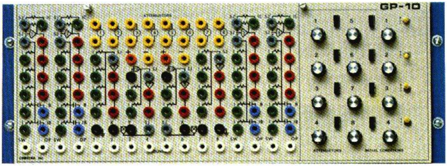
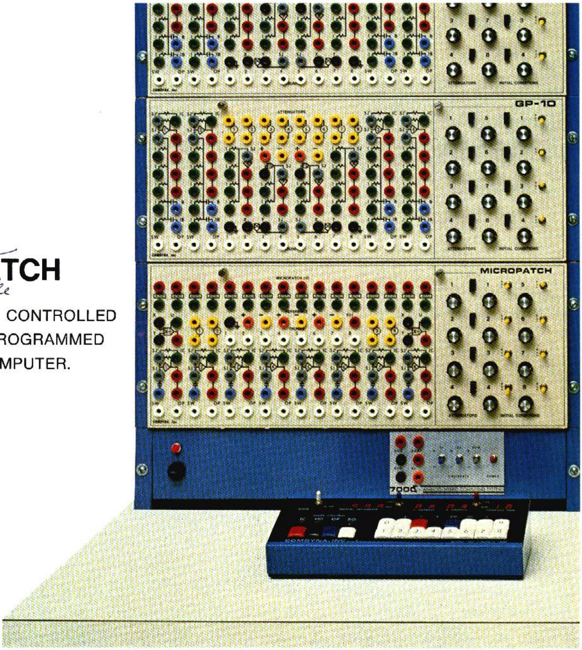


7000 BUILDING BLOCK ANALOG/HYBRID COMPUTING SYSTEMS



featuring

MICROPATCH

not available

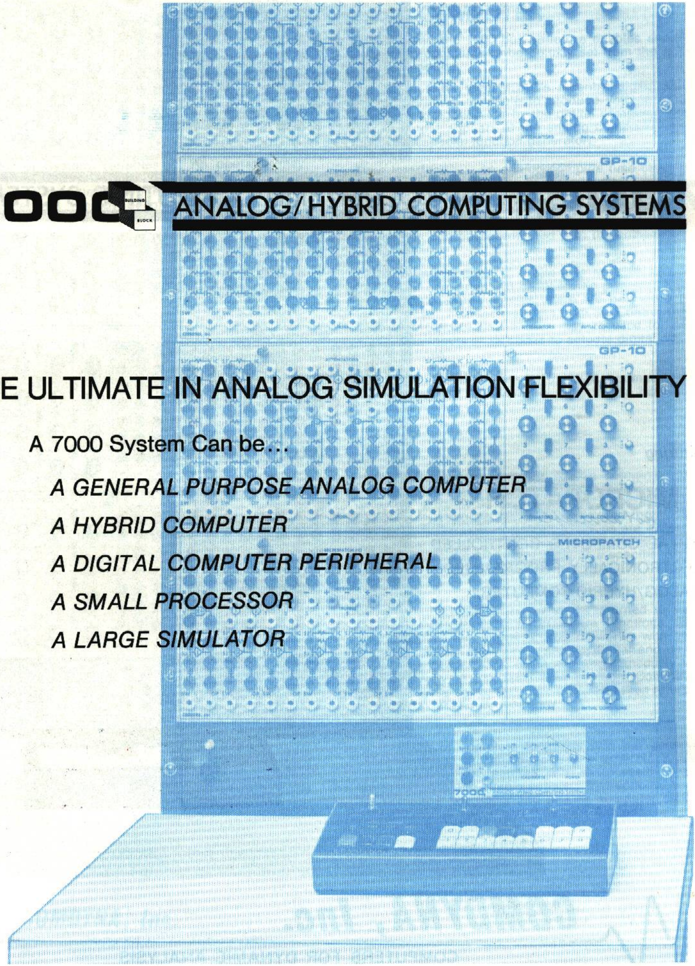
DIGITAL COMPUTER CONTROLLED ELECTRONICALLY PROGRAMMED ANALOG/HYBRID COMPUTER.

