model. During the first TW, FOURT outputs a sync pulse of all ones to lock in DELEAV and IFOURT, compensating for any delays in the system.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
HAAR TRANSFORM	Transforms	1	April, 1972
LIBRARY MODEL NAMES			
HAAR IHAAR INVERSE HAAR			

DESCRIPTION

This model samples a signal and outputs the HAAR Transform of these samples. (IHAAR-Inverse HAAR Transform - reconstructs the signal given the transformed values.)

USAGE

N1 <HAAR(N, LOG2N, TS)> N2

or N1 <IHAAR(N, LOG2N, TS)> N2 for the inverse

where: N = number of samples per transform
(N must be a power of 2)

LOG2N = log base 2 of N, $N = 2^{\text{LOG2N}}$

TS = time window per transform

NOTE: The actual time window used is the integer multiple of N*DT nearest TS.

OUTPUT

Each TS, this model takes N samples of its input, and takes the transform of these samples (or the inverse transform), producing N transformed values. The output of this model during this time window is the N transformed values calculated during the previous TS.

REFERENCE

For a discussion of HAAR functions and the HAAR Transform, see COMSAT Laboratories, "Orthogonal Transform Feasibility Study, Final Report", Contract NAS9-11240, November 1971, Section 3.4.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
HAAR TRANSFORM	Transforms	2	April, 1972

APPLICATION

The output of the HAAR Transform during the first TS is +1. IHAAR uses this string of ones as a sync pulse to lock on to the transformed coefficients.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
HADAMARD TRANSFORM	Transform	1	April, 1972
LIBRARY MODEL NAMES			
HDMRD HADAMARD	IHDMRD INVERSE HADAMARD		

DESCRIPTION

This model samples a signal and outputs the HADAMARD Transform of these samples. (IHDMRD-Inverse HADAMARD Transform-reconstructs the signal given the transformed values.)

USAGE

N1 <HDMRD(N, LOG2N, TS) > N2

or N1 <IHDMRD(N, LOG2N, TS) > N2 for the inverse

where: N = number of samples per transform
(N must be a power of 2)

LOG2N = log base 2 of N, $N = 2^{\text{LOG2N}}$

TS = time window per transform

NOTE: The actual time window used is the integer multiple of $N \cdot \text{DT}$ nearest TS.

OUTPUT

Each TS, this model takes N samples of its input, and calculates the transform (or the inverse transform) of these samples, producing N transformed values. The output during this time window is the N transformed values determined during the previous TS.

REFERENCE

For a discussion of this transform, see COMSAT Laboratories, "Orthogonal Transform Feasibility Study, Final Report", November 1971, Contract NAS9-11240, Section 3.3.

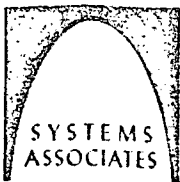


ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
HADAMARD TRANSFORM	Transform	2	April, 1972

APPLICATION

The output of the HDMRD Transform during the first TS is +1. IHDMRD uses this string of ones as a sync pulse to lock on to the transformed values.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
ORDERED HADAMARD TRANSFORM	Transforms	1	April, 1972
LIBRARY MODEL NAMES			
OHMRD ORDERED HADAMARD		IOHMRD INVERSE ORDERED HADAMARD	

DESCRIPTION

This model samples the input signal and outputs the Ordered Hadamard Transform of these samples. (IOHMRD - Inverse Ordered Hadamard Transform - reconstructs the signal given the transformed values.

USAGE

N1 < OHMRD(N, LOG2N, TS) > N2
or
N1 < IOHMRD(N, LOG2N, TS) > N2 for the inverse

where: N = number of samples per transform
(N must be a power of 2)

LOG2N = log base 2 of N, $N = 2^{\text{LOG2N}}$

TS = time window per transform

NOTE: The actual time window used is the integer multiple of $N \cdot \text{DT}$ nearest TS.

OUTPUT

Each TS, this model takes N samples of its input and calculates the transform (or the inverse transform) of these samples, producing N transformed values. The output during this time window is the N transformed values determined during the previous TS.

APPLICATION

The output of the OHMRD Transform during the first TS is +1. IOHMRD uses this string of ones as a sync pulse to lock on to the transformed values.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
ANALOG-TO-DIGITAL CONVERTER	Coders	1	April, 1972
LIBRARY MODEL NAMES			
ATOD			

DESCRIPTION

The A/D Converter model determines a bit sequence based upon the analog input level at sampling time. The output is a binary bit-stream (0 or +1). Flexibility is provided by inputting the number of bits per word, peak input level, minimum input level, and bit time.

