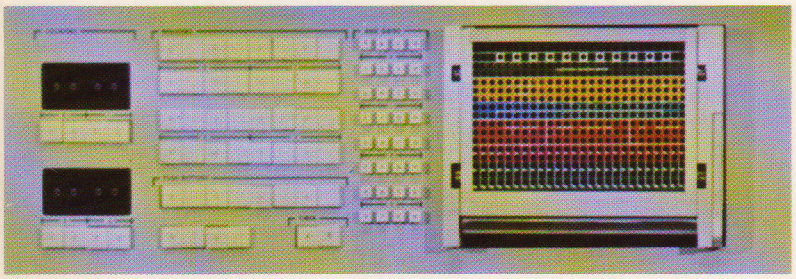
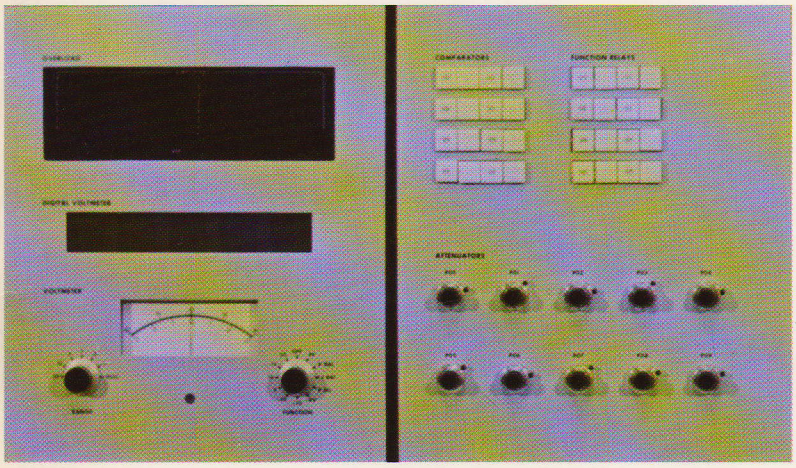
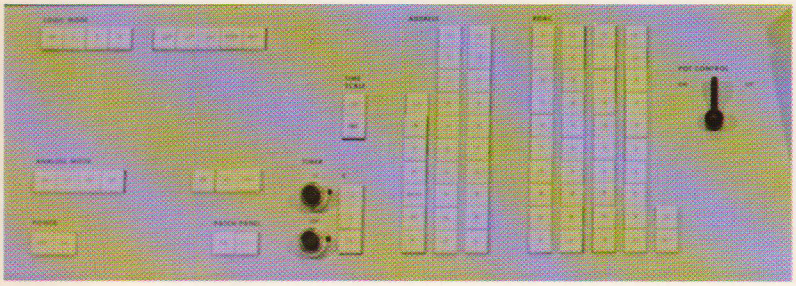
EAI®

ELECTRONIC ASSOCIATES, INC.

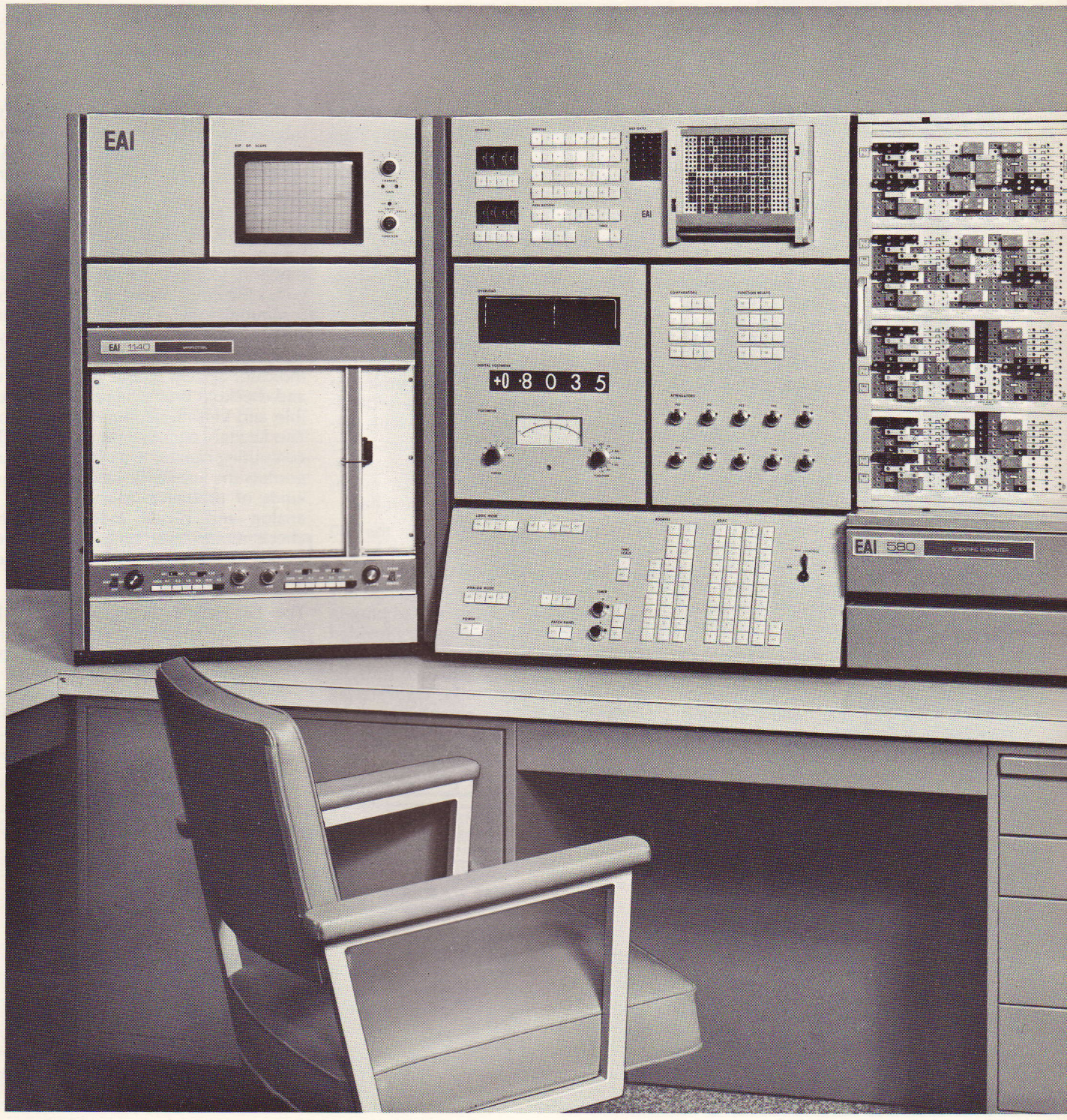
580 DESK-TOP ANALOG/HYBRID COMPUTING SYSTEM

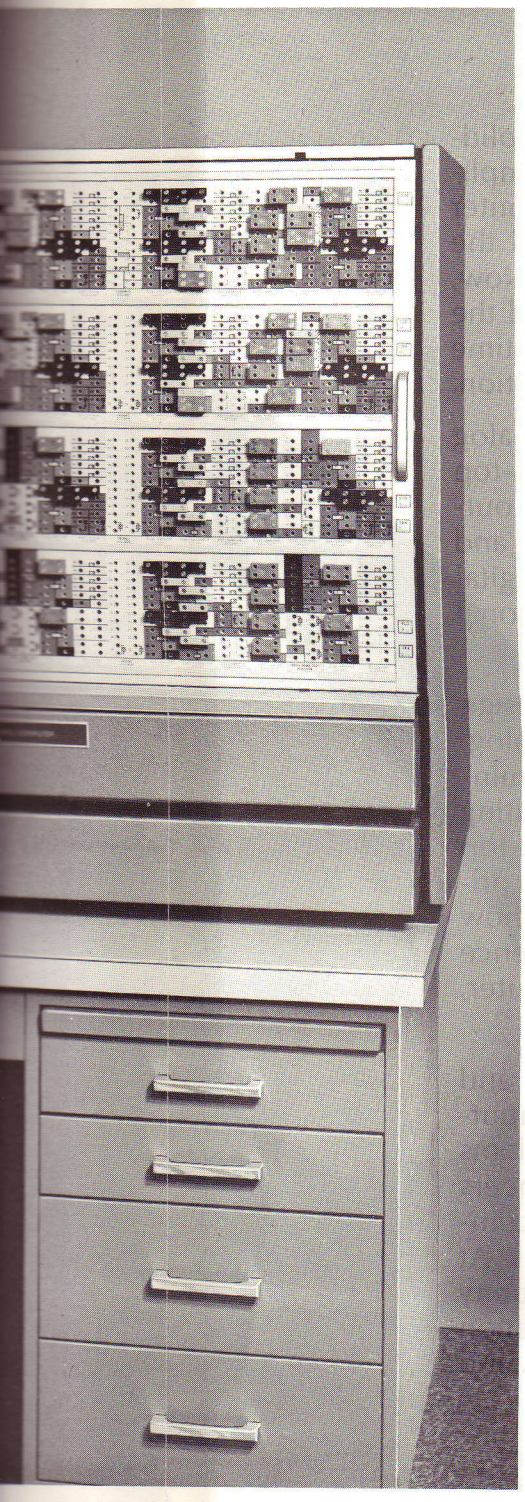






EAI 580 Analog/Hybrid Computing System Equipment





FEATURES

EAI 580 Analog/Hybrid System

- Includes many of the features previously obtainable only in large-scale analog/hybrid systems.
- Expandable from a basic analog computer to a full hybrid system.
- 10 Volt Reference offering the advantages of: excellent static and dynamic performance, compactness, low power consumption, and complete safety for the operator.
- Easy to understand and use by the beginner, yet includes advanced capabilities for the programmer to perform complex simulations.
- Accurate performance in slow time and compressed time computations up to and beyond 5000 solutions per second.
- Desk-top mounting makes it easy to locate and move.
- Mode slaving system for centralized control of multi-console simulations.

