TYPICAL AD/FIVE CONFIGURATION

ANALOG COMPUTING COMPONENTS

Integrator/Summers	36
Summer/High Gain	24
Summer/Inverters	36
Summer/Dual Electronic Switch	24
Inverters (associated with non linear equipment)	36
Inverters (committed to non linear equipment)	192
Hand Set Potentiometers	12
Servo Set Potentiometers	108
Multipliers (quarter square)	24
Sine/Cosine DFG	6
Logarithmic DFG	6
Arbitrary Function Generators	22
Dual Digital to Analog Switches	24
DPDT Relays	12
Function Switches	12
Hard Limiters	12
Comparators	16
Track/Store Networks	4
Analog Trunks	110

LOGIC ELEMENTS

Flip Flop Pairs	16
Flip-Flop/Differentiators	16
OR/NOR Gates	60
Two Input Gates	36
Four Input Gates	16
Six Input Gates	8
Multiple Carry-Out Two-Decade BCD Counters	4
Variable Carry-Out Two-Decade BCD Counters	4
Logic Switches (3 position)	6
Function Switches (2 position)	12
Logic Trunks	20

HYBRID ELEMENTS

Analog to Digital Converter Channels	16
Digital to Analog Converter Channels	16
Digital Sense Lines	16
Digital Control Lines	16
Digital Interrupt Lines	8

(The above counts are typical and may be modified to fit the users' requirements.)

TYPICAL PERFORMANCE CHARACTERISTICS

AMPLIFIER

Voltage Range	±13 v
Output Current (at ±10 volts)	45 ma
Output Protection	Short circuit proof to any voltage in the range ±15 volts
Open Loop D.C. Gain	2×10^8
Velocity Limit	50 V/μsec
Bandwidth (10K/10K)	1.5 MHz
Peaking	1.0 db
Noise peak-to-peak (0-800 KHz)	1.5 mv
Output Capacitive Load Tolerance	0.2 μfd.
Offset at Summing Junction	±20 μv
Phase Shift at 1.0 KHz	0.02°
Phase Shift at 10 KHz	0.2°
T.I.D.E. at 1.0 KHz	0.04%
T.I.D.E. at 10 KHz	0.4%
Overload Recovery from either voltage or current overload condition	0.5 msec

INTEGRATOR

Time Scales	x1, x10, x100, x1000
Inputs	3 Gains of 1, and 3 Gains of 10
Mode Control	Electronic Switching for IC, OP, HOLD
Switching Time Between any Two Modes	900 nanoseconds
Drift in Hold (x1 or x10 time scale)	50 μv/sec

POTENTIOMETERS

Resistance	5 Kohms
Setting Time	1.5 sec
Resolution	0.02%
Phase Shift Range at 1.0 KHz for settings greater than 0.1	±0.1°

MULTIPLIERS

Static Error ($\|x\| + \|y\| < 20$ v)	±5 mv
Zero Error (i.e., x=y=0)	±0.5 mv
Bandwidth (x=10v, y=20 v peak-to-peak)	1.0 MHz
Phase Shift at 1.0 KHz	0.03°
Phase Shift at 10 KHz	0.3°
T.I.D.E. at 1.0 KHz	0.06%
T.I.D.E. at 10 KHz	0.6%

LIMITERS

Limit Range—Plus Limit	−10 v to +10 v
—Minus Limit	−10 v to +10 v
Slope after Limit	1.0 mv/v

LOGIC

Clock Frequency	1.0 MHz ±10 ppm
Output Fan Out	10 unit loads
Input Drive Requirement	1 unit load

ADDRESSING SYSTEM

Circuitry and Switches	All solid state
Number of addressable elements	721
Readout System Input Impedance	10^8 ohms
Multiplex Rate for Hybrid Operation	5,000 points/sec

INTERVAL TIMER (REP-OP TIMER)

Number of Pre-settable Periods	3
Circuitry	BCD Counter
Counter Input	Derived from 1.0 MHz Logic Clock
Programmable from Digital	Optional

DIGITAL-TO-ANALOG CONVERTER

Configuration	14 bits plus sign, double buffered
Track/Store	Optional
Phase Shift at 1.0 KHz	0.05°
Bandwidth	500 KHz
Settling Time to ±0.02%	7 μsec.
Accuracy	Within ±0.025%

ANALOG-TO-DIGITAL CONVERTER

Configuration	14 bits plus sign
Hold Amplifiers	Optional
Throughput Rate	100 KHz
Throughput Accuracy	Within ±0.025%

DIMENSIONS

Height	62.5 in
Length	65.5 in
Depth with Work Shelf	46 in
Depth without Work Shelf	29.5 in

POWER REQUIREMENTS—ANALOG COMPUTER

Voltage	105-125 v a-c, 50-60 Hz.
Current	15 amp. max.