USAGE

N1 <ATOD(NBIT, FLOOR, CEILING, BT)> N2

where: NBIT = number of digital bits per analog word
FLOOR = a lower bound of the analog input
CEILING = an upper bound of the analog input
BT = bit time (the actual bit time is the multiple of DT closest to BT)

DETAILED DESCRIPTION

ATOD represents an analog value with a string of NBIT binary bits (0 or +1). This string of bits may be considered a binary number, B, whose value is within the range 0 (all 0 bits) to $2^{NBIT}-1$ (all one bits). FLOOR is presented by the value 0, and CEILING is represented by the value 2^{NBIT} . Each word time (NBIT*BT), ATOD constructs this number B such that the expression

$$FLOOR + B * ((CEILING - FLOOR) / 2^{NBIT})$$

is as close to the analog input as the range and resolution allow.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
ANALOG-TO-DIGITAL CONVERTER	Coders	2	April, 1972

OUTPUT

Each BT, ATOD selects the next most significant bit of the digital word, to track the value of the analog input.

APPLICATION

ATOD may be used with either DTOA or SHDTOA as the decoder.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
DIGITAL-TO-ANALOG CONVERTER	Coders	1	April, 1972
LIBRARY MODEL NAMES			
DTOA			

DESCRIPTION

The D/A Converter determines an analog value from a binary bit stream (0 or +1) and the model parameters. This model assumes the output is continuous and attempts to produce output with as few abrupt changes as possible.

$N1 < DTOA(NBIT, FLOOR, CEILING, BT) > N2$

where: NBIT = number of digital bits per analog word
FLOOR = a lower bound of the analog output
CEILING = an upper bound of the analog output
BT = bit time (the actual bit time is the multiple of DT closest to BT)

NOTE: These parameters are related to the A/D Converter which coded the signal.

OUTPUT

Each bit time, DTOA examines the new bit of the digital word. If, by some combination of remaining bits, the current analog output value can be represented, then the output remains the same. Otherwise, the output is adjusted up or down until it is within range. For a description of the relationship between the input bit stream and the analog value, see Analog to Digital Converter.

APPLICATION

Since this model tries to maintain the analog output at a constant level, only changing it when it has to, this model is best for use where the analog signal is continuous.



MODEL	GROUP ID	PAGE	DATE
SAMPLE-HOLD DIGITAL-TO-ANALOG CONVERTER	Coders	1	April, 1972
LIBRARY MODEL NAMES			
SHD TOA			

DESCRIPTION

The Sample-hold DIA Converter determines an analog value from a binary bit stream and the model parameters. This model determines a value during one word time and outputs that value during the entire next word time.

USAGE

N1 < SHD TOA(NBIT, FLOOR, CEILING, BT) > N2

where: NBIT = number of digital bits per analog word
FLOOR = a lower bound of the analog output
CEILING = an upper bound of the analog output
BT = bit time (the actual bit time is the multiple of DT closest to BT)

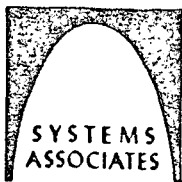
NOTE: These parameters are related to the A/D converter which coded the signal.

OUTPUT

Each digital word time (NBIT*BT), SHD TOA forms an analog value from the input and its parameters (for a description of the relationship between the input bit stream and the analog value, see Analog to Digital Converter). During this word time, its output is the analog value calculated during the previous word time.

APPLICATION

This model is for use when discrete values are being decoded, such as output from the orthogonal transform models.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
MULTI LEVEL PCM	Coders	1	April, 1972
LIBRARY MODEL NAMES			
MULTI LEVEL PCM MLTPCM			

DESCRIPTION

This code modulator produces an m-level signal based upon a serial input bit stream (polar or binary).

USAGE

$N1 <MLTPCM(BT, M) > N2$

where: BT = bit time

- M = number of levels (symbols)

N = $\text{LOG}_2 M$

The signal at the input mode (e. g., N1) is assumed to be a polar or binary bit stream.