Computer Console

- Fully wired to accept all computing components and subsystem expansion.
- Analog computing components in compact, removable trays, located directly behind the analog program panel.
- Motor-driven analog program panel interlock system.
- Central overload system with automatic hold and storage features.
- Initial derivative readout aids for program checkout.
- Solid-state integrator mode control.
- Program control of integrator modes and time scale selection.
- Servoset potentiometer selection and setting system.
- Pot control features permitting alteration of servoset potentiometer coefficient settings in *any* computer mode.
- Separate analog and logic program panels.
- Easy-to-use variable function generator setup system.
- A system of clocked parallel logic components for control, timing, sequencing and program decision making—available for direct addition to the console.
- State indicators and pushbutton controls for comparators, function relays and logic elements provide greatly simplified program checkout and operation.

Computing Components

- Solid-state summing amplifiers offer no velocity limit within a 125 KHz bandwidth.
- Four time scale capacitors for each integrator are EAI manufactured polystyrene passive elements with extremely low leakage characteristics and low temperature coefficients, eliminating the need for temperature-controlled ovens.
- High-speed track/store networks provide a low drift analog storage capability, and can be program initialized.
- Ten segment variable slope *and* breakpoint diode function generator include associated amplifiers.
- Quarter-square multipliers can also become dividers, and selected units may be programmed as dual square, one square and one square root, or dual square root generators.
- Each electronic comparator contains its own solid-state amplifier.
- Excellent dynamic performance is illustrated by total error at one (0%: Amplifier (10k ohm/10k ohm)—0.25%, Multiplier—0.25%, and Variable Diode Function Generator —0.5%.
- Precision pushbutton divider allows pot coefficient settings from 0.0000 to 1.9999.
- 0.01%, 5-digit, high-speed digital voltmeter for readout.
- Essential communication maintained between analog and logic programs by digital-to-analog switches, analog comparators, function relays, and interpanel logic trunks.
- One MHz, crystal controlled central timing reference synchronizes logic operations.
- Normal *and* complementary outputs of *all* logic elements simplify the programming function.
- General purpose logic gates are programmable for any Boolean logic function.
- General purpose 4-bit registers offer alternate modes of operation: four individual set-reset flip-flops, shift register, binary up-counter, or binary down-counter.
- Counter/Timers may be used for counting events or providing time delay intervals from 1 microsecond to 9.9 seconds.
- All amplifiers and computer reference are short-circuit proof; all switching and logic circuits are fully protected from damage by any voltage on the program panels.

Peripheral Equipment

- Four channel repetitive operation display unit for console or desk-top mounting, allows high-speed presentation of program solutions.
- Display selector permits up to four variables to be displayed against time or up to four against a fifth variable from the computer program.
- A variety of solid-state, portable X-Y plotters available from EAI, offering 0.075% static accuracy and high slewing rates.
- Plotter pen lift control occurs automatically with computer mode selection, or can be under logic program control.
- Choice of solid-state multi-channel strip-chart recorders for display of program variables.
- Recorder chart drive automatically controlled from computer modes or under logic program control.

EAI 580 Analog/Hybrid Computing System

The EAI 580 Analog/Hybrid Computing System is a completely new solid-state ten volt, desk-top computer with a capacity of 80 computing amplifiers and eight comparator amplifiers. It is an advanced analog computer that is easy to understand and operate, in addition to providing all the capabilities needed for integration into a hybrid computing system. Now, for a minimum investment, you can obtain an EAI 580, then expand the system with additional analog and logic components, and at any time in the future, combine it with a digital computer for full hybrid operation.

The 580 was born out of the growing need for high performance analog computation, as well as the requirement for a hybrid oriented desk-top computer. It combines the low cost of a desk-top computer with the outstanding characteristics and sophistication of more costly medium and large scale analog/hybrid computers, and it offers the features a digital computer user needs so that he may take advantage of the additional capability afforded by both hybrid and modern analog computation.

EAI's Analysis and Computation Centers were instrumental in the design of the 580. Their extensive experience in practical problems using analog, digital and hybrid computing systems was a major influence in determining what the EAI 580 required to provide the most advanced computing capabilities and efficient man/machine interface available in a desk-top computer. A major study of user and customer needs was another primary contribution to the design concept. The user oriented know-how reflected in the design of the 580 is also a result of the same experience that led to EAI's development of the first all solid-state analog computer, and installation of over 2000 desk-top computing systems.

The EAI 580 is the ideal machine for use in government, industrial and educational facilities, providing the user with an analog/hybrid computing capability to analyze the myriad of increasingly complex problems occurring in virtually every scientific discipline. Scientists and engineers involved in the study of dynamic physical systems will find that the computer gives them the ability to solve an extensive variety of problems. At the same time, simplicity of operation offers the beginner the opportunity to become familiar with the superior performance and sophistication demanded by and essential to seasoned users of analog and hybrid computers.

EAI 580 Advanced Analog And Hybrid Features

The following features of the EAI 580 reflect the advanced analog and hybrid computing capabilities of the system.

• Mode selection, time scale selection and computing component control are accomplished by logic signals. All integrator trays in the computer can be controlled individually, or in groups from the analog mode control, digital logic program or by a digital computer. This important feature **permits the efficient use of iterative analog and hybrid techniques for the solution of boundary value problems and partial differential equations.**

• Electronic Mode Control (EMC) **allows higher problem solution speeds and more flexible control of integrators from logic devices** by incorporating solid-state switches in place of relays.

• Outstanding dynamic and static characteristics of the analog computing elements **permit high speed repetitive and iterative, as well as real time operation, with maximum accuracy.**

• The self-contained logic expansion of general purpose logic gates, flip-flop registers, counters and digitally controlled analog switches **allow decision making, event initiation, data reduction, timing and control to be accomplished directly in the EAI 580.** When operating with a digital computer the logic can be either **synchronized with an internal clock system or slaved to an external signal from the digital computer.**

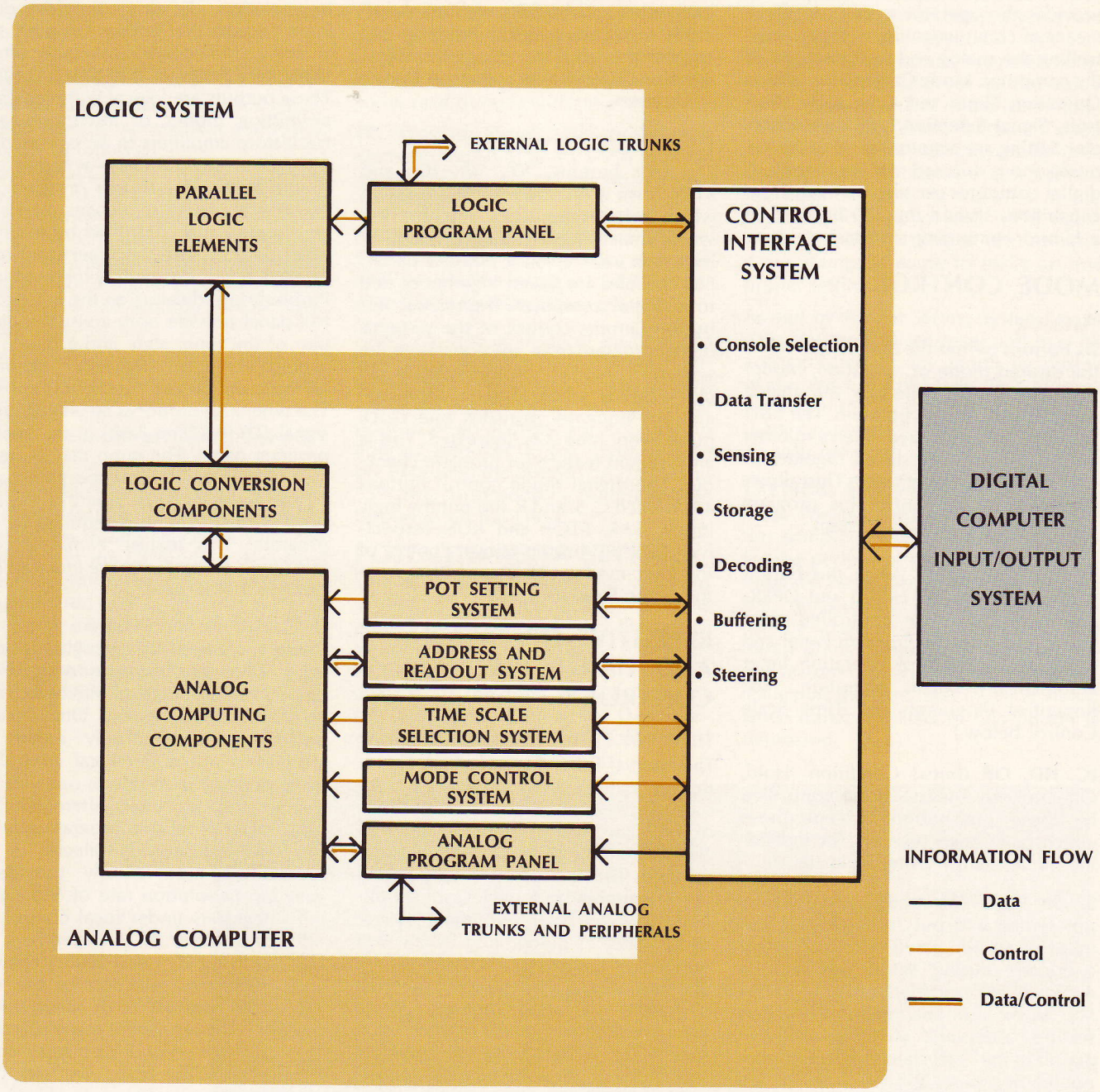
• The EAI 580 is the first desk-top analog computer with servo set potentiometers. Up to 70 servo pots can be read and setup using either the keyboard addressing system of the analog console or the digital computer. In pure analog problems they **allow faster potentiometer setup.** In hybrid problems these **automatically adjustable potentiometers may be set to coefficients calculated by the digital computer.** They may also be used directly to vary parameters during a simulation by means of a manual proportional controller.

• The computing capability of the 580 can be conveniently **expanded in the field without additional console wiring.** The computer console is completely pre-wired to accept a variety of plug-in components. Power supplies provided with the basic computer are **capable of operating a fully expanded console.** In addition, extensive trunking and slaving facilities **permit the combined operation of several 580's as one large system.**

• **The EAI 580 simplifies and insures full integration into a hybrid computing system** by providing for the direct addition of a built-in hybrid control interface.