FOR FRESH IDEAS IN AUTOMATION

RELIANCE ELECTRIC COMPANY

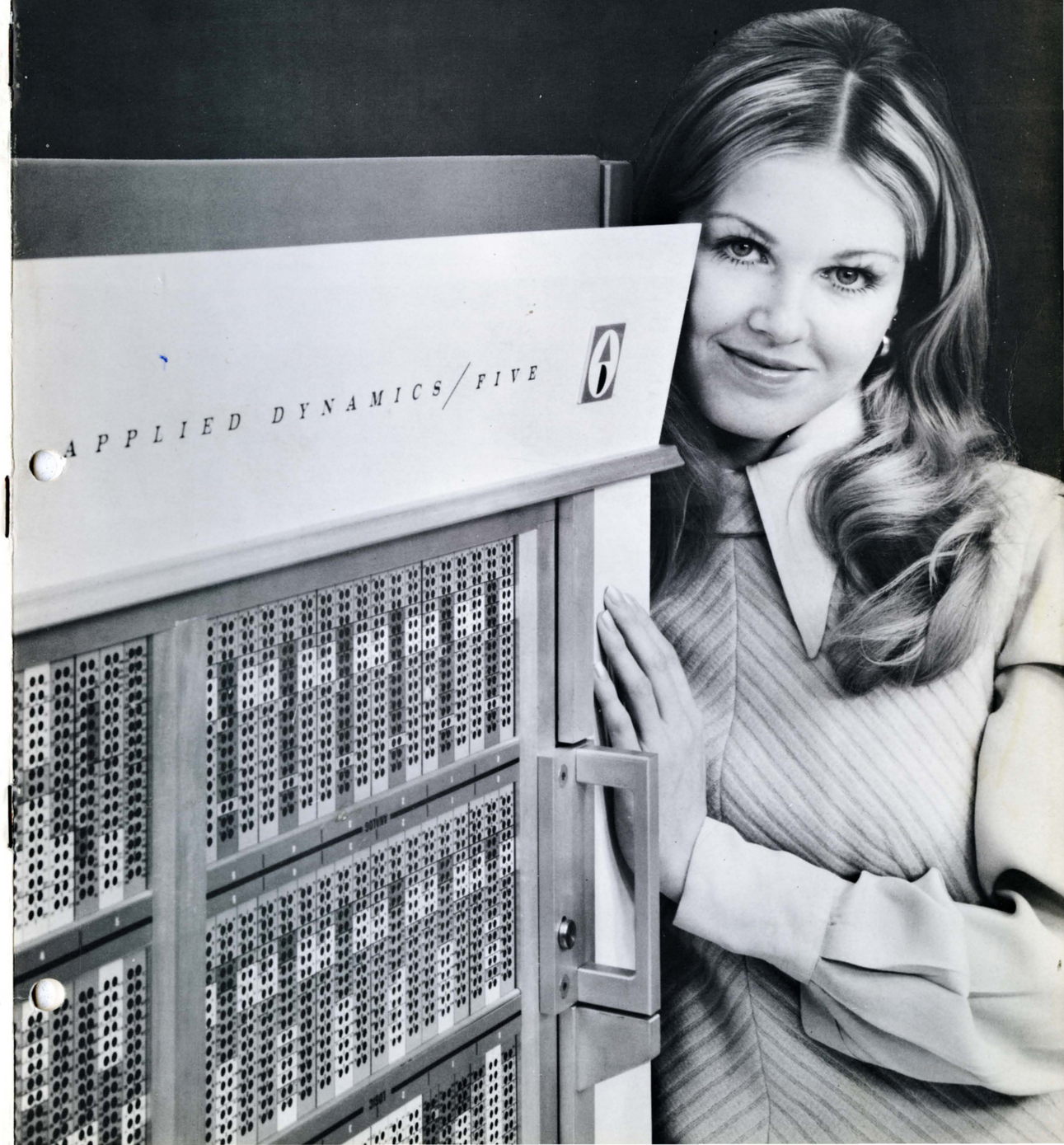
APPLIED DYNAMICS DIVISION
750 North Maple Road / Saline, Michigan 48176
Area Code 313/429-4956—TWX 810-223-8151

Bulletin S-2500

Printed in USA

572 2.5M

AD/FIVE



AD/FIVE gives you more than hybrid computation speed and accuracy.

You expect speed and accuracy from any computer. You get both, plus major advances in analog/hybrid computer design in the AD/FIVE. Measure these advances in terms of configuration, control convenience, design, patchboard termination, slaving, man-machine ease of communication and hybrid interfacing. You won't be disappointed. You will be impressed. By the unique interface and control structure which gives you equally efficient manual or digital processor control. By the small amount of digital programming required to accomplish hybrid control. By the way the AD/FIVE handles hybrid and interactive analog computation quickly and precisely.

Drift free, virtually spikeless switching performance is easy for the AD/FIVE, assuring you of computational accuracy in your computer laboratory.

Total system "up-time" is due both to the conservative circuit design that has become a trademark of Applied Dynamics products and to the balanced design for static and dynamic performance of the components that make up the AD/FIVE. Most-wanted features of the AD/FIVE include:

- All solid-state addressing system.
- Modular design easily expanded to complete hybrid system.
- Performs in normal ambient conditions without special air-conditioning requirements.
- Operates on 115v a-c, 15 amp, 1 phase supply.
- Completely mobile and easily moved through standard 30" doorways.
- Basic clock is 1 megahertz crystal with accuracy to ten parts per million.
- 10 volt reference source.
- Central overload indicator panel.
- High speed overload detection within 50 microseconds; recovery within 500 microseconds.
- Voltage and current limit circuits protect against patching errors.
- Optional dynamics terminal system available.

You also get complete installation of the AD/FIVE at your application site, full maintenance documentation and a 90-day warranty beginning on the date of installation.

Each AD/FIVE console entitles you to enroll, on a tuition-free basis, up to three persons in the AD/FIVE operator's course and in the AD/FIVE maintenance course. Similar tuition-free courses are also offered with the purchase of peripheral hardware from Applied Dynamics.

We invite you to compare the features and specifications of the AD/FIVE to any other hybrid system. Then, to find out exactly how the AD/FIVE will measure up to your performance requirements, contact your Applied Dynamics representative.

Compatibility, mobility and hybrid computer versatility.

The AD/FIVE interface system design makes optimum use of the control and operational features of both the AD/FIVE and the PDP-11 family of digital computers.