OUTPUT

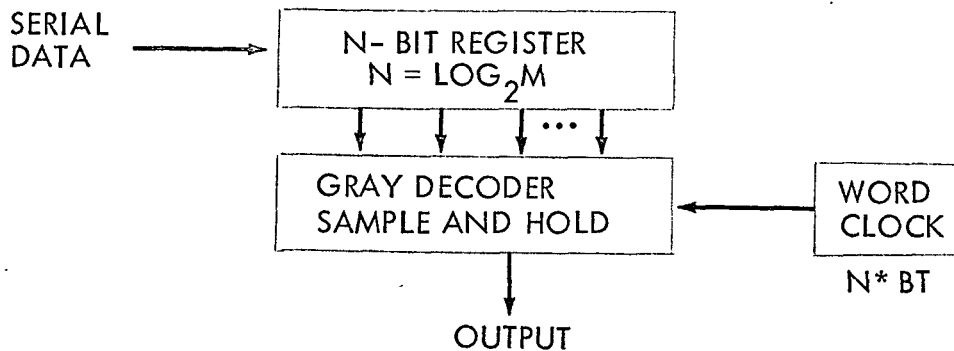
A serial-to-parallel conversion is made and a gray code level selection is used in generating an output bit stream at a rate of $N \cdot BT$. Output levels are normalized to a peak value of unity (+1), represented by equal levels separated by $1/(M-1)$. The minimum level (0) corresponds to the null symbol.

BLOCK DIAGRAM

Functionally, the model is represented as follows:



MODEL	GROUP ID	PAGE	DATE
MULTI LEVEL PCM	Coders	2	April, 1972



DETAILED DESCRIPTION (Example)

The serial bit stream is loaded into an N-bit register. At time intervals of $N*BT$, the register is sampled and the output waveform value (0 to +1) is determined from the reflected (gray) code in the register. The output is held at this level for $N*BT$, at which time the register is sampled for the next word. The following diagram depicts the time sequence for an arbitrary input bit stream. The parameters for this example are:

$M = 16$ (4 Bits)

$BT = 1$

Register History

	Time	Contents 1234	Output
	0	1---	0
	1	10--	0
	2	100-	0
	3	1001	0
	4	1---	14/15
	5	10--	14/15
	6	101-	14/15
	7	1011	14/15
	8	1---	13/15
	9	10--	13/15
	10	101-	13/15
	11	1010	13/15
	12	1---	12/15
	13	10--	12/15
	14	100-	12/15
	15	1001	14/15
	16	0---	14/15
	17	00--	14/15
	18	001-	14/15
	19	0011	14/15
	20		2/15



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
MULTI LEVEL PCM	Coders	3	April, 1972

APPLICATION

The multi-level coder may be used to drive the FM and PM modulators to produce m-ary PM carrier signals. Attention should be made to appropriate scaling of the MLTPCM output to produce the correct modulating signal magnitudes.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
COMPLEX ADDER	MATH	1	April, 1972

LIBRARY MODEL NAMES

COMPLEX ADDER
CADD

DESCRIPTION

The complex input to this model is added to a specified complex number passed through the argument list.

USAGE

N1 < CADD(XREAL, XIMAGE) > N2

where: XREAL = the real part of the addend
XIMAGE = the imaginary part of the addend

OUTPUT

The complex output at N2 is the complex sum of (XREAL + i*XIMAGE) and the input at N1.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
COMPLEX MULTIPLIER	MATH	1	April, 1972
LIBRARY MODEL NAMES			
COMPLEX MULTIPLIER CMULT			

DESCRIPTION

The complex input to this model is multiplied by a specified complex number passed through the argument list.

USAGE

N1 < CMULT(XREAL, XIMAGE) > N2

where: XREAL = the real part of the multiplier
XIMAGE = the imaginary part of the multiplier

OUTPUT

The complex output at N2 is the complex product of (XREAL + i*XIMAGE) times the input at N1.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
DIFFERENTIATOR	MATH	1	April, 1972
LIBRARY MODEL NAMES			
DIFFERENTIATOR DIFFER DIF			

DESCRIPTION

This model differentiates the input signal utilizing the bilinear z-transform of s.

USAGE

N1 < DIFFER > NZ

OUTPUT

Let the signal at N1 at time T be INP(T).
Let the signal at N2 at time T be OUT(T).

Then:

$$OUT(T) = \left[2*(INP(T)-INP(T-DT))/DT \right] - OUT(T-DT)$$

where $OUT(TSTART-DT) = 0$

With this scheme, the output may alternate wildly above and below the actual differential. The fluctuation is proportional to the derivative error at time = 0, since it is initialized to zero. If the output of the differentiator is fed into a filter, this fluctuation does not matter. This scheme has the advantage that if the output of the differentiator is fed into one of the system integrators, the input samples at N1 can be reconstructed exactly.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
INTEGRAL WITH INITIAL CONDITIONS	MATH	1	April, 1972

LIBRARY MODEL NAMES

INTEGRAL WITH INITIAL CONDITIONS
INTGIC

DESCRIPTION

This model provides for integration with initial conditions.