The EAI 580 Analog/Hybrid Computing System contains many subsystems which function together furnishing the user with efficient, convenient and reliable computing capability. The Programming System, Addressing and Readout System, Pot-Setting System, and Overload Indicator System reduce problem setup and checkout time while providing flexible and versatile computer operation. The Digital Logic System augments the computing capability of the EAI 580 and permits the automatic solution of many kinds of problems. Master control of analog and digital modes, problem check modes and time scale modes, assure speed and flexibility in the operation of the entire system.

The EAI 580 is best appreciated by considering specific features—features which are the result of EAI's concern with present and future customer needs and extensive experience in the design, manufacture *and use* of analog, digital and hybrid computing systems.



EAI 580 ANALOG/HYBRID COMPUTING SYSTEM

EAI 580 Master Control Panel

In the EAI 580 the Master Control Panel provides the operator with an efficient means of communicating with and controlling the analog and logic sections of the computer. **Mode Control, Repetitive Operation Timer and Time Scale Controls, Signal Selection, and Potentiometer Setting** are accomplished using the pushbuttons located on the panel. A digital computer can also achieve these capabilities should the 580 be used in a hybrid computing system.

MODE CONTROL

Analog

Six buttons permit the operator to select the desired mode of operation. Modes may also be controlled by the analog timer or digital logic program. The RMT (Remote) button is used when a number of 580 consoles are slaved together or tied to a digital computer. This allows the operator to control his program from any console in the system.

PP (Program Panel). When this button is depressed the IC, HOLD and OPERATE modes may be controlled from logic signals on the Program Panel and the internal repetitive operation timer automatically begins operation. (See Repetitive Operation and Time Scale Control below.)

IC, HD, OP (Initial Condition, Hold, Operate). All integrators are controlled by these pushbuttons except those which have been selected for individual mode control using logic signals.

SP (Set Pots). This mode is used during pot setting and puts reference on the input of an addressed pot. To prevent overloads during setup *feedback is automatically provided for every amplifier.* As an additional operator oriented feature, electronic switches are also placed in the "on" state to insure proper pot loading.

ST (Static Test). This mode forces all integrators and track/stores into the IC mode regardless of local patching, and enables the operator to use the Signal Selector System to help him perform a static test.

Logic

The four buttons, 10^6, 10^5, 10^1, and STEP, form a mutually exclusive group which selects the clock rate for the synchronized logic elements. The RMT button is used when a number of EAI 580 consoles are slaved together or tied to a digital computer. Depressing this button permits control of the system's digital program from any console in the system. The STEP button inhibits all clock pulses when initially depressed and subsequently provides one clock pulse every time it is depressed. This is an excellent feature for problem checkout. The digital mode control buttons are marked C, S, and R and put the logic into CLEAR, STOP and RUN, respectively. The PP button allows control of the logic modes CLEAR and RUN from the Logic Program Panel.

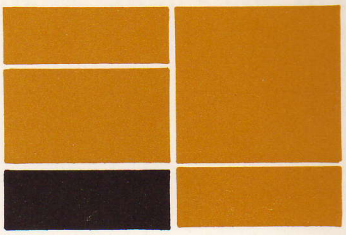
REPETITIVE OPERATION AND TIME SCALE CONTROL

Interval Timer Controls

The Interval Timer Controls, in conjunction with the Time Scale Selectors are used to program solutions or portions of solutions repetitively in the range of 100 microseconds to 100 seconds per solution. This is accomplished by cycling integrators and track/store amplifiers between their two main operational states as determined by the two intervals of the timer. Calibrated vernier dials are used to vary the basic duration of the two intervals for each cycle, while the associated multipliers (x10, x1, x0.1) specify the desired range of operation. *Speed-up of the timer (x500) occurs automatically with time scale selection.* In operation, the timer provides dual logic outputs that appear on both the analog and logic program panels, effectively performing as two timers in one. These outputs are logical complements, *permitting modes of integrators and track/store amplifiers to be operated in complementary fashion—a highly desirable feature for certain program requirements.* Logic sequences may also be initiated and controlled by the two timer outputs, and the timer itself may be started and stopped by logic signals. Pushbutton/indicators on the logic control panel provide both a visual indication of the timer state and a means of setting or resetting the timer manually for initialization and checkout purposes. The timer also produces an analog ramp signal (TB for Time Base) at the analog program panel. The ramp may be used as a plotter or oscilloscope time base, or for any other use where a voltage proportional to time is required in the program. This feature *eliminates the need for a general-purpose integrator to provide a time base.*

Time Scale Selectors

Overall control of a program's time scale is possible from the Master Control Panel by means of the time scale selectors. Choosing the One Second pushbutton automatically causes all integrators not under local control to have an integration rate of one volt per second per input volt. Alternately, for high speed repetitive program-solving, the Two Milliseconds selector is depressed to automatically provide a speedup in solution rate of 500 times. For integrators under local control, an additional factor of ten speed-up occurs, allowing 10:1 and 5000:1 changes with respective selection of the two time scale controls. Such speed-ups in program running *permit many solutions to occur each second for display on an oscilloscope.* The computer user then



can *visually evaluate the effects on the solution of each program change that he initiates.*

SIGNAL SELECTOR SYSTEM

There are seven pushbuttons for selecting the types of component addressed. They are as follows:

DIG (Digital)—This button is the *key to using the EAI 580 in a hybrid configuration.* It causes a variety of terminations within the computer to be made available to the internal interface chassis for control from a digital computer, either directly or via an external control interface.

A (Amplifier)—reads the amplifier outputs. Optional trunk readout is also provided in this mode.

P (Pot)—reads the servo-set or hand-set pots.

D (Derivative)—*an excellent program checkout feature eliminating special connections during checkout.* With the computer in the ST mode a derivative address permits the appropriate summing junction of the integrator or track/store to be monitored by the DVM. The display is the sum of the inputs multiplied by the appropriate gains. An interlock is provided to prevent accidental addressing of a derivative in the IC or OP modes.

D/10 (Derivative Divided by Ten)—performs the same function as the "D" address but the display output is 1/10th of the actual value. It is used whenever the value of the derivative is too large to be read directly without attenuation.

PP (Program Panel)—This pushbutton connects the DVM to the DVM terminal of the control tray on the Analog Program Panel.

F (Function Generator)—allows balancing any of the 16 amplifiers normally associated with the eight VDFG's (Variable Diode Function Generators).

There are two columns of pushbuttons labeled "Address", each column numbered from 0 through 9. These buttons are used for entering the numerical portion of an address. For example, to address amplifier 15 the operator simply depresses the buttons "A", "1", and "5". The corresponding output will be displayed on the DVM

POTENTIOMETER SETTING

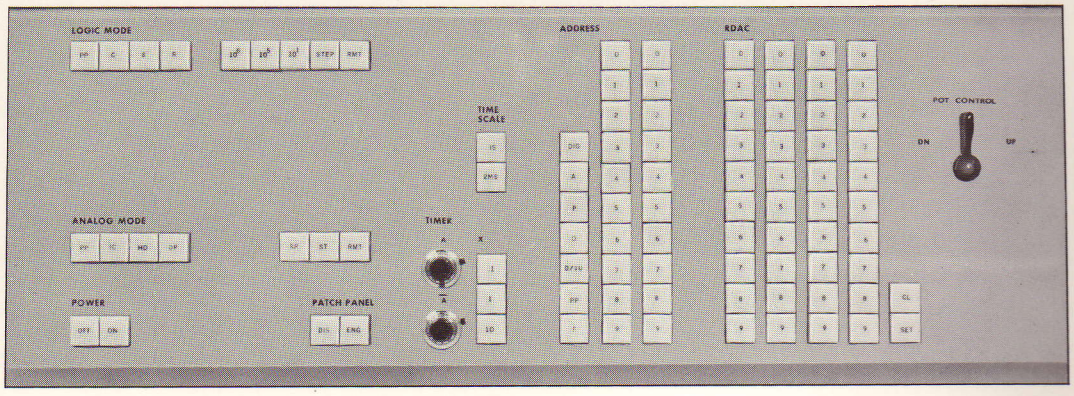
Setting a servo-pot from the keyboard on the 580 is simple. The computer is placed in the SP mode and the pot to be set is addressed using the Signal Selector System. The value to be set is entered in the four vertical columns labeled RDAC (Reference Digital-to-Analog Converter). Each column is numbered 0 through 9 to permit pot setting to four places. After a value has been set on the keyboard, the SET button is depressed and the potentiometer is automatically set to the value *(in less than a second)* of the RDAC keyboard. The CL (Clear) button is used primarily to terminate the setting procedure when an improper pot address has been selected. A red light in the left-hand window of the DVM lights while the pot is setting or continuously if an attempt is made to make an improper setting.

As part of the Pot-Setting System, manual adjustment of servo-set pots may be accomplished *in any mode* by means of the **Pot Control Lever.** This proportional controller *permits the operator to vary parameters while the program is actually running.*

OTHER CONTROLS

Main Power Switches apply power to the computer and two service outlets for the peripheral equipment.

Program Panel Drive Switches marked ENG (Engage) and DIS (Disengage) are for the insertion and removal of the motor driven program panel. A protective feature is provided which automatically puts the computer in the SP mode when either the ENG or DIS button is depressed.



Master Control Panel

EAI 580 Analog Readout Panel

This panel contains the overload indicators, digital voltmeter (DVM) display, analog voltmeter, hand-set potentiometers, comparator display and controls, and function relay display and controls. All control and readout devices are readily accessible and readable to the operator seated at the console.

Overload Indicators

The overload indicators for the amplifiers are laid out in four rows similar to the Analog Progam Panel so that *the operator can quickly locate the source of any program inconsistency*. When a component overloads, the appropriate overload indicator glows. In addition, an audible alarm with an adjustable volume control signals whenever any component overloads.

The Overload Indicator System of the EAI 580 incorporates the same override hold and stored overload features that users of larger analog/hybrid systems find especially valuable in *saving time during program checkout and solution*. Whenever any component overloads, a special output terminal on the Analog Program Panel provides a logic signal. In order to halt a program run before additional overloads occur, the programmer can connect this terminal to override hold so that every integrator is placed into HOLD, regardless of local logic control. The override signal may also be used to inhibit any logic sequence. This allows the operator to isolate the source of trouble as soon as it occurs. Stored Overload permits him to "trap" transient overloads (without stopping the solution) where the overload might otherwise occur too rapidly to be found, but could cause inaccuracies in a problem solution.