COMDYNA, Inc.

COMPUTERS FOR DYNAMIC ANALYSIS

7000 BUILDING BLOCK

ANALOG/HYBRID COMPUTING SYSTEMS



THE ULTIMATE IN ANALOG SIMULATION FLEXIBILITY

A 7000 System Can be…

A GENERAL PURPOSE ANALOG COMPUTER

A HYBRID COMPUTER

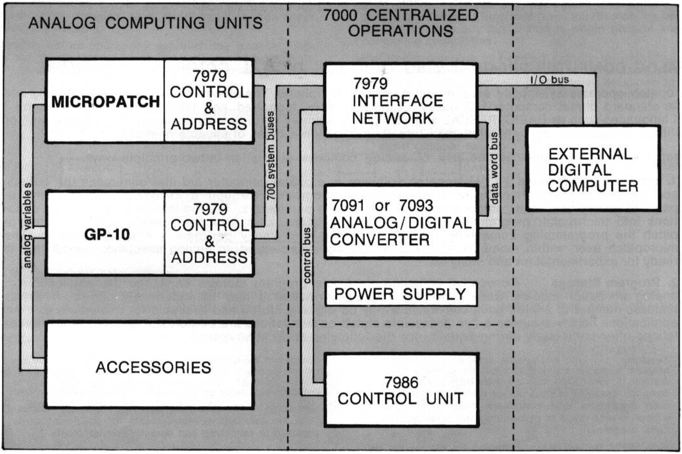
A DIGITAL COMPUTER PERIPHERAL

A SMALL PROCESSOR

A LARGE SIMULATOR

The 7000 Building Block Analog/Hybrid Computing Systems is an assemblage of analog computing units, accessories and interface networks that may be configured to meet small, medium or large simulation requirements.

A schematic of the 7000 organization is shown below...



Analog Computing Units . . . The electronically programmed Micropatch and the patch cord programmed GP-10 analog computing units plus a wide assortment of computing components offer a versatile choice of analog computer operations. Performance, capacity and operator conveniences are cost-benefit determinations as prospective users may custom select the best mix of computing units, computing accuracies and operating features. Following installation, a 7000 system may be expanded, contracted or upgraded by the addition, deletion or exchange of computing units and internal components.

Interface . . . An internal bus structure organizes into single operating systems the analog computing units, desk top control module, analog/digital and digital/analog converters and an external digital computer. The 7000 system features an all electronic amplifier address, electronic integrator mode control and time scaling, digital voltmeter or digital computer set of coefficient attenuators and a digital computer I/O port.

Operator Control and Monitor . . . A desk top control unit serves the 7000 system as a centralized base of operations. Operator features include a push button slow time and high speed repetitive operation mode control with LED indicators; a two axis electronic address with digital location displays; digital selection and display of the compute time period; a lamp indicator of amplifier overrange; a digital voltmeter for measurement of coefficient attenuator settings or amplifier outputs.

Analog/Digital & Digital/Analog Conversion . . . Within a 7000 system are analog to digital and digital to analog convertors that are interfaced to the host digital computer via a bi-directional data bus. All analog variables may be accessed for digital processing as the electronic address network is the ADC multiplexer. Multiplying digital to analog convertors, located within the analog computing units, provide analog computer processing of digital variables. In addition to the MDAC's, a central digital/analog converter is available to transmit digital computer generated functions.

External Digital Computer . . . A twenty four bit parallel data bus and ribbon cable connector terminations are easily used with standard digital computer input/output ports. Digital information is transfered as analog variables and as control states. A 7000 system may be operated by the host computer solely as a dedicated peripheral, or it may be operated as a hybrid computer where simulation control is shared with the desk top control module.

MICROPATCH

Micropatch, centerpiece of the new 7000 Building Block Analog/Hybrid Computing Systems, replaces mechanical panels and patch cords with a digital computer controlled electronic switch network. Once programmed, Micropatch operates identically to traditional patch panel computers. Through a host digital computer, simulations are programmed directly from differential equation statements. From digital computer memory, stored simulation programs are instantly recalled for immediate use.