USAGE

N1 < INTGIC(FV) > N2

where: FV = initial value of the integral at TIME=TSTART

OUTPUT

This model integrates the input at N1 using the trapezoidal rule approximation. The output at N2 is this integral plus FV, the first value (initial value) of the integral.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
INTEGRATOR	MATH	1	April, 1972
LIBRARY MODEL NAMES			
INTEGRATOR INTGRT			

DESCRIPTION

This model integrates the input signal using the trapezoidal rule, which is the bilinear z-transform of $1/s$.

USAGE

N1 < INTGRT > NZ

OUTPUT

The output at N2 is the trapezoidal approximation of the input signal at N1.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
INTERLEAVER	MISC.	1	April, 1972
LIBRARY MODEL NAMES			
INTLEV INTERLEAVE			

DESCRIPTION

The Interleaver allows complex values to be carried over a single line. During the first half of one sample time, the output of this model is the real part of the input. During the remainder of the sample time, the output is the imaginary part of the input.

USAGE

N1 < INTLEV(N, TW) > N2

where: N = number of samples per TW
TW = Time Window

NOTE: This model is usually used in conjunction with a model such as the Fourier Transform, where N and TW would be identical to the parameters of the Fourier Transform.

OUTPUT

Each sample time (TW/N), INTLEV samples the complex input and stores the real and imaginary parts. It then outputs the real part of the input for (TW/N)/2 and the imaginary part for the remainder of the sample time.

APPLICATION

This model was designed to appear after the Fourier Transform, or other models with complex outputs. It converts a complex valued signal to a real signal for use by other models which can only deal with real signals. See also DE-INTERLEAVER.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
DE-INTERLEAVER	MISC.	1	April, 1972
LIBRARY MODEL NAMES			
DELEAV DEINTERLEAVE			

DESCRIPTION

The De-interleaver decoder real signals output by the Interleaver back into their complex form. It causes a phase delay of one sample time.

USAGE

$N1 \quad \langle \text{DELEAV}(N, TW) \rangle \quad N2$

where: N = number of samples per TW
 TW = time window

NOTE: These parameters should be the same as those in the Interleaver

OUTPUT

Each sample time (TW/N) this model samples the input for the real value. One half sample time later it gets the imaginary value from the input. The output of the model during this sample time is the complex value found in this way during the previous sample time.

APPLICATION

This model is used in conjunction with the Interleaver. Particularly to reconstruct complex values for input to the Inverse Fourier Transform. It is started by the sync pulse from the Fourier Transform.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
DELAY	MISC.	1	April, 1972
LIBRARY MODEL NAMES			
DELAY			

DESCRIPTION

This model introduces a specified time delay into a real signal.

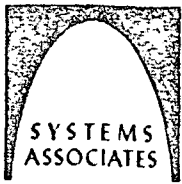
USAGE

N1 < DELAY(LAG) > N2

where LAG = an integer number of DT to delay the signal

OUTPUT

The output at N2 at time T equals the input at N1 at time $T - \text{LAG} * \text{DT}$.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
PHASE SHIFTER	MISC.	1	April, 1972

LIBRARY MODEL NAMES

PHASE SHIFTER
PHSHFT

DESCRIPTION

This model causes a phase shift (delay) of a specified number of degrees.

USAGE

N1 < PHSHT(DGREES, FC) > NZ

where DGREES = number of degrees to delay signal

FC = frequency of input signal



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
SPLIT	MISC.	1	April, 1972

LIBRARY MODEL NAMES
SPLIT

<u>DESCRIPTION</u> The input signal is split into its real and imaginary parts. <u>USAGE</u> N1 < SPLIT > N2 <u>OUTPUT</u> The real part of N2 is set to COS (N1). The imaginary part of N2 is set to SIN (N1).



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
ZERO CROSSING DETECTOR	MISC.	1	April, 1972

LIBRARY MODEL NAMES

ZERO CROSSING DETECTOR
ZRODET

DESCRIPTION

This model detects when the input signal becomes zero or crosses the zero reference.

USAGE.

N1 < ZRODET > NZ

OUTPUT

N2 is generally set to zero. If, during one simulation step (DT) the signal at N1 goes to zero or crosses zero, N2 is set to 1 for that DT only.



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
LIBRARY MODEL NAMES			



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
LIBRARY MODEL NAMES			



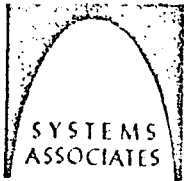
ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
LIBRARY MODEL NAMES			



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
LIBRARY MODEL NAMES			



ASYSTD LIBRARY

MODEL	GROUP ID	PAGE	DATE
LIBRARY MODEL NAMES			

APPENDIX C
DISTRIBUTION LIST

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