Digital Voltmeter

This is an accurate, 5-digit display for reading the value of whatever component is addressed on the Signal Selector. Its instantaneous operation and extremely high input impedance *permit direct potentiometer setup with rapid reading of coefficient settings, as well as general readout of program variables*. The DVM also *provides analog-to-digital conversion with digital outputs that can drive external devices or be supplied to a digital computer*.

Analog Voltmeter

This is a precision multi-range meter for the monitoring of amplifier outputs, input trunks, and power supply voltages, and is also used for the balancing of operational amplifiers. Six meter ranges are selected by a rotary switch.

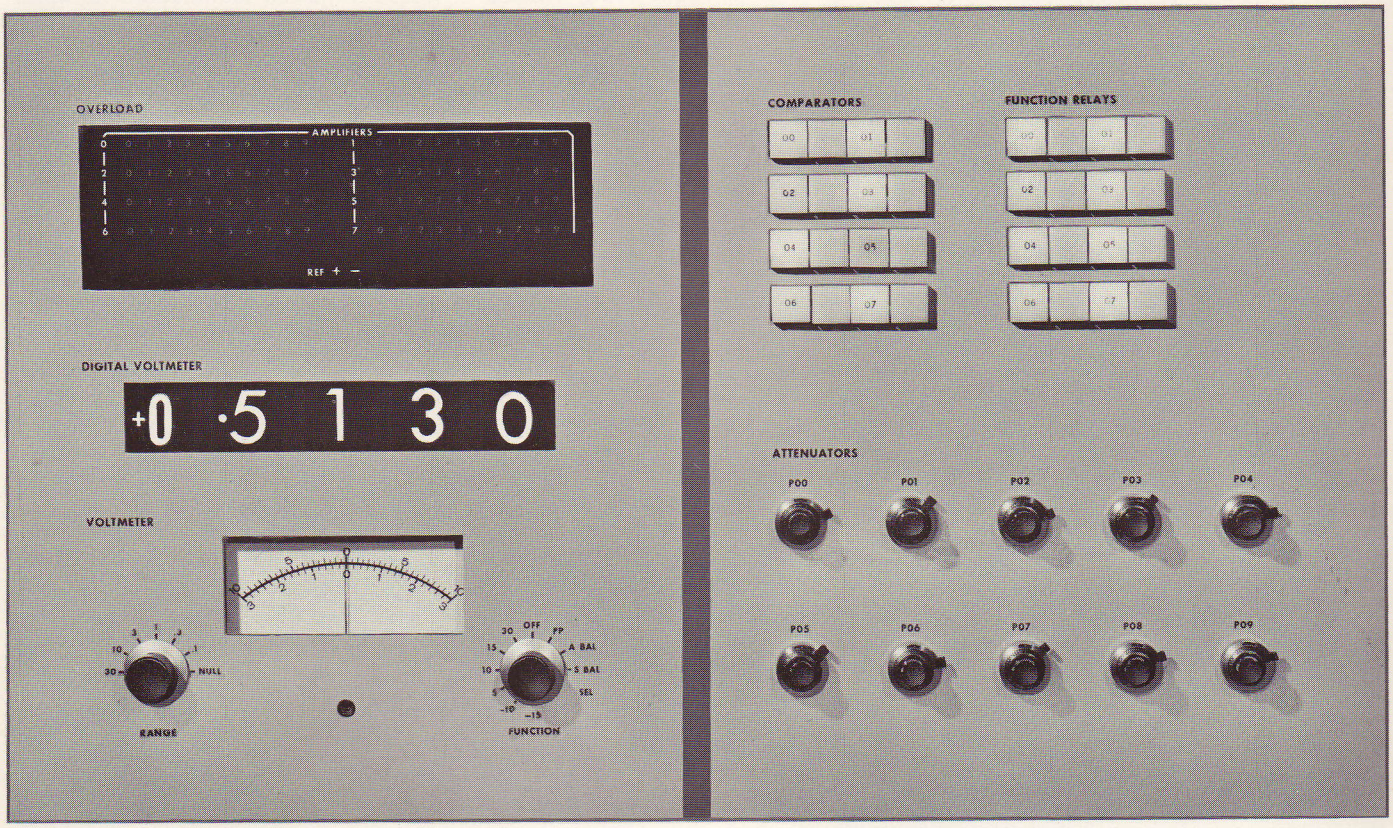
Hand-Set Potentiometers

Manual potentiometer control is provided by 10-turn hand-set potentiometers. Up to 10 hand-set pots may be installed in the console.

Comparators and Function Relays

Comparators, by comparing two analog signals, provide a logic signal output which represents the occurrence of some event in the analog program. It may be used to communicate with logic elements, digitally controlled analog switches, function relays, and a digital computer. The EAI 580 provides convenient central control and indication of the state of all comparators in the computer. Each comparator has a pair of push-buttons for these purposes. This is *extremely useful for problem checkout* since it allows the establishment of test signals at the comparator outputs.

A similar arrangement is provided for each of the function relays. Flip-flop storage provides the memory for the function relays. The relays may be used as manual function switches, driven by comparator outputs or controlled by digital logic or signals from a digital computer.



Analog Readout Panel

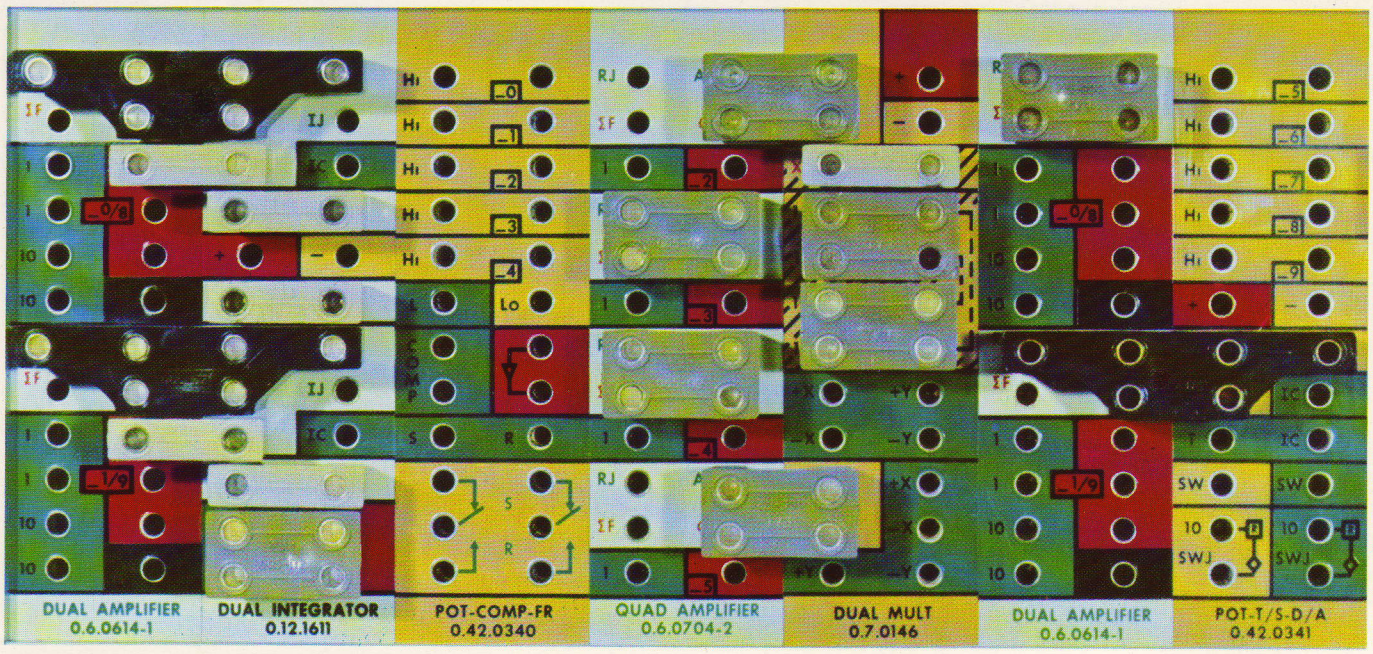
EAI 580 Analog Programming System

The Analog Programming System of the EAI 580 provides the user with a high degree of flexibility and sophistication. The programmer can make extensive use of prewired panel connectors (bottle plugs) to build simple devices which perform the mathematical operations of integration, multiplication, addition, etc. These special bottle plugs also aid the user by covering terminals and markings on the Program Panel which may not be required during a particular problem solution. To further help the programmer, a consistent panel color-coding system is used and all markings are printed with large high contrast lettering to make them easy to read and prevent the programmer from connecting terminals incorrectly.

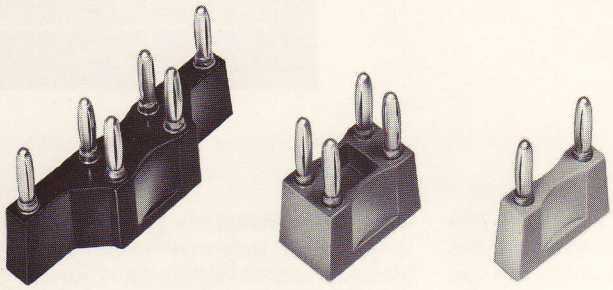
Facility in programming, assigning and locating components results from the EAI 580 Program Panel being divided into four horizontal rows consisting of eight nearly-identical areas called fields. Two fields horizontally separated by a vertical strip constitute a row. This symmetrical arrangement means that *the programmer need only learn the basic pattern for a single field.*

Each field is divided into seven component blocks arranged in a coordinate addressing scheme. These blocks correspond to the computing components housed in slideout trays directly behind the panel. The computing capability of the 580 is conveniently expanded by simply adding plug-in trays to the fully wired console. The vertical input/output strip area in the center of the panel provides centralized terminations for readout, control signals and analog and digital trunks.