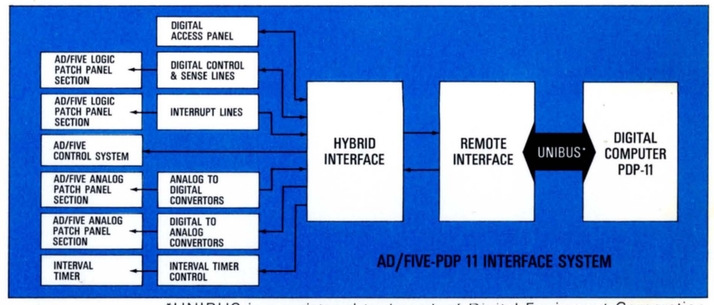
The PDP-11 from Digital Equipment Corporation is a 16-bit, parallel-logic machine using two's complement arithmetic. The computer may be equipped with up to 128 K words of addressable core memory. All computer system components and peripherals communicate with one another on a single high-speed data bus known as the Unibus™. The Unibus concept is the key to the many strengths of the PDP-11 and one of the reasons this machine was chosen by Applied Dynamics for the digital subsystem. Devices on the Unibus are addressed in the same manner as core memory locations and special I/O instructions are not needed. The PDP-11 may be equipped with disk, magnetic tape, paper tape and punched card memory systems. An optional Extended Arithmetic Unit provides high-speed hardware, multiply and divide capability.

The AD/FIVE and PDP-11 are joined by interface hardware to allow digital computer control of the analog and logic modes, repetitive operation, address and data registers, time scale, autohold, problem verify, setting and reading coefficient devices, interval timer, digital ratiometer, analog-to-digital conversion, digital-to-analog conversion, sense lines, control lines, and interrupt lines. The interface can also become master of the PDP-11 Unibus, allowing full use of the priority bus request and non-processor request features. These permit direct memory access (DMA) and cycle steal (CS) modes of operation.

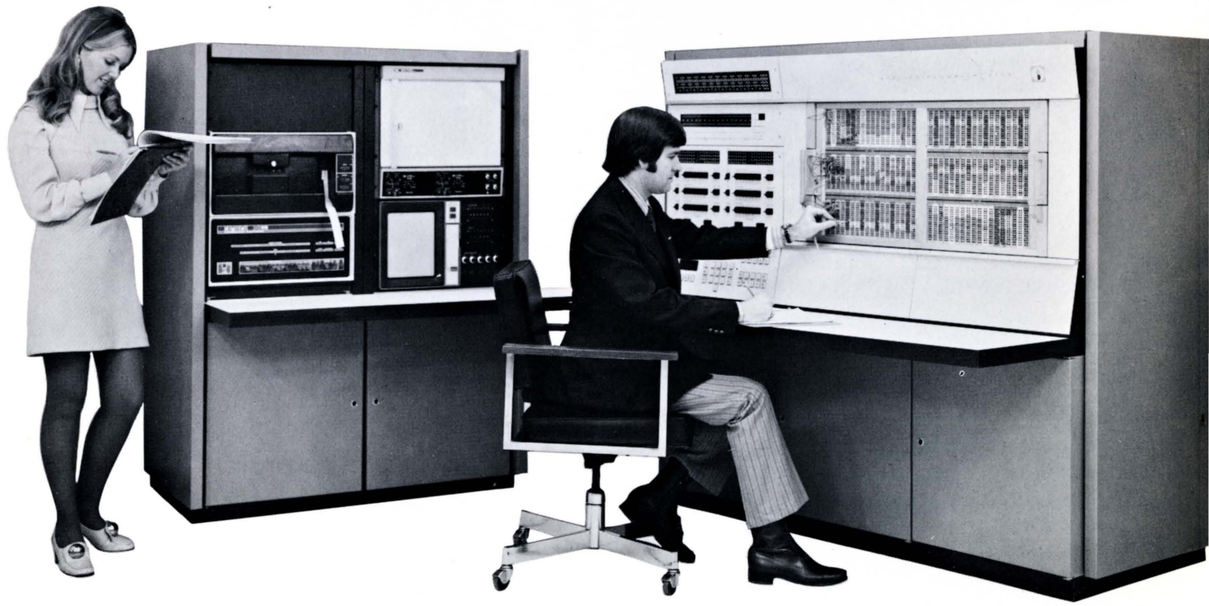
The analog-to-digital converter system in the interface is a 100-KHz, 14-bit plus sign, 10-volt unit. Eight multiplexer channels are supplied with the basic converter. An additional eight channels may be readily added, at extra cost. The A-to-D converter features random access or sequential modes of operation under computer control.

The digital-to-analog converter system includes double-buffered, 14-bit plus sign multiplying D-to-A converters.

The sixteen control lines, sixteen sense lines and eight interrupt lines are terminated in the logic section of the patch panel. The control lines are set and the sense lines read by the digital computer through the interface system. Alternately, an operator may manually set the control lines or read the sense lines through appropriate commands from the optional digital access panel (DAP).



*UNIBUS is a registered trademark of Digital Equipment Corporation.