ANALOG COMPUTER PROGRAMMING THROUGH DIGITAL COMPUTER SOFTWARE

Micropatch operates essentially as a digital computer peripheral. The electronic switch organization is adaptable to standard digital computer I/O buses. Coding is easily formatted and implemented with common high level languages such as BASIC, PASCAL and FORTRAN. Memory requirements are modest. Complex, high order, non-linear simulations are generated with less than a hundred bytes of usuable memory.

Micropatch software enhances the use of analog computer simulation in two principle ways.

1. Program Development . . . Micropatch software is a digital computer aid that eliminates the tedious scaling, patching and checkout of analog computer programs. Through a keyboard/CRT, the micropatch programmer directly enters equations and system parameters. The digital computer formats equations into micropatch programming codes, scales variables, computes coefficients, outputs to micropatch the programming commands, enters parameters and finally performs a checkout routine. The micropatch user, within moments after equation entry, is presented an analog simulation model that is ready for experimentation and analysis.

2. Program Storage . . . Convenient unlimited electronic program storage enhances the application of analog simulation models. Once a model is digitally formatted it may be indefinitely stored. A virtual limitless number of analog computer models may be digitally stored and available for immediate use. An applications library assumes a live accessible status as simulations are perpetually on-call. On-call simulations offer particularly strong benefits for the following application areas:

Teaching . . . One micropatch computing unit, through program recall, is a potential simulator of many physical systems. Student experiments benefit from powerful digital computer graphics and the unique realism of analog computer simulations. Simulations are instantly available to support a wide range of engineering and scientific educational programs.

Math Model Development . . . Analog models are derived with the help of hands-on operations and intuitive evaluations. Micropatch enables a proposed model to be quickly programmed, evaluated, easily modified, set aside and periodically recalled.

Simulation Aided Design . . . Stored programs may be recalled to assist component selections, search for parameters, conduct design concept validations and perform evaluations of a design's operation in untested applications.

Simulation for Test and Checkout . . . Micropatch simulations are inexpensive replacements for equipment parts, products or processes and operating environments.

Simulation for Operator Training . . . With methods similar to those used for teaching, electronic program storage converts a Micropatch analog/hybrid computing system into a general purpose operator training simulator.

ELECTRONIC PATCHING

To simulate a model of differential equations, micropatch applies both electronic switching and patch cord programming. Electronic switching programs a model's basic framework. Patch cord programming adds non-linearities and other subleties that are common to analog computer simulations.

Electronic switching is implemented through a set of micropatch attenuator-switch networks, each of which is coded with an eight bit programming word. The host digital computer formats a set of equations into a list of programming words. When individual networks are coded, a program is electronically patched.

At the digital computer, programming is initiated from differential equations that are expressed in a state variable form. To use the micropatch programming software, state variable equations are reduced to combinations of three principle ingredients . . . variables, first derivatives (with respect to time) of variables and attenuators. Equations are of the general form:

$$X(n) \text{ or } dX(n)/dt = \pm A(k1)*X(m1) \quad \pm A(k2)*X(m2) \ldots \quad \pm A(ki)*X(mi)$$

where:
n is a left hand side variable selector.

A ( )∗X ( ) is a right hand side term, and
m1, m2, . . mi are variable selectors,
k1, k2, . . ki are attenuator selectors.

For each equation, programmers assign a left hand variable selector. For each right hand side term, programmers designate the term's polarity and assign attenuator and variable selectors.

Software variable selectors are hardware summer-integrator amplifier locations. An assignment of the variable selector also assigns the amplifier that is to simulate the variable.