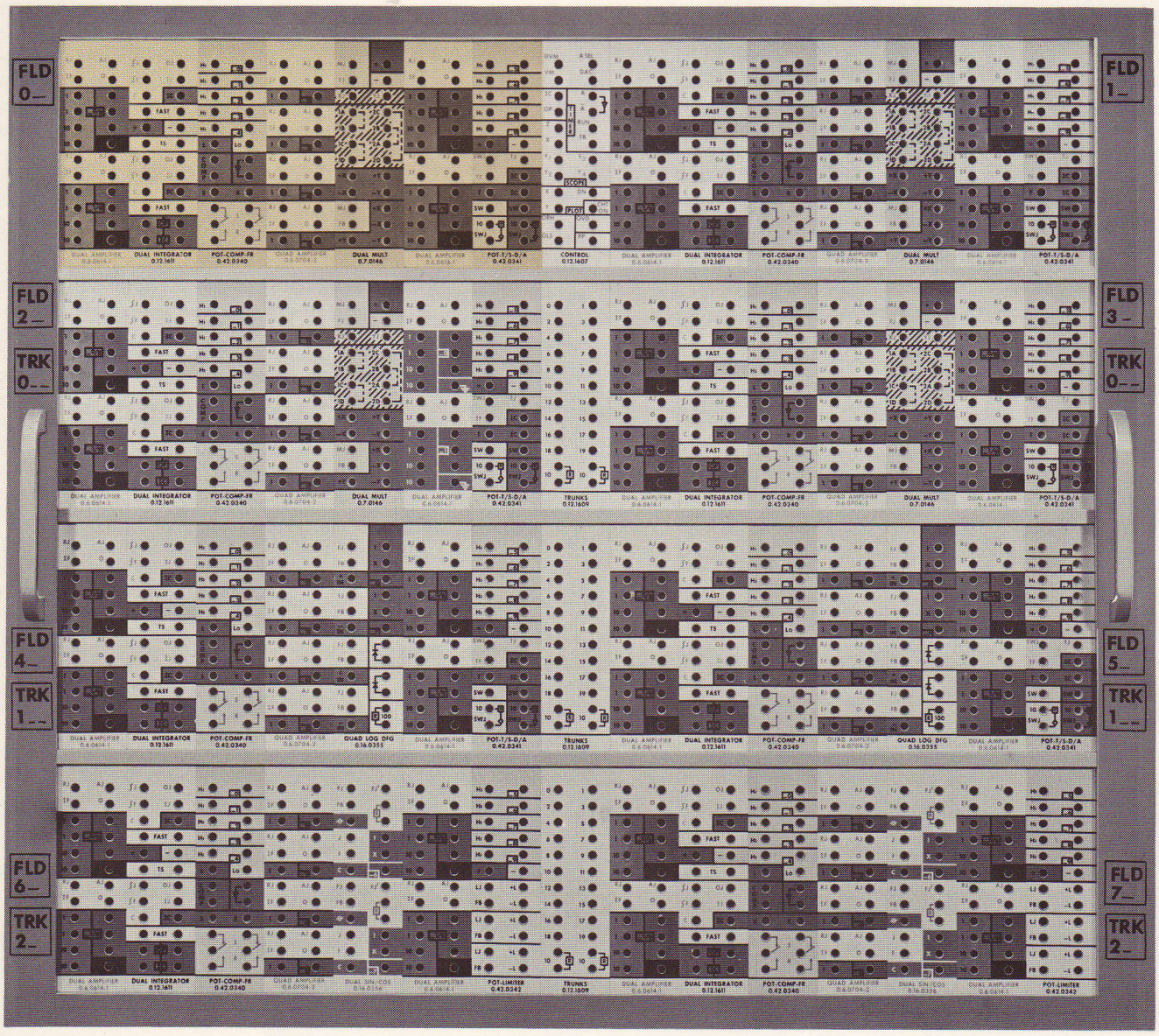
A motor-driven eccentric cam rapidly moves the Program Panel sideways, causing the spring loaded contacts of the computing modules to make solid contact with the terminations of the Program Panel. This contact is designed to be performed with a wiping action that assures positive connection and also keeps contact surfaces clean and free of oxidation. Guide slots insure correct insertion of the panel and hold it in place until the operator is ready to remove or engage the panel.



One field of the Analog Program Panel with bottle plugs



Six, four, and two prong bottle plugs



Analog Program Panel

EAI 580 Digital Logic System

The logic section of the EAI 580 has been designed to provide ease of use in programming and in operation. It is an integrated system of synchronous parallel logic elements terminated on a removable logic Program Panel for high-speed decision making, timing, control, and sequencing of analog programs. The logic design employs the latest integrated circuit techniques. To aid the user, the status of all logic elements is displayed on the Logic Control Panel. Where desirable, the indicators are pushbuttons, *allowing operator intervention for making program alterations and for performing initialization and override functions.*

The EAI 580 employs *synchronous* (clocked) logic *to eliminate operator concern about rise times, propagation delays through various components, and race conditions.* As a result, *more efficient operation is obtained in terms of both operator time savings and program performance.* The logic elements are driven with a basic timing reference to insure changes of state in the logic program at prescribed times, and to allow such changes to take place one-at-a-time under operator control. The use of "clocked" logic also greatly *simplifies the checkout of programs involving a number of elements by allowing a logical step-by-step procedure to be used.*

The Logic Program Panel of the EAI 580 is compact, lightweight, and *offers the user simplicity and flexibility in the organization of a program.* Each logic element is easily located, and necessary connections are completed with a minimum number of operations. In addition to normal outputs, the binary complement is available and indicated by an inverter symbol, *removing the need for separate inverters.* The panel also terminates all trunk lines required for communication with the analog panel and external equipment.

Counter/Timers

The EAI 580 system employs two-decade counters with a patchable input counting rate. By proper choice of input pulse rate and related thumbwheel switch settings, delay intervals from 1 usec to 9.9 seconds may be obtained. The interval may be set directly on the decimal coded thumbwheels, without need for trimming adjustments on an oscilloscope. In addition, the same unit may be used for counting, as well as timing, making it more flexible than a monostable timer. A pair of pushbutton/indicators inform the operator of the state of the counter and may also be used to set and reset the counter.

Logic Gates

Each of the 32 logic gates in the computer is provided with an indicator which lights when the gate output logic is ONE. Each gate may be programmed for AND, NAND, OR, or NOR functions, *providing excellent programmer flexibility.*

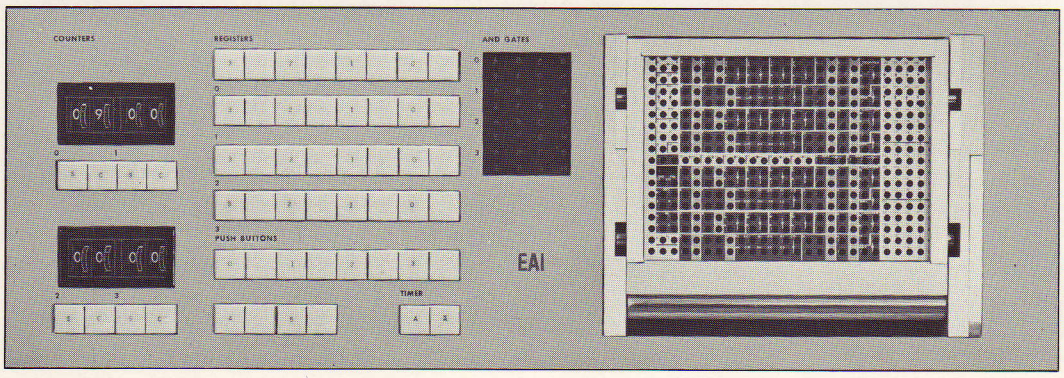
General Purpose Registers

General Purpose Registers provide the operator with several programming advantages. In addition to including 4 independently usable flip-flops, the registers are readily converted into up counters, down counters, or shift registers. These various modes may be programmed by the operator, with a minimum of effort.

A pair of pushbutton/indicators, for each of the sixteen flip-flops in the general purpose registers, indicate status and permit rapid program checkout and initialization. Each pair of buttons may be used to set and reset its associated flip-flop and the left-hand button which lights in the set mode, serves as the status indicator.

Digital Pushbuttons

Six pairs of general purpose digital pushbutton/indicators provide a logic ZERO or logic ONE at output terminals on the Logic Program Panel. These buttons *aid in program checkout, initiation, and sub-routine control, and are an essential aid in maximizing the effective use of the logic.*



Digital Logic System

The complement of high quality computing components which constitute the EAI 580 makes possible *a new standard of performance never before obtainable in a desk-top computer.* The 580 comprises many elements which up to now have been available only in larger, more expensive systems. These components are characterized by their high speed operation, low drift, and excellent static accuracy.

The system's high speed operational amplifiers perform at full amplitude over their entire bandwidth with no velocity limiting. Resistor networks are arranged so that each amplifier is conveniently converted into inverter or summer operation by means of bottle plugs.

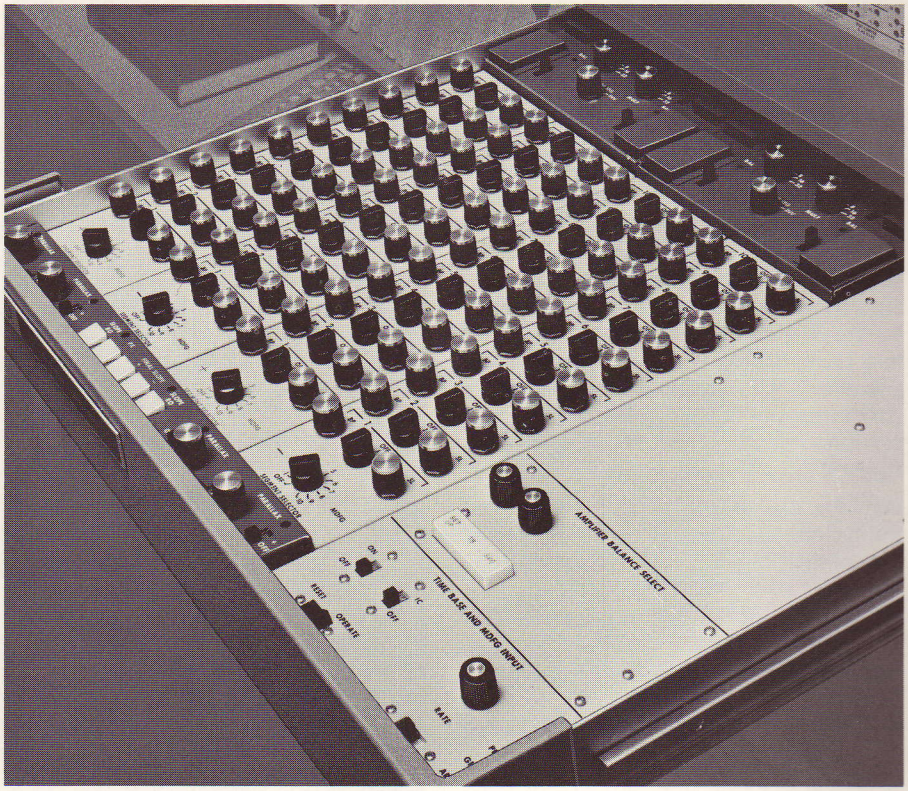
Integrating amplifiers are provided with adjacent integrating networks. Simple bottle plug connections convert the high gain amplifier to an integrator which uses any of four time scales. Integrators can be operated simultaneously at different speeds and in different modes—*capabilities which are particularly useful for iterative and hybrid computation.* Also useful in this regard is the integrator's ability to reset very rapidly from the operate mode to the initial condition mode.