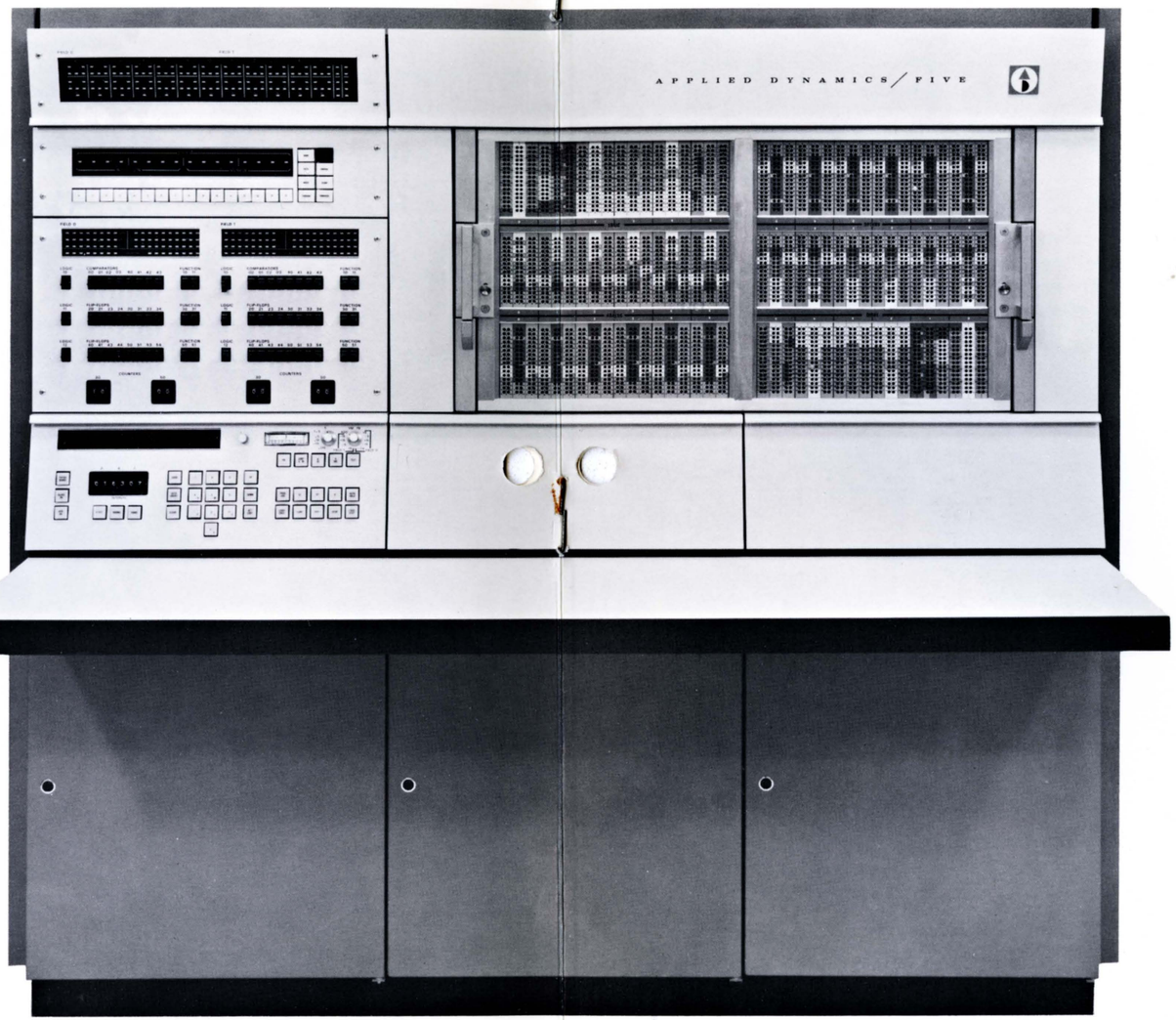


Central Overload Panel alerts you to overload conditions by illuminating indicators for the programmable operational amplifiers and to the fixed and variable diode function generators. Overload panel layout corresponds to the patch panel and includes indicators for "plus" reference, "minus" reference and the address selector unloading amplifier. Six unassigned indicators can be used to accommodate future expansion.

Digital Access Panel permits monitoring of the interface operation and manual access to the interface system. It is used to simplify both programming and maintenance.

Logic Control and Indicator Panel takes a compact, orderly approach to the arrangement of the logic state indicators, analog and logic function switches, comparator override control switches, flip-flop load switches and the binary-coded decimal counter thumbwheel switches.

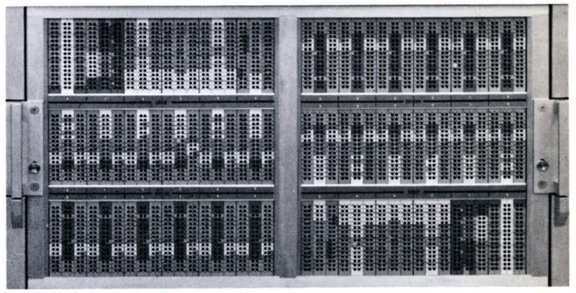
Control Panel contains the in-line readout display for the address selector system, the digital ratiometer, the coefficient device data register, and controls for the interval timer, the address selector system, the analog and logic modes, the time scale, the analog voltmeter and other miscellaneous controls.

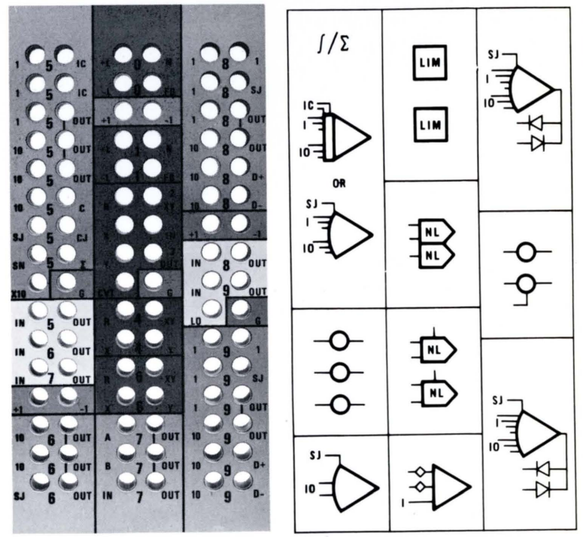


Patch Panel terminates both analog and logic components. The same type of patch cord is used for analog and logic patching. Patch panel motor drives assure uniform patch panel movement between the patchcord tips and the patchbay springs no matter how the patchbay frame is loaded. Configuration is easily modified by changing circuit cards and patch-panel modules. A reversible patch panel may be used with up to a half-full AD/FIVE making it possible for two problems to be patched on the same patch panel for a 50% reduction in patch panel costs.

The upper third of the patch panel is for patchable logic components and controls; the bottom two thirds for terminating analog components. Each third is divided into twelve vertical sections.

The panel contains 36 modules, each with 96 holes. Modules are put into the patch panel in the order and location needed by the user. Patchcords may be inserted or removed with the patch panel engaged and with the power on or off.





A typical patch panel module illustrating component termination.

THE ADDRESS SYSTEM

The all solid-state, serial-entry-type address system uses field effect transistors, rather than relays, for speed and reliability. It is possible to address up to 721 points in the AD/FIVE from momentary-contact push buttons located in the center of the control panel. The system may be used as a 300-readings-per-second multiplexer with the digital ratiometer in hybrid operation, and as a 5,000-readings-per-second multiplexer when used with an analog-to-digital converter. The six addressable classes of components in the system are:

1. Amplifiers
2. Potentiometers
3. Trunks
4. D-to-A converters
5. Non-linear
6. Miscellaneous

The address called for and its corresponding digital ratiometer value appear on the in-line display windows.