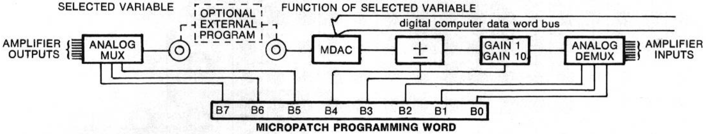
Attentuator selectors assign the micropatch attenuator-switch networks that operate with the summer-integrators. Micropatch attenuators are programmed much like simple, coefficient potentiometers but they are considerably more complex. They simulate complete equation right hand side terms. Essentially, the terms are created as transfer functions of right hand side variables. An attenuator transfer function may be as simple as a variable multiplied by a constant or as complex as a multi-amplifier, non-linear function of a variable.

Preliminary set-up operations establish the transfer functions that are performed by each attenuator network. Software attenuator selectors call specific transfer functions to be appropriate right hand side terms.

Equation terms are potentially any function that can be simulated with analog computer operational elements. An attenuator network inherently provides sign determination and the multiplication of a variable by a digitally set constant. Programmers may optionally add variable multiplication, division, diode function generation, diode simulated discontinuites, complete patch panel programs and even external devices and equipment. The unrestricted choice of attenuator functions gives micropatch the versatility to simulate any model that is within general analog computing capabilities.

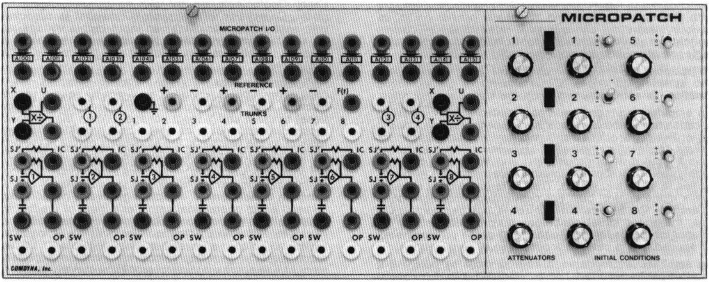
Electronic patching is handled entirely by individual attenuator-switch networks. Variable and attenuator transfer functions are electronically programmed as shown in the Micropatch Attenuator-Switch Network Schematic.

Micropatch attenuator-switch network schematic



GENERAL CAPABILITIES

A fully expanded micropatch computing unit handles up to eighth order linear or non-linear simulations. Programming is performed electronically based on a patched set-up of computing elements that are shown in the photograph and described below.



Summer-Integrators . . . Summer-integrator amplifiers simulate equation variables. Each equation requires the use of one amplifier. The amplifier's role as a summer or an integrator determines whether the equation is algebraic or differential.

Integrators have three mode electronic switch networks that are independently controlled with patch panel logic. Operation may be slow or high speed as determined by time scale logic. Initial conditions are entered by adjusting the manual potentiometers that are located to the right of the patching area.

Attenuator-Switch Network . . . As shown on the Micropatch Attenuator-Switch Network Schematic, the outputs and inputs of sixteen networks are terminated at the patch panel. To simulate linear terms, where a variable is multiplied by a digitally set constant, the output is simply patched to the input terminal. To simulate more complex terms, the output is patched to an external program of operational elements. The input is patched from the external program.

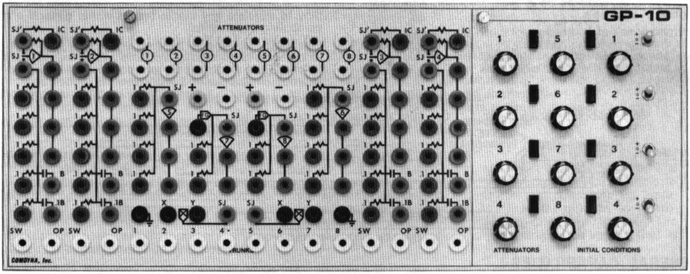
Manual Attenuators . . . Four coefficient potentiometers provide manually adjusted attenuation of variables. Equation terms may include knob adjustments by patching a manual attenuator as the attenuator-switch external function.

Multiplier/Dividers . . . Two multiplier networks may be arranged as multipliers, dividers, squarers or square root extractors of input variables. Two attenuator-switch networks are needed to electronically program a multiplier or divider. One output is patched to the "X" terminal; the other is patched to the "Y" terminal.