Another feature which is especially useful for iterative and hybrid computation is the exceptional performance of the system's track/store units. Extremely fast signal tracking combined with low drift storage is achieved through a novel circuit that uses two capacitor sizes in each unit. The tracking operation is performed using a small size capacitor; and a large capacitor is switched in for the storage function.

The standard complement of nonlinear, special and digital components include electronic quarter-square multipliers, diode function generators, comparators, limiters and logic components. Two types of electronic multipliers are available to satisfy a variety of requirements. Multipliers may be used to perform the operation of multiplication and division. Terminations provided on certain multipliers permit two entirely independent squaring or square-root operations to be performed at the same time.

Function generator setup is remarkably simple. The Variable Diode Function Generators (VDFG's) and their controls are conveniently located in slide-out drawers in the console. The operator makes all his adjustments while seated at the console. Once the function is set a continuous plot of output versus input may be made on the EAI 580 *without making additional connections* because the 580 VDFG setup panel contains a built-in ramp integrator to provide a smooth sweep for setup. An additional input resistor for each DFG allows alternative applications such as the use of the unused output amplifier as an inverter and combined summation and function generation.

Comparators are provided with their own amplifiers *eliminating the need for extra high gain amplifiers* which would otherwise be required for this purpose. A fully expanded 580 contains eight comparators each with associated amplifier *in addition to* the 80 computing amplifiers in the system.



Slide-out VDFG Drawer

EAI 580 Individual Computing Components

The complement of high quality computing components which constitute the EAI 580 makes possible *a new standard of performance never before obtainable in a desk-top computer.* The 580 comprises many elements which up to now have been available only in larger, more expensive systems. These components are characterized by their high speed operation, low drift, and excellent static accuracy.

The system's high speed operational amplifiers perform at full amplitude over their entire bandwidth with no velocity limiting. Resistor networks are arranged so that each amplifier is conveniently converted into inverter or summer operation by means of bottle plugs.

Integrating amplifiers are provided with adjacent integrating networks. Simple bottle plug connections convert the high gain amplifier to an integrator which uses any of four time scales. Integrators can be operated simultaneously at different speeds and in different modes—*capabilities which are particularly useful for iterative and hybrid computation.* Also useful in this regard is the integrator's ability to reset very rapidly from the operate mode to the initial condition mode.

Another feature which is especially useful for iterative and hybrid computation is the exceptional performance of the system's track/store units. Extremely fast signal tracking combined with low drift storage is achieved through a novel circuit that uses two capacitor sizes in each unit. The tracking operation is performed using a small size capacitor; and a large capacitor is switched in for the storage function.

The standard complement of nonlinear, special and digital components include electronic quarter-square multipliers, diode function generators, comparators, limiters and logic components. Two types of electronic multipliers are available to satisfy a variety of requirements. Multipliers may be used to perform the operation of multiplication and division. Terminations provided on certain multipliers permit two entirely independent squaring or square-root operations to be performed at the same time.

Function generator setup is remarkably simple. The Variable Diode Function Generators (VDFG's) and their controls are conveniently located in slide-out drawers in the console. The operator makes all his adjustments while seated at the console. Once the function is set a continuous plot of output versus input may be made on the EAI 580 *without making additional connections* because the 580 VDFG setup panel contains a built-in ramp integrator to provide a smooth sweep for setup. An additional input resistor for each DFG allows alternative applications such as the use of the unused output amplifier as an inverter and combined summation and function generation.

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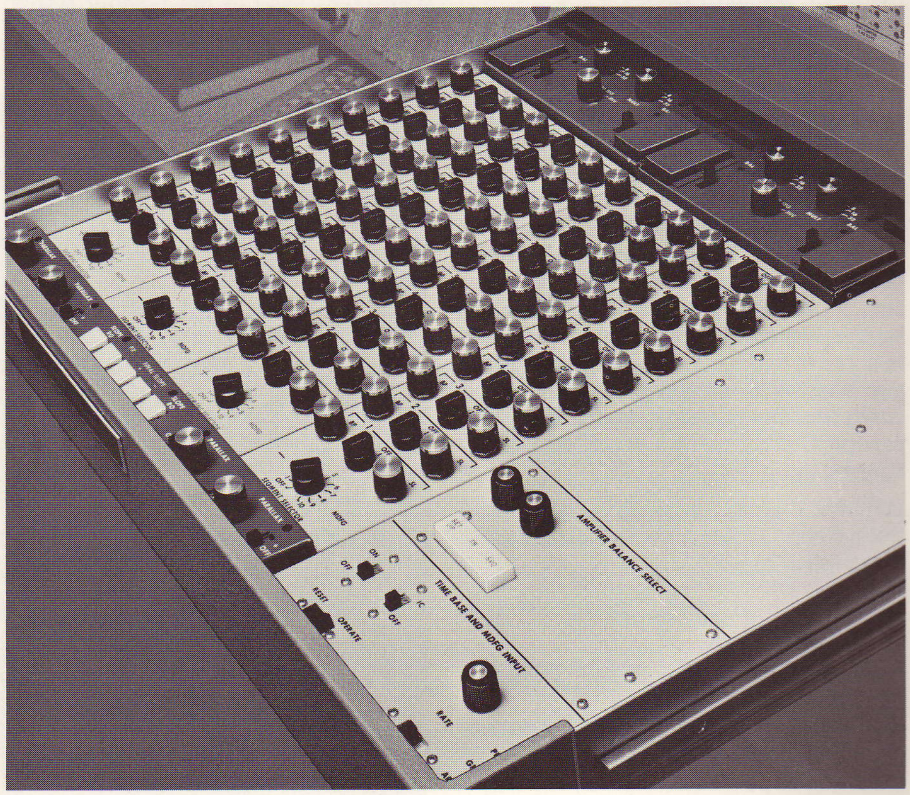


Slide-out VDFG Drawer

EAI 580 System Expansion

The modular design concept of the EAI 580 provides a growth potential which allows the customer *to start with a minimum investment* then expand the system later as the workload and problem complexity dictate. All components can be added to the system in the field with no additions of wiring harness or soldering required. Full slaving capability is another of the ready-expansion features of the EAI 580.

The installation of a self-contained logic expansion provides analog/hybrid capability to the desk-top user. The combination of analog and digital computing components *increases the spectrum of applications for the EAI 580 and makes possible the solution of a wide variety of more complex problems.* This logic expansion is easily added to the basic console and all connections are made via standard cables.

Further expansion into a full hybrid computing system is made possible with the addition of a hybrid control interface. This control interface simplifies integration with a digital computer by directing communication with the digital computer through the analog and digital trunks, mode control lines, and addressing system within the analog console. The digital computer is also able to transfer data and control signals to the 580 by means of this interface. In a basic hybrid system the DVM may also be used as an analog-to-digital converter and a digital-to-analog conversion channel is also included in the control interface.

When a digital computer is added to the system, facilities can be expanded to accomplish five major functions:

- **Selection of analog modes by the digital computer**
- **Sensing of analog modes by the digital computer**
- **Selection and readout of all addressable analog components**
- **Setting of potentiometers by the digital computer**
- **Exchange of data between analog and digital computer programs**

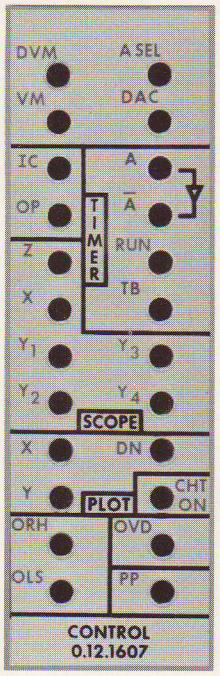
The selection and readout of analog components and setting of potentiometers are readily achieved by the digital computer under direct program control utilizing the interface expansion.

READOUT AND DISPLAY

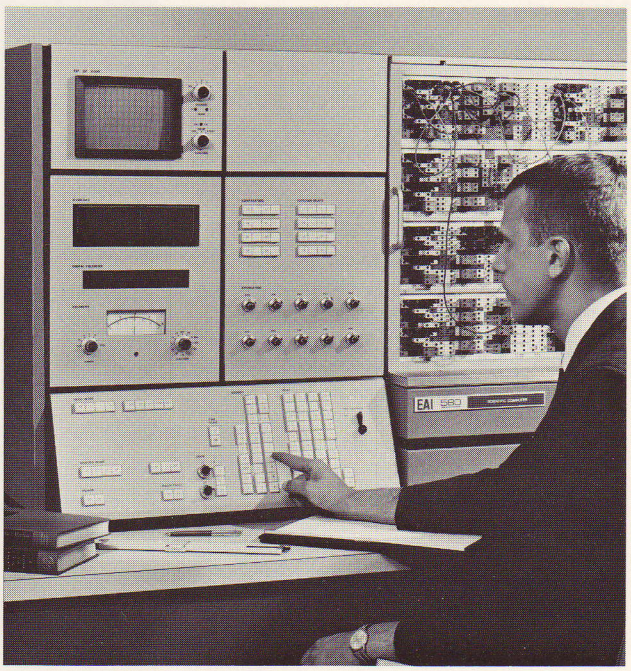
The very necessary man/machine communication involving the display and documentation of problem results is another area that is emphasized in the design of the EAI 580 Analog/Hybrid Computing System. Recognizing the need not only for the "availability" of results but also for their accurate and reliable presentation EAI offers a complete selection of equipment to satisfy these requirements.