A CLEAR button permits the operator to reset the address register at any time during the selection sequence. The address system provides digital computer access through optional hybrid interface expansion modules.

SETTING THE SERVO-POTENTIOMETER

To set the servo-potentiometer, the operator addresses the pot, depresses the DATA ENTRY push button and enters the five-digit value on the serial-entry keyboard. Then he depresses the SET COEF button. In less than 1.5 seconds, the addressed pot sets itself to the desired value. At the completion of the setting operation the control state returns to ADDRESS. If the operator wishes to control the servo pot manually, he uses the buttons labeled UP and DOWN. The pot setting control rate is regulated by a knob on the control panel.

ANALOG MODE CONTROL

The mode of the AD/FIVE integrators is controlled by the push buttons IC (Initial Condition), OP (Operate), and H (Hold). Solid-state "FET" switching circuits switch all three modes in less than 900 nanoseconds.

All integrators are controlled by the analog mode control push buttons, unless the programmer chooses to control individual integrators from the patch panel logic section.

LOGIC MODE CONTROL

Logic mode control push buttons are directly below those for analog mode control. In the Load mode, all logic components are set to their initial states or cleared when appropriate. In the Run mode, clocking signals are applied to all patched elements. The Stop mode interrupts the clocking signals, freezing the logic. The Logic Step push button allows the operator to advance the logic program manually.

LOGIC EXECUTIVE

The LOGIC EXEC push button transfers the console analog mode control from the control panel push buttons to control by the interval timer. This lets the operator control the interval timer from the LOAD, RUN, STOP logic control push buttons and activates the Repetitive Operation mode without any patching.

INTERVAL TIMER CONTROL and TIME SCALE CONTROL

Three two-digit thumbwheel switches, A, B and C, let the operator select three sequential timing intervals for cyclic control of all three analog modes. The three push buttons located below the thumbwheel switches are the basic clock increment selectors for the interval timer. The time scale controls are the x10 and x100 push buttons.

$$\text{Interval} = \frac{(\text{thumbwheel setting}) \times (\text{basic clock increment})}{(\text{time scale})}$$

Intervals from 10 microseconds to 99 seconds are available by using the push buttons and thumbwheel switch controls.

The patch panel gives additional local control. The AD/FIVE interval timer counts clock signals derived from the one-megahertz, crystal-controlled basic clock. It exhibits timing precision far better than analog techniques. In hybrid operation, the interval timer may be controlled from the digital computer, a valuable optional feature.

As for time scale control, it's easily achieved by using the x10 and x100 push buttons. Time scales include x1, x10, x100 and x1000. Local time scale control is available at the patch panel.

OTHER CONTROLS

SLAVE ON BUTTON allows the AD/FIVE to be slaved to another AD/FIVE.

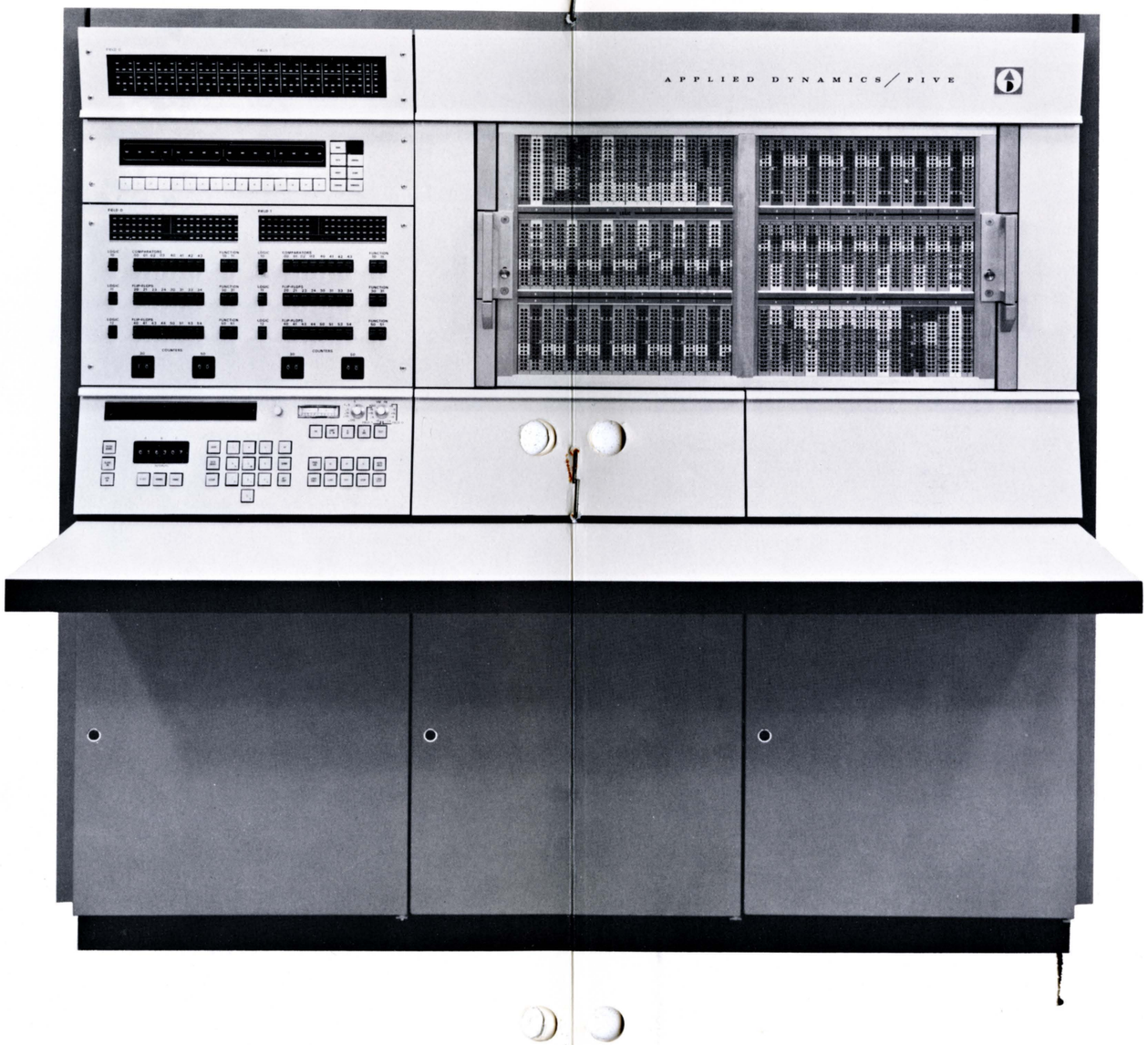
HYBRID ON BUTTON transfers control of the AD/FIVE to the digital computer or the optional Digital Access Panel.