Other Functions . . . Inputs to and outputs from remote programs may be transported to the patch panel via eight trunk lines. Patch panel trunks are convenient terminations for attenuator transfer function inputs and outputs. One termination "f (t)"is reserved for time dependent forcing functions such as sine, saw tooth or square waves, digital computer generated functions or any input of the user's choosing.

GP-10 ANALOG COMPUTING UNIT

The GP-10 is a traditional, patch cord programmed analog computing unit. It has a capacity to simulate up to fourth order linear or non-linear models. For larger requirements, a number of GP-10 or other computing units of the 7000 series may be combined into single operating systems.



Summer-Integrators . . . Amplifiers 1 thru 4 may be used as summers, integrators, high gain operational amplifiers or as logic controlled, single pole, double throw electronic switches. Each has: a precision summing resistor network with patch panel gain 1 and 10 values; provisions for up to four integrating capacitors; a three mode electronic switch that is independently controlled with patch panel logic; an attenuator for entering initial conditions.

Logic applied to the SW switch control termination creates two summing junctions. Either the SJ or SJ' summing junctions is active depending on the switch control state.

An amplifier is programmed as an integrator by patching a capacitor as the feedback and applying switch control logic. The panel offers a choice of two feedback capacitor values. In slow time operation capacitors B and .1B and a gain 1 input resistor produce 1:1 and 10:1 time scales; in high speed operation an internal relay switches the time scales to 400:1 and 4000:1. The OP termination is the system's mode control bus. For centralized integrator mode operation, the SW switch control is patched to the OP bus. Integrator initial conditions may be entered by an attenuator that is located to the right of the patching area or applied with a patched input to the IC termination.

An amplifier is programmed as a summer by patching a resistor as the feedback. When there is no switch control patching, SJ is the active summing junction. In this condition, SJ and SJ' may be patched together so that the initial condition network provides the feedback resistor and the IC termination is one additional summing input.

An amplifier is programmed as an electronic function switch by patching the appropriate feedback element and switch control logic.

Summers . . . Amplifiers 5 thru 8 may be used as summers, inverters or for special functions that require high gain operational amplifiers. Each has a precision resistor network. Amplifiers 5 and 6 have patch panel gain 1 and gain 10 values; amplifiers 7 and 8 have gain 1 values. Amplifiers 7 and 8 also have provisions for function generator networks.

An amplifier is programmed as a summer or inverter by patching a resistor as the feedback.

Attenuators . . . Eight attenuators are located to the right of the patching area. Each is a grounded potentiometer that has its top end and wiper terminated at the patch panel. Coefficients are set with an external digital voltmeter. Depression of the push button that is associated with each attenuator places an input/output voltage ratio on a potentiometer readout bus. While the button is depressed, the attenuator is adjusted until the desired setting is observed.

Multipliers/Dividers . . . Two multiplier networks may be used as multipliers, dividers, squarers or square root extractors. Each network produces a current that is proportional to the X and Y input voltages. When the network is patched as an input to an operational amplifier that has a resistor as the feedback, the amplifier's output is the product of the input variables. When the network is patched as the amplifier's feedback, the amplifier output is the quotient of the two input variables.

Function Generators . . . Function generator networks may be used as an operational amplifier's input or feedback to create either arithmetic or empirical functions of input variables. Possible arithmetic networks include logarithm, squaring, cubing, sine and cosine generators. Variable diode function generators may be used for adjustable, straight line approximation of empirical curves.

Trunks . . . Eight uncommitted trunk terminations are available for transporting variables to and from the patch panel. The trunk terminations help organize patch panel interconnections with external devices and other computing units.

Reference . . . Reference is used as computer unity for entering constants and for scaling output variables. A precision positive and negative 10 volt reference is available as patch panel terminations.