In addition to the high speed, solid-state DVM used in the readout system of the 580, the system has provision for peripheral devices such as X-Y recorders, multi-channel strip chart recorders and a multi-channel high speed repetitive operation display unit. This display unit is a self-contained precision display system that employs an 8-inch oscilloscope. The user has the option of mounting the display scope above the Analog Readout Panel or connecting a portable version of the same unit. Either way, this unit provides simultaneous display of four traces and requires the setting of only three operator controls-intensity, position and number of traces. Sweep speed is automatically controlled by the rep-op timer of the 580, or the operator can cross-plot four input channels against a fifth.

Standard on all EAI 580's is a Control Module on the Analog Program Panel that provides convenient terminations for all readout and display equipment used with the system as well as outputs from the timer system of the computer.



Central Control Module



EAI 580 with self-contained rep-op display

EAI 580 Applications

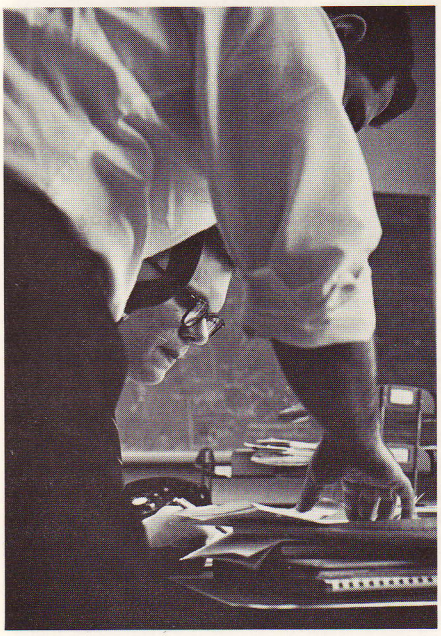
In many fields of science and industry, analog, analog/hybrid and hybrid computation are three of the most powerful engineering and design tools available. Much is written about analog computation and how it is being used to solve problems by simulating all kinds of dynamic physical systems. The following section, therefore, concentrates on the uses for analog/hybrid and hybrid computation and briefly describes some applications where they are proving to be the most economical, time-saving methods of solving complex problems. Significantly, the EAI 580 is well suited to perform all of these applications and many others.

ANALOG/HYBRID COMPUTATION

Analog/hybrid computers are characterized by having parallel digital logic elements as well as analog computing components. Since many physical systems are a combination of both continuous and discrete subsystems, the addition of logic increases the computing capability of the modern analog computer. Subsystems such as relay switching systems, pulse circuits, and on-off devices can be conveniently simulated by the digital components included in the EAI 580. For example, simulating the **switching system** in a large railroad terminal can be done with AND gates, OR gates, logic inverters and flip-flops. **Sampled data** systems in which continuous processes are monitored by digital data acquisition systems and perhaps also controlled by digital controllers require analog, digital and analog/digital interface elements for a realistic simulation. Uncommitted analog and digital components can best perform computation tasks required in the investigation of **adaptive control systems** and **optimization** or **maxima-minima** problems.

The use of parallel logic to **control the analog computer** results in a significant improvement in efficiency and reduction of program run-time. It is possible to automate parameter changes and mode control changes by using the digital components for decision making, timing and control. Many data reduction tasks which are normally performed manually can be implemented on the analog computer and performed concurrently with the computer run under the timing and control of the logic section. "Slow time" plotting of variables produced in the high speed repetitive-operation mode, time mark generation for parameter plots such as phase plane and Nyquist diagrams, automatic rescaling and many other similar tasks are practical using the parallel logic of the EAI 580.

One specific example is the automatic plotting of stability areas for a mathematical expression such as Mathieu's Equation, $\ddot{y} + (a - 2q \cos 2t)\, y = 0$. In this case the analog section operates in high speed rep-op making the necessary thousands of runs while the parallel logic controls the analog computer, senses the stability of the system equation and controls the X-Y plotter so that it automatically plots the stable areas for values of a versus values of q.



Iterative computation is another area where the EAI 580 analog/hybrid computer can be put to good use. This task is characterized by the need to examine the results of a computer run, make logical decisions based on this examination, and implement changes in the computer program based on these decisions. Such changes are typically made on parameter values and initial conditions. Some of the subclasses in this category are optimization studies, system identification, boundary value problems, and curve fitting.

In optimization, for example, a system (usually nonlinear) is given and it is necessary to determine the correct values of n parameters so that a certain error or criterion function is either maximized or minimized, or fulfills other given conditions. The functional relationship between this error function and the parameters of interest is in general *not* known, and in any case, is exceedingly complex. In such situations, unless only one or, at most, two parameters are to be investigated, the human operator must be completely removed from the loop and the process of seeking the optimum. This would involve making numerous trial runs to determine the parameter changes which would give the greatest promise of driving the error function towards its desired shape. With parallel logic, this tedious process can be automated by putting to use the logical decision-making, timing and control elements of a logic system.

Therefore, parallel logic *augments the computing capability of the analog computer.* It is able to simulate discrete subsystems of larger dynamic systems as well as accomplishing decision making, timing and control. In many cases, the combined use of parallel logic with high speed rep-op permits thousands of runs to be made in a few minutes while, at the same time, an X-Y plotter automatically makes a plot of the desired parameters, eliminating tedious hand-plotting.

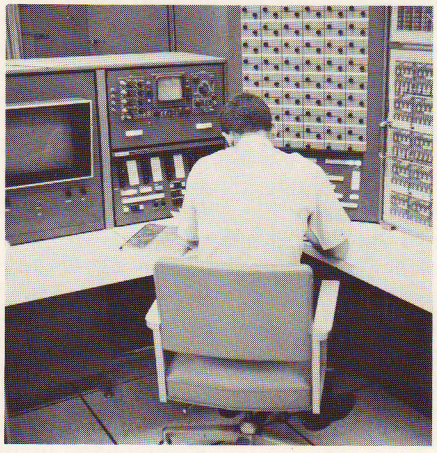
EAI 580 Applications

HYBRID COMPUTATION

A full hybrid computing system is an analog/hybrid computer and digital computer working together through a hybrid control interface, each computer performing the tasks for which it is best suited. Hybrid computation is able to resolve many complex problems which were impractical to approach by either analog or digital techniques alone. The following explores a few of the areas of application.

Bio-Medical Engineering

The hybrid computer is a very effective tool for both data analysis and physiological simulation in the Life Science field and its uses have been increasing rapidly. The hybrid computer offers an automatic means for correlating the results of these simulations to actual data. For example, using a hybrid computer it is possible to simulate the cardiovascular system, cause the "patient" to have a heart attack, observe the results and automatically relate this simulation to real EKG data in memory storage. It enables the bio-medical researcher to do in the laboratory that which would otherwise be impractical, impossible, or dangerous. Furthermore, complex experiments and analyses can be made more rapidly and more thoroughly than before, through use of the automatic capabilities of the system.



Chemical Process Industry

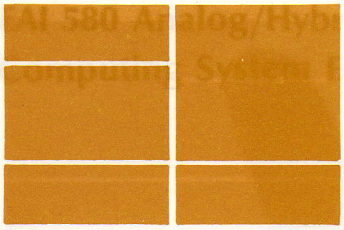
Analog and hybrid computers have proven to be both convenient and economical tools for the solution of a wide range of problems in the chemical and petroleum field. Analog computers have been used for many years in the simulation of chemical processes; however, the pure analog approach imposes restrictions on the size of the system which can be simulated. The cost of a digital simulation often exceeds the marginal savings which may result from the study. Furthermore, digital simulation lacks the man-machine-problem interaction provided by analog or hybrid computers. Thus, hybrid computers have proven to be both convenient and economical tools for the solution of a wide range of problems in the chemical and petroleum fields.

The primary applications have been in the design and optimization of process control systems where a chemical process is simulated by the analog computer and functions such as transport delay, complex functions, or a digital control system are represented by a digital program. A common difficulty in the simulation of a chemical or nuclear reactor is providing an adequate representation of the transport of fluid in pipes from one point to another—from reactor to heat exchanger. The simulation of this transport delay of a dynamic variable, such as the time variation of the fluid temperature, is accomplished by the use of the digital computer; the digital memory stores the temperature function for a fixed or variable length of time. By simulating systems such as chemical reactors, heat exchangers, and distillation columns, studies on design feasibility, maximum yield and minimum cost become economically practical.

A hybrid computer permits simulation of a control system's performance as the real physical system actually performs; that is, analog devices are represented on the analog/hybrid system, and if direct digital control is the objective, the digital system is used to design the control program.