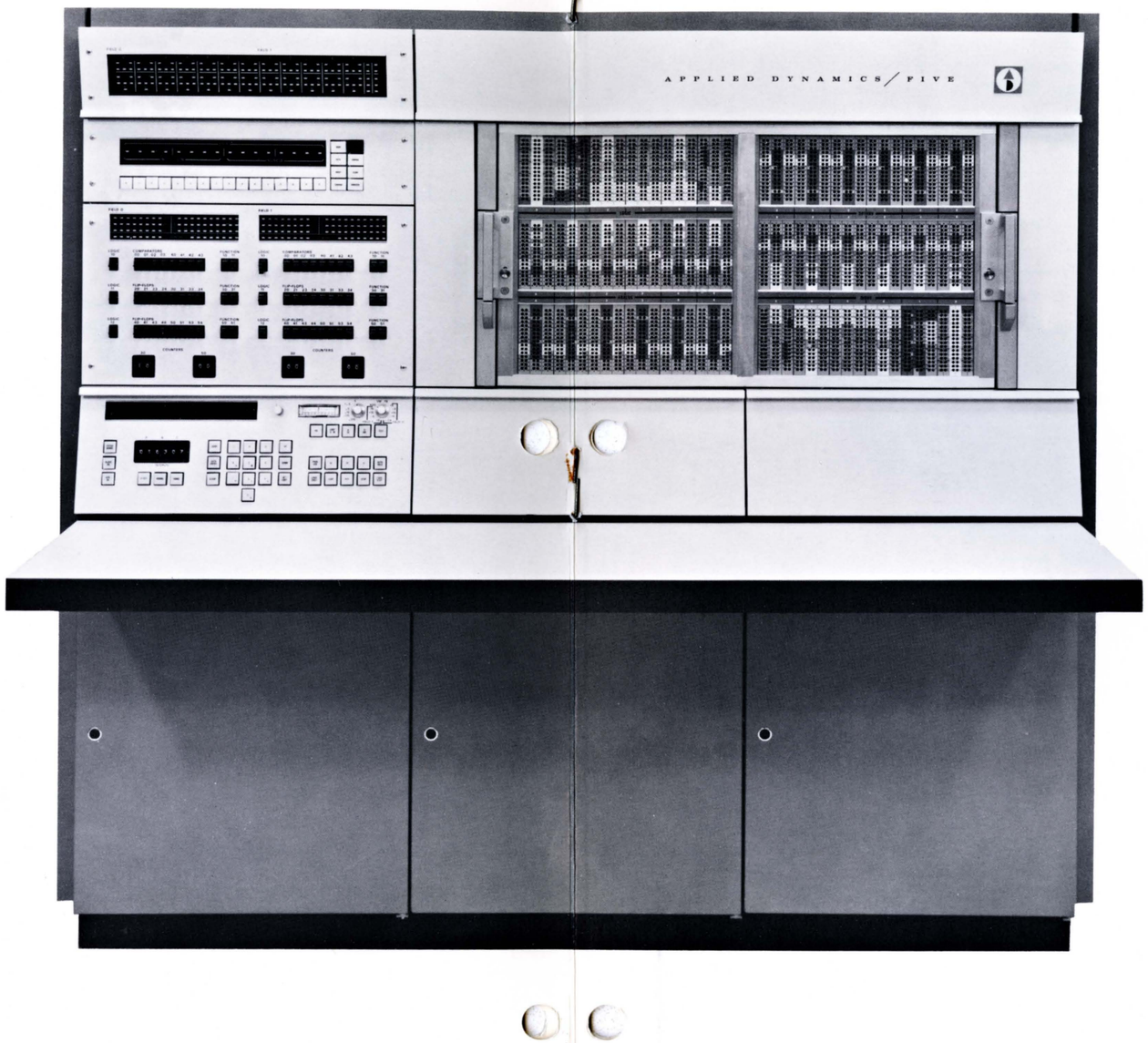
PROBLEM VERIFY push button controls relays that disable certain patch panel reference terminals and activate others. This action allows test initial conditions to be applied to integrators for problem verification.

TEST BUTTON activates the integrator test mode, determining the derivative current present at the summing junction of an addressed integrator in the IC mode.