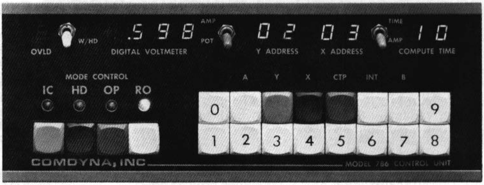
Accessories . . . An assortment of accessories, in the form of networks and devices, are offered to simplify programming and provide more realistic simulations. The accessories generate non-linearities and discontinuities, provide controller functions, simulate basic processes and generally expand the computing unit's capabilities.

REPLACEMENT OF MANUAL WITH DIGITAL ATTENUATORS

Multiplying digital/analog converters, set from a host digital computer, may either replace or be added in series with the manual coefficient potentiometers. The MDAC's attenuate analog variables by digital data words. Setting occurs from digital computer data that is transferred via the central interface and bus system.

CONTROL UNIT

Simulations are controlled and monitored with the 7986 Control Unit. A keyboard type panel and LED displays provide a desktop base of operations for all system analog computing units.



Mode Control . . . Logic control of analog computing unit and central time base integrators is produced from operation of the MODE CONTROL push buttons and LED state indicators. The four modes are described as follows:

IC . . . The initial condition mode is a manual reset of slow time operation integrators.

HD . . . Hold mode logic electronically disconnects the summing resistor networks from integrator inputs. Integrators hold their values until released either into the initial condition or operate modes.

OP . . . The operate mode is a manually actuated run state for slow time operation integrators.

RO . . . Repetitive operation is a high speed run state where integrator time constants are reduced by a factor of four hundred and modes are alternately switched from initial condition to operate. Integrators are held in the operate state for the duration of the compute time period. When observed on an oscilloscope, repetitive operation outputs appear as solid XY curves.

Keyboard Functions . . . Amplifier address selections and other numeric data inputs are entered via push buttons that are arranged in a sixteen position keyboard matrix.

Monitor of System Variables . . . A two axis electronic address places the outputs of any two analog computing unit amplifiers on the X and Y Readout Buses. An operator may choose to either simultaneously plot the X and Y selections as a function of time or Y as a function of X.

Y Address . . . An amplifier output is placed on the Y Readout Bus by first depressing the "Y" push button and then entering, in sequence, a two digit number that selects the computing unit and amplifier locations. The selected Y amplifier location apears as the Y ADDRESS numeric LED display.

X Address . . . Depression of the "X" push button followed by the computing unit and amplifier locations places a selected amplifier output on the X Readout Bus. The selected X amplifier location appears at the X ADDRESS display.

Compute Time Period . . . As indicated by the COMPUTE TIME display and measured in computer time units, the compute time period is the full scale X axis coordinate of XY oscilloscope and recorder time response curves. The X axis is generated by an internal time base integrator that sweeps from negative to positive reference where the duration of the sweep is the compute time period.

Compute time period settings have a range of 10 to 90 time units with increments of 10. To change a setting, first the "CTP" button is depressed and then the period's ten's digit is entered.

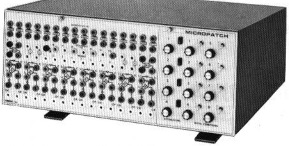
A toggle switch located to the left of the COMPUTE TIME display enables the oscilloscope or recorder's horizontal input to be either the time base or X Readout Bus. In the TIME position, Y vs. time response curves are produced; in the AMP position, Y vs. X curves occur.

Other Data Entries . . . The keyboard can also be used for communication with external digital devices. Facilities are available for parallel, hexidecimal data transmission through the 7976 Interface Network. The "INT", "A" and "B" buttons are for external use identification and have no significance for general 7000 operations.

Digital Voltmeter . . . Coefficient attenuator settings and measurements of amplifier outputs are performed by a digital voltmeter that features a 3½ place accuracy and autopolarity. Readings appear at the DIGITAL VOLTMETER display. To the right of the display is a toggle switch that connects the digital voltmeter input to either the system's potentiometer bus or the X Readout Bus.