Computing System in Education

The presence of analog and hybrid computers in the university enables the faculty and students to investigate and evaluate the rapidly evolving techniques of electronic computation and simulation. Furthermore, the role of the computing facility is:



- **To provide equipment for the simulation of computer control of process and systems for graduate and faculty research, e.g., the kinetics and control of a chemical process.**

- **To demonstrate to undergraduate and graduate students the solution of significant problems by analog and hybrid techniques.**

- **To provide a tool for instruction in information processing and computer design courses.**

- **To provide a tool for instruction in science and engineering courses that enables students to obtain a deeper understanding of the dynamic behavior of physical systems and phenomena.**

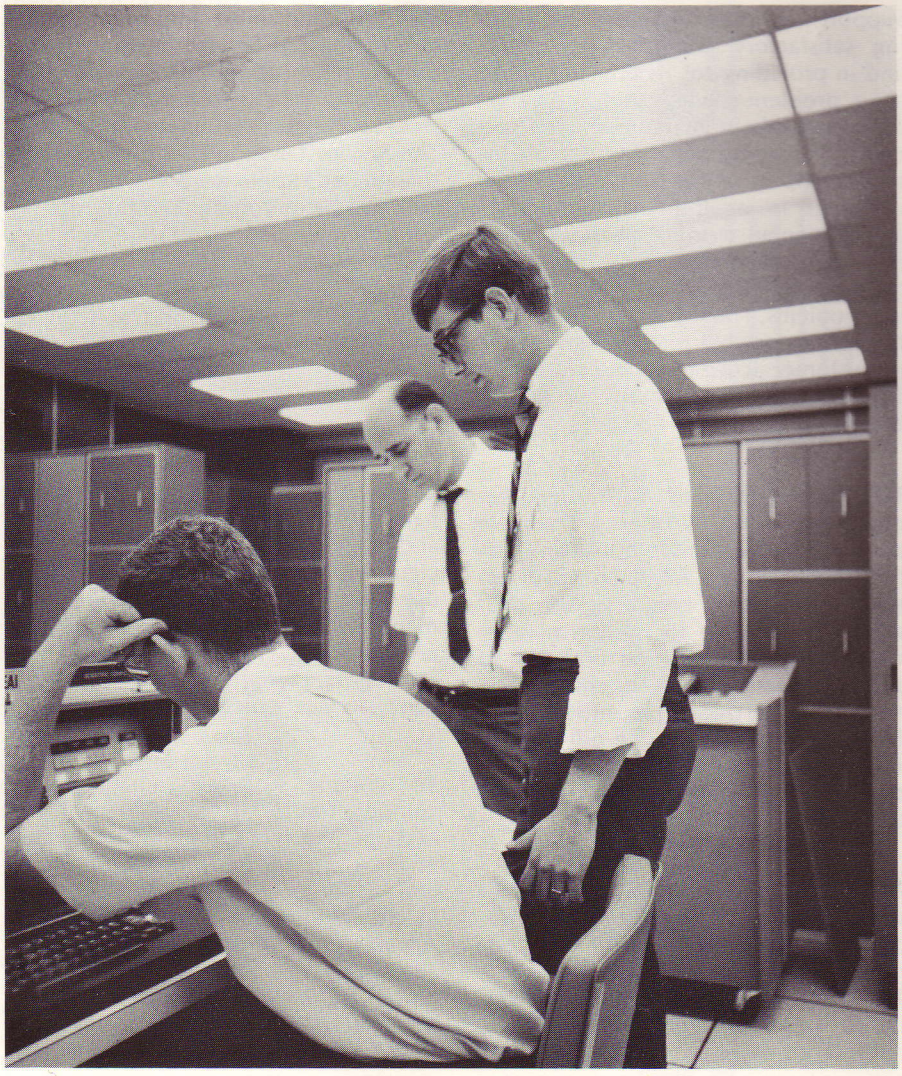
This diversity of requirements demands a flexible system in which the analog and digital sections will often be used independently.

Since the computing facility serves a number of purposes in nearly all departments of the university, there are a myriad of specific applications. The 580 can be used to simulate most systems which are represented by a set of ordinary differential equations. The digital computer may be used to automate the setup and checkout of the analog program. For problems in which the physical system is represented by partial differential equations, the entire hybrid computer will generally be used. Some studies, such as aerospace vehicle simulation, may be represented by a mathematical model which is composed of a set of ordinary differential equations—in which case the portion demanding high accuracy will be computed on the digital computer and the lower accuracy computations will be performed on the 580.

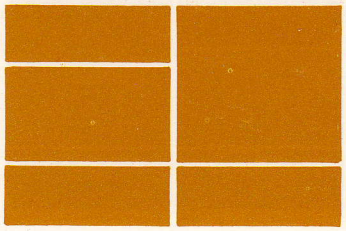
The Aerospace Industry

The Aerospace industry, from which hybrid computation developed, has successfully applied hybrid techniques to a wide range of problems. It is possible to establish certain classes of problems which place rather specific demands on the simulation hardware. These classes are listed as follows:

- **Aircraft Simulation**
- **Short Range Missile Simulations**
- **Helicopter (VTOL) Simulations**
- **ICBM Simulations**
- **Space Vehicle Mission Simulations**
- **Telemetry Data Reduction**



EAI System Support



Support services — essential in assuring satisfactory computer operations and in providing for its effective usage as a problem-solving tool — play an important role in guaranteeing the success of a computer laboratory. Customer support ranges from assisting the customer in equipment maintenance and personnel training to the application of new computing techniques in the solution of scientific and engineering problems. These activities have been largely responsible for the high degree of customer acceptance and regard for EAI, its scientific computing systems and its service.

The **Service Division** is *the maintenance arm of EAI.* It offers a complete service program from in-house and factory repairs to the fulfillment of long-term maintenance contracts. The division is responsible for system maintenance, refurbishment and updating of *any* computing equipment and offers a number of service plans under which EAI personnel will assume full responsibility for maintaining customer equipment or serve to supplement the customer's own maintenance staff.

Another function of the Service Division is *to provide assistance to the new customer in installing new EAI equipment and fulfilling warranty provisions.* The division has the manpower essential to the provision of these two very important services.

The last, and most important, function of the EAI Service Division is *the fulfillment of contracts to provide comprehensive on-site computational services in the user's computer laboratory.* The Service Division has the personnel trained and experienced in all the complex phases of computer center operations including administration, analysis, operation and maintenance. Service Division personnel will also develop, expand and maintain hybrid and digital computer software for the laboratory, if required.

The Service Division is responsible for the worldwide network of EAI regional service engineering offices and parts depots. Each office is equipped and staffed to provide quick and efficient service to guarantee maximum use of the customer's computing equipment—whether or not it is made by EAI. Trained service engineering personnel are available to provide emergency service whenever it is needed.

To provide "off-site" analysis and computation services, EAI maintains and operates five **Computation Centers** in the United States and several more in Europe. The Computation Centers, located in this country in Princeton, Los Angeles, San Francisco, Washington and Houston, *offer equipment time rental, applications assistance and systems analysis.* A complete professional staff of experienced engineering and scientific personnel is available at each center to analyze technical problems, interpret scientific data and provide complete engineering assistance to customers. The EAI Computation Centers also provide facilities and instructors for EAI's program of regularly scheduled training courses. More than 5,000 students receive instruction yearly in the centers. These students take courses ranging from basic analog computing techniques through equipment operation and maintenance to advanced analog programming. Special courses, covering topics such as analog computer applications in the process industries and biomedical engineering are given periodically.

Close cooperation and inter-related operations in research, engineering, manufacturing and marketing activities make it possible for EAI to provide this extensive back-up support by the Service Division and the Computation Centers—support that can only come from a major manufacturer. This complete technical capability and EAI's exceptionally high standard of quality stands behind every computing system. Every EAI representative is backed by the corporation's reputation for quality products and services. EAI's willingness and ability to maintain and operate any manufacturer's computing equipment assures the customer of the finest in complete professional support in the operation and maintenance of his facility.

EAI 580 Analog/Hybrid Computing System Equipment

SUMMARY

A fully-expanded EAI 580 System is described as representative of the many configurations that are available to satisfy individual requirements.

COMPUTER CONSOLE

Mode Control and Timing System
Analog mode control selector (with static test bus)
Time scale selector
Repetitive operation interval timer
Interval timer controls (with frequency multipliers)
Slave selector

Addressing and Readout System
Parallel input keyboard
Derivative check selector (with 0.1 attenuator)
Address selection matrix
Analog voltmeter (with range selector)
Solid state digital voltmeter
Comparator and function relay indicator/pushbutton control panel

Servoset Potentiometer System
Servo amplifier
Precision reference voltage divider
Four-digit coefficient selector/keyboard
Control for continuous coefficients

Overload Indicator System
Overload indicator panel
Overload indicator bus (with automatic Hold and Storage feature)
Audible overload alarm (with volume control)

Analog Program System
Program bay (with latching mechanism)
Pre-Program panel
Engage/disengage selector (motor-drive)
Programming cord and bottle plug kits

Variable DFG Set-Up System
Set-up panel
Amplifier balance selector
Time base generator
Set-up amplifier

Power Distribution System
Bus-bar distribution matrix
Power supply monitor selector
±10 volt reference supply
Analog system power supplies

Logic System Expansion
Program bay (with latching mechanism)
Pre-Program panel
General purpose logic communication lines
Programming cord kit
One Megahertz System clock
Logic mode control selector
Slave selector
Logic gate state indicators
Register indicator/pushbutton controls
Digital function switch
indicator/pushbutton controls
Preset counter controls
Logic power supplies

Control Interface System Expansion
Console selector
Analog and logic mode control register
Analog address register
Servoset potentiometer coefficient selector
Analog value register
Time scale selector

Analog Computing Components

Summer-Integrators	16
Summers	16
High Gain Inverters	32
Other Inverters	8
Other Amplifiers (assigned to variable function generators)	8
Other Amplifiers (assigned to comparators)	8
Track/Store networks	6
Handset Coefficient Attenuators	10
Servoset Coefficient Attenuators	70
Multipliers (quarter-square)	8
Ten Segment Variable Function Generators	8
Sine/Cosine Function Generators	4
Logarithmic Function Generators	8
Feedback Limiters	6
Free Resistors and Diodes	14

Logic Conversion Components

Digital-to-Analog Electronic Switches*	12
Analog (voltage) Comparators	8
Function Relays (DPDT)	8

Parallel Logic Elements

General Purpose Logic Gates	32
General Purpose Registers (each with four flip-flops)	4
Preset Counter/Timers	4
Logic Differentiators	6
Digital Function Pushbuttons	6

Trunk Line Terminations

Analog Panel Trunks	60
Logic Panel Trunks	60

Peripheral Equipment

X-Y Plotter	1
Rep-Op Display Scope	1
Multichannel Strip Chart Recorder	1

**In addition, each integrator may also be converted to a switched amplifier (electronic switch) by removing one bottle plug.*

ent

Logic System Expansion
Program bay (with latching mechanism)
Pre-Program panel
General purpose logic communication lines
Programming cord kit
One Megahertz System clock
Logic mode control selector
Slave selector
Logic gate state indicators
Register indicator/pushbutton controls
Digital function switch
indicator/pushbutton controls
Preset counter controls
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Dear Sir:

I would like further information about EAI 580 Analog/Hybrid Computers

- ☐ Please have the sales engineer in my area contact me.
- ☐ Please send literature about other EAI Desk Top Computing Systems
- ☐ Send me literature on the following EAI products.

_____ _____

_____ _____

Name and Title: _____

Company: _____

Address: _____

City: _____ State _____ Zip _____

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