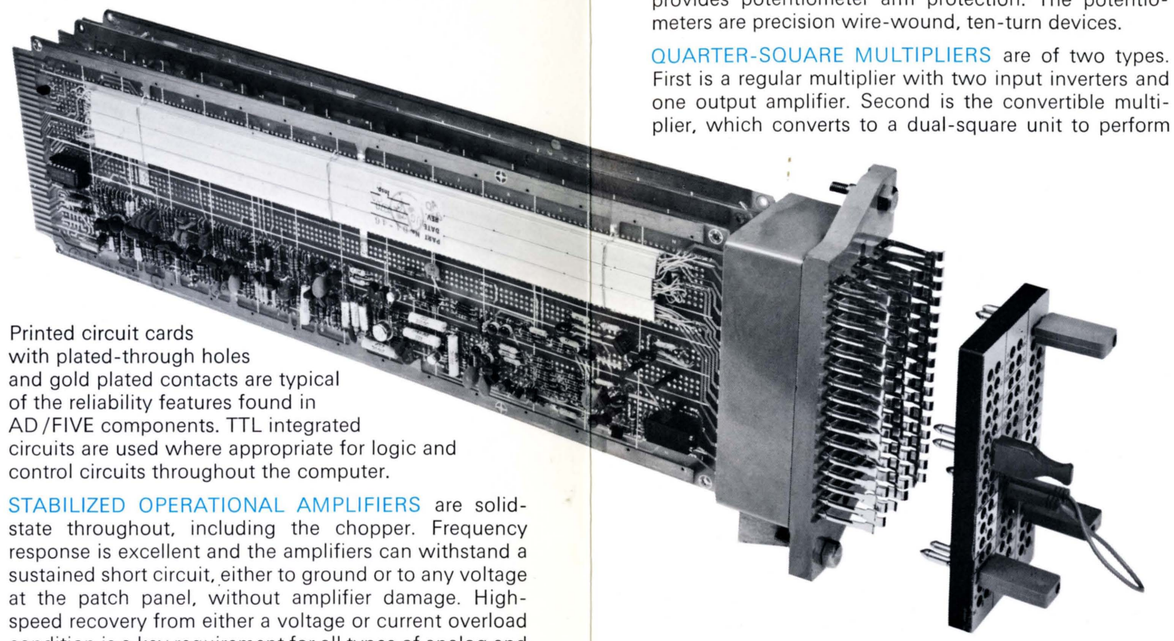
AUTO HOLD BUTTON places all the integrators in the Hold mode automatically when any amplifier or non-linear device goes into an overload condition. If the LOGIC EXEC push button is activated, all logic elements in the AD/FIVE will also freeze, a useful feature when running a hybrid problem.

ANALOG VOLTMETER CONTROLS allow the operator to select voltage range, and to monitor address selector outputs and the power supply outputs.





AD/FIVE COMPUTING COMPONENTS



Printed circuit cards with plated-through holes and gold plated contacts are typical of the reliability features found in AD/FIVE components. TTL integrated circuits are used where appropriate for logic and control circuits throughout the computer.

STABILIZED OPERATIONAL AMPLIFIERS are solid-state throughout, including the chopper. Frequency response is excellent and the amplifiers can withstand a sustained short circuit, either to ground or to any voltage at the patch panel, without amplifier damage. High-speed recovery from either a voltage or current overload condition is a key requirement for all types of analog and hybrid computations.

SUMMER/INTEGRATOR is configured as an integrator by the use of a bottle plug. The high-speed, electronic mode control switching circuitry is normally controlled by the console Operate and Hold busses. For iterative and hybrid applications, this circuitry may be controlled from the logic section of the patch panel. Time scale control is also available from the patch panel. Each integrator network has three gain-one inputs, three gain-ten inputs, two initial-condition inputs and three outputs.

SUMMER/HIGH GAIN AMPLIFIERS have three gain-one inputs, three gain-ten inputs, three outputs and two output diodes which may be patched to limit the output of the summer to either positive or negative voltages, or to generate simple non-linear functions.

SWITCH/SUMMER AMPLIFIERS have two electronically-switched inputs and one unity-gain input. The high-speed input switches are normally closed, configuring the switch/summer as a three-input summer. Control of the 900-nanosecond switches is available on the logic section of the patch panel.

TRACK-STORE NETWORKS may be used with the summer/high gain amplifiers, summer/integrator amplifiers or the inverter amplifiers. There are two track inputs and an initial-condition input available on the patch panel. Track and IC control lines terminate in the logic section of the patch panel. Network switching time is less than 900 nanoseconds.

SERVO-SET POTENTIOMETER SYSTEM is built for accuracy, speed and reliability. Each potentiometer has a d-c servo motor and a motor pulley connected to the potentiometer shaft by a rubber belt drive. There are no gears or clutches to wear out, or to cause backlash. A non-linear resistor (a lamp in series with the wiper arm) provides potentiometer arm protection. The potentiometers are precision wire-wound, ten-turn devices.

QUARTER-SQUARE MULTIPLIERS are of two types. First is a regular multiplier with two input inverters and one output amplifier. Second is the convertible multiplier, which converts to a dual-square unit to perform square or square root operations. It has two input inverters and two terminating amplifiers, one of which is available as an inverter when in the multiply or divide modes. Both multipliers have high accuracy and high bandwidth characteristics with total error at 1 KHz of less than .09%. Sine/cosine generators and log function generators are also available.

DUAL VARIABLE DIODE FUNCTION GENERATOR may operate as two independent, ten-segment, fixed-breakpoint DFG's or a single, ten-segment DFG with variable breakpoints. Each DFG has an input inverter and a terminating amplifier. When neither function generator in the pair is used, the terminating amplifiers may be used as inverters elsewhere in the program. A three-position switch labeled F (fixed), V (variable) and I (inverters) selects the desired mode. Function generator set-up is simple using an optional VDFG calibrator unit.

MASTER/SLAVE CLOCK SYSTEM eliminates the problems of logic systems that operate on leading and trailing edge clock pulses. The AD/FIVE two-phase clocked logic system prevents propagation delay errors, race conditions and erroneous state changes. It is ideal when two consoles are slaved together.

OR/NOR LOGIC GATES have 2, 4 or 6 inputs and both normal and complemented outputs. AND/NAND functions need no further equipment. Each gate has state indicators on the logic control and indicator panel. The dual flip-flops may be used independently or as cells in binary counters, or shift registers. Each flip-flop pair has common Enable and Load inputs. Each flip-flop of the pair has individual Trigger, Set, Clear and Load Set inputs and both normal and complemented outputs.