Overload . . . The OVLD display is a state indicator of the system's overload bus. The bus is enabled by individual analog computing unit networks as an alarm to indicate when any of the system's amplifier outputs exceed an overrange amplitude. If the toggle switch to the display's right is in the W/HD position, an overrange amplitude will place the system into the Hold Mode. The hold feature allows an operator to determine the overranged amplifier location and the time at which the overrange occurred.

7000 Analog/Hybrid Computers are normally housed in an electronic enclosure. A desk top chassis is also offered for operation of single analog computing units.



OPERATION WITH AN EXTERNAL DIGITAL COMPUTER

A 7000 system is made into a hybrid computer by connecting an external digital computer to an interface I/O port. Three parallel, eight bit words, arranged in configurations that are compatible with integrated circuit peripheral devices, enable the digital computer to control 7000 operations and to handle digitized analog variables. Some standard hybrid computing functions are described below.

Monitor of System Variables . . . An operator may transfer address of the X Readout Bus from the Control Unit to the external digital computer. The X Address network thereby becomes an analog multiplexer for digital conversion of analog variables.

Analog/Digital Conversion . . . In addition to the multiplexer function, interface features allow the digital computer to start the analog/digital converter, sense the end of conversion and place digitized analog variables on a bi-directional data bus to be read by the digital computer.

Digital/Analog Conversion . . . Digital/analog conversion is applied to analog simulations by attenuation or voltage representation. The multiplying digital/analog converters that are located within individual analog computing units attenuate analog variables by digital data words. An extensive network of MDAC's and the 7000 bus structure enables analog simulation constants to be quickly set from the host digital computer.

In addition to the local MDAC's, a central digital/analog converter is available to produce voltage functions that are generated by the digital computer. The DAC's output appears at the analog computing unit panel as a special function generator.

Time Interface . . . An analog compute time clock is available for synchronization of digital computer programs with analog computer simulations. The clock pulses are discrete analog time units. By sensing the clock pulse train, analog/digital or digital/analog conversion can be coordinated with the simulation's time domain.

Operator Interaction . . . While it is anticipated that the digital computer will be operated primarily from its own data entry facilities, there are provisions to input parallel, hexidecimal data from the Control Unit keyboard. Control Unit entries may be used for numeric data inputs or as codes to actuate digital computer routines.

There are also provisions for the digital computer to sense integrator mode control logic and to issue bit state commands.

ANALOG TO DIGITAL CONVERSION

The conversion of analog variables to digital data is conditioned to meet specific user requirements. An internal printed circuit connector provides a facility for general analog/digital converter operations without a committment to a particular design. The type of converter (its linearity, resolution, speed, etc.) can be determined by user needs and future advancements in converter technology.

Conversions may be handled entirely by the internal 7000 system ADC, be shared by the internal and an external ADC or be handled entirely by a converter that is dedicated to the host digital processor. Standard converter assemblies are offered but custom units are practical if standard designs are not suitable. The modification of an existing design or implementation of a new one may add only a minor expense to the total system cost.

Internal and external ADC's may both utilize the X Address network as a system multiplexer. Digital computer address commands to individual analog computing unit multiplexers place selected amplifier outputs on the X Readout Bus. The X Readout Bus is the normal input to the internal ADC and is also available for external use.

When synchronized with the analog compute time clock, conversions may be time as well as space oriented. Complete time dependent functions are digitized by enabling the converter's start logic with the clock pulse train. Digitized functions are entered as strings of data words where each data word rerepresents a variable's amplitude at a specific point in time.

Strings of data words can also be returned to the analog simulator as time response functions. By synchronizing the digital/analog converter with the analog compute time clock, analog/digital and digital/analog conversions can occur simultaneously or independently at the same time position. Complete curves may be converted, processed and then returned as time dependent functions.

Conversion of complete functions and the general employment of the analog compute time clock are distinguishing 7000 features. With an accessible time unit reference and simple software instructions, digital computer programs and analog computer simulations may be space and time coordinated.

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COMPUTERS FOR DYNAMIC ANALYSIS

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