AD-FIVE/PDP-11 SOFTWARE

OPERATING SYSTEMS

PAPER TAPE SOFTWARE SYSTEM

(for PDP-11's not equipped with magnetic tape or disk)

PAL-11 RELOCATABLE ASSEMBLER

The Relocatable Assembler translates your assembly language program into a relocatable object module. This two-or-three-pass assembler can be used on small systems. It will run with 8K words of core memory and an ASR-33 Teletype.

PAL-11A ABSOLUTE ASSEMBLER

Available in both 4K and 8K versions, PAL-11A lets you define a source program with letters, numbers or symbols and then assemble an object program in absolute binary so that it will be meaningful and usable by the PDP-11. Position-independent code can be assembled with PAL-11A.

ABSOLUTE LOADER

This is used to load programs punched in absolute binary format into core memory.

PAPER TAPE EDITOR (ED-11)

The Editor lets you enter portions of a source program from a teleprinter or paper tape and make corrections or additions to text.

ODT-11 ON-LINE DEBUGGING TECHNIQUE

Paper tape debugging programs are similar to ODT-11R (described below) except they do not work in a relocatable environment. Two versions are available, one being a subset of the other.

10X INPUT/OUTPUT UTILITY PERIPHERAL DRIVER

10X is a service routine that allows single-or-double-buffered I/O processing on an ASR-33 Teletype or with a paper tape. These routines let you make simple assembly language calls in a device-independent manner.

FLOATING POINT AND MATCH PACKAGE (FPP-11)

A number of commonly used subroutines are available to perform arithmetic operations. These routines are re-entrant and position independent to provide maximum flexibility.

HYBRID COMMUNICATION ROUTINES (HCR's)

The HCR's are Fortran callable subroutines written in Assembly language. The extensive HCR LIBRARY includes a wide variety of functions used to control and communicate with the AD/FIVE Analog/Hybrid System.

AD/FIVE HYBRID BASIC (HYBASIC/PT)

HYBASIC is an extension of Dartmouth BASIC to include all of the HYBRID COMMUNICATON ROUTINE (HCR) functions in an interactive environment. It operates in a minimum of 8K core.

PDP-11 LINKER (LINK-11)

LINK-11, like its disk counterpart, combines relocatable object modules into absolute modules, suitable for loading into core.

DISK OPERATING SOFTWARE SYSTEM

(for PDP-11's equipped with magnetic tape and disk)

EDIT-11 TEXT EDITOR (DOS)

EDIT-11 is a text editing program for use with the Disk Operating System. Operated by user commands from the keyboard, EDIT-11 will read ASCII files from any device, make direct changes and write on any device. In addition to basic editing functions EDIT-11 provides for command macros and multiple input and output files. Utility commands such as SAVE, UNSAVE, EXECUTE MACRO, EDIT OPEN, END FILE and EXIT are part of the EDIT-11 package.

MACRO ASSEMBLER (MACRO-11)

MACRO-11 translates symbolic assembly language programs, which may include macro definitions, into relocatable binary object modules.

PDP-11 LINK (LINK-11)

LINK-11 combines the outputs of several assemblies and/or Fortran compilations into one load module. It is a powerful tool when constructing large software systems.

FORTRAN IV

ANSI FORTRAN IV (DOS) is available for preparation of hybrid programs where this standardized mathematical language is more beneficial.

HYBRID COMMUNICATION ROUTINES (HCR's)

As described in column 1 on this page.

HYBASIC (DOS)

HYBASIC (DOS) is an extension of Dartmouth BASIC which includes all of the HYBRID COMMUNICATION ROUTINE functions in an interactive environment. In addition, HYBASIC (DOS) features a powerful file handling capability when used with the Disk Operating System.

PERIPHERAL INTERCHANGE PROGRAM (PIP)

PIP is a general utility program which is used to transfer a file from one system device or peripheral to another. Also included are routines for file and directory maintenance.

ON-LINE DEBUGGING TECHNIQUE (ODT-11R)

This is a core-resident program, operating in a relocatable environment, that lets you debug your binary programs at the console by running them in specific segments and checking for expected results at various points.

TRACE UTILITY

TRACE allows you to trace operations of your program with listing on the output medium.

DIAGNOSTIC PROGRAMS

MAINDEC

MAINDEC is a complete set of comprehensive tests for the PDP-11 hardware such as the CPU test, memory test and peripheral tests.

LINKAGE DIAGNOSTICS (LKD)

LKD is a main line program consisting of thirteen independent subroutines designed to completely check out the hybrid interface system and the AD/FIVE control registers and servo-set potentiometer system. The DAC system, ADC and DRM systems, sense and control system are readily tested by the operator.

The Assembly language version of LKD will operate in the 8K version of the PDP-11 paper tape system whereas the Fortran LKD version is available for PDP-11's equipped with the Disk Operating System.

PROGRAM LIBRARIES

FORTRAN IV LIBRARY—EAELIB

For use with PDP-11's equipped with the Extended Arithmetic element, the library includes such functions as exponential, truncation, logarithm, square root, sine, cosine, plus many more.

FLOATING POINT AND MATH PACKAGE (FPP-11)

A number of commonly used subroutines is available to perform arithmetic operations. These routines are re-entrant and position independent providing maximum flexibility.

As new programs and routines are developed they will become available to PDP-11 users through the PDP-11 program library or from DECUS, the Digital Equipment Users Society. DECUS is a voluntary, non-profit users group whose objective is to serve as an exchange center among users for ideas and information. DECUS maintains an extensive software library, publishes a newsletter and conducts technical symposia twice a year in the U. S. and annually in Europe and Canada.

PERIPHERAL EQUIPMENT

A complete line of analog readout and display equipment is available for the AD/FIVE Analog/Hybrid System. X-Y Recorders, Multi-channel Strip Chart Recorders, Multi-channel High Speed Repetitive Operation Scopes, Storage Oscilloscopes and the Dynamics Terminal System may be added to the AD/FIVE to satisfy the user's requirements.