The
Simulation
Council
Newsletter

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Bits

This month we have Ed Holmes' notes covering the Southeastern Simulation Council meeting on Analog-to-Digital Conversion, which we have condensed considerably because of previous writeups on the same subject in these columns. We also offer a rather complete version of Harold Ehler's recent Western Simulation Council presentation from which only the detailed math has been deleted. Harold described work done at Autonetics to standardize frequently-encountered aerodynamic equations, and a method of mechanizing these standardized equations for the analog computer which might be compared with the use of subroutines for digital computers.

Este mes no mas, senoras y senores.

Pieces

SE S/C MEETING OF 27 SEPTEMBER ON ANALOG-DIGITAL CONVERSION

On September 27, 1957, Radiation, Inc., was host to a meeting of the Southeastern Simulation Council, when 33 members met at the Belcena Hotel in Melbourne, Florida, to discuss "Analog-to-Digital Conversion." After a welcome and a short history of the Simulation Councils by Dave Prince (Federal Telecommunications Lab., Atlanta, Ga.) each person present introduced himself.

Hoeppner on Analog-Digital Conversion

Ed Holmes (E. G. Holmes & Assoc., Atlanta, Ga.) then introduced Conrad Hoeppner (Radiation, Inc.), who described some problems of analog-digital conversion and methods of overcoming them:

1) Establishing a binary number by first comparing a voltage equal to one-half the range of the converter with the unknown voltage. If the latter is greater, the most significant binary digit is a 1, and the unknown voltage is next compared with a voltage equal to ½ of the converter range. Again, if the unknown voltage is greater, the second most significant binary digit is a 1 and the next comparison is made against ½ maximum voltage, etc. Comparisons whenever the unknown voltage is smaller of course result in a zero, and a reduction in the reference voltage for the next comparison.

2) Mr. Hoeppner also described the 640 fixed-styli plotter manufactured by Radiation which actually plots digital information in such small increments that it appears to be in analog form.

Burns on A-D Converters in Systems

Ed then introduced Meryl Burns (Radiation, Inc.) who discussed "Analog-to-Digital Converters as Applied to Simulation Systems." Mr. Burns pointed out that in data-processing applications it is sometimes necessary to convert analog information to digital form because of the mathematical processes involved. He first described a digital-to-analog converter whose output can be fed to an analog computer for certain mathematical operations.

Simulation Councils, Inc.
Dr. R. M. Howe, University of Michigan, Ann Arbor, Mich.; Chairman, Steering Committee.

Western Simulation Council
Dov Abramis, Convair-Pomona, Calif.; Chairman, Steering Committee.

Midwestern Simulation Council
Tom Wood, Detroit Tank Arsenal, ORDNC-RE.1, Center Line, Mich.; Chairman, Steering Committee.

Eastern Simulation Council
Hideo Mori, Hydel Inc., 99 First St., Cambridge 41, Mass.; Chairman, Steering Committee.

Southeastern Simulation Council
M. David Prince, Federal Telecommunications Laboratory, Atlanta, Ga.; Chairman, Steering Committee.

Central Simulation Council
Bruce Estes, Department 669, McDonnell Aircraft Corp., St. Louis, Missouri; Chairman, Steering Committee.

Canadian Simulation Council
F. W. Pruden, Analog Computation and Simulation Group, Mechanical Engineering Div., National Research Council, Ottawa, Canada; Chairman, Steering Committee.
The output of the analog computer can then be fed to an analog-to-digital converter. This is particularly useful when computations are required on a real-time basis.

Mr. Burns also described a digital delay synthesizer. The analog input goes into an analog-to-digital converter, the output of which is fed into a high-speed digital memory. A control device can then program the output from the memory to a digital-to-analog converter to subsequently recover the analog information when and as desired.

Dave Prince commented that the delay is limited by the storage capacity and went on to say that for alarm applications in logging operations the average of several samples is desired, as well as the digital value of each sample.

Graeber on Shaft-Angle Digitizers

The next speaker, Ralph Graeber (RCA, Patrick Air Force Base, Florida), gave "A Review of Shaft-Angle Digitizing Systems" in which he described many shaft-angle digital encoders which are now in use or have been described in the literature. At present there are three general categories: (1) The brush-commutator units, (2) phase-comparators, (3) photoelectric types.

In general, the brush-commutator units are the simplest and, by the use of tricks such as "evelin," binary, "V"-brush logic, ambiguity bits, etc., they meet the majority of digitizer requirements. In cases where high inertia, high torque, or gearing is a problem, photoelectric units can be used. Phase-comparison devices are more in the nature of laboratory instruments; however, when properly used, they are capable of high precision. Low, intermediate, or high-precision encoders may be required, depending on the application. A typical low-precision requirement would be the digitizing of various types of aircraft instrument data for use in conjunction with an airborne digital fire-control computer. An encoder now available off the shelf may meet such requirements quite adequately. A digital encoder for precision radar may require intermediate precision. Photoelectric encoders, possibly using cascaded gearing, seem to be the most popular type for this kind of application. In the field of super-precision the phase comparators seem to offer great promise, though units available at present require a good deal of complex electronic circuitry.

 Asked by Captain E. Dingley, Jr. (Electronic Communications, St. Petersburg, Fla.), what he considered low, medium, and high accuracy, Mr. Graeber replied, "My own classification is that one part in less than a thousand would be low accuracy, one in a thousand to one in a hundred thousand would be medium accuracy, and high accuracy would call for one part in over a hundred thousand."

Leshan on A-D Converters and Data Transmission

The final speaker, Jay Leshan (Milgo Corp., Miami, Fla.), discussed "Analog-to-Digital Conversion As Applied to Data Transmission Systems." He described a system which Milgo is manufacturing currently for Patrick Air Force Base to transmit range, elevation, and azimuth information. In this system a set of three analog-to-digital converters feed digitized information to a transmitter. At the receiving end the signals are detected and preserved in the digital form.

The analog-to-digital converter uses an operational amplifier whose feedback resistor is made up of 13 series elements, each of which can be shorted out by means of an individual relay. The output of the amplifier is compared with a reference voltage, and a clock pulse sequentially closes the relays which short the resistive elements of the feedback resistor until the output is equal to or greater than the reference voltage. When this happens a turn-off pulse is fed to the clock generator, and the relay whose closure caused the pulse is left open. The clock generator then closes the next relay unless another turn-off pulse is received, etc.

The turn-off pulses are fed to a single-shot multivibrator, the output of which keys the transmitter to produce a 13-bit code.

Asked by Bob Marquand (Radiation, Inc.) how long it takes to sample, Mr. Leshan answered "0.1 second."

Captain Dingley asked whether the data come directly from the radar, and was told "No; another computer does translation and we take their information."

In reply to a question, "How long does it take to sample one bit?" Mr. Leshan said "About three microseconds."

This prompted Bob Marquand to ask whether sampling can be done faster than three microseconds.

Mr. Leshan replied that he was sure it could be done in 0.5 to 1.0 microsecond. Then in answer to the question, "How much current is required to switch the cores?" he said, "About 60 milliamps."

Following this discussion the meeting adjourned for lunch, after which the Simulation Council members were conducted on a trip through Radiation, Inc.

**WS/C Meeting of 14 Nov. on "Standard Simulation Circuits"**

Fifty-nine representatives of 21 organizations gathered at Autonetics, a division of North American Aviation, in Downey, California, on the 14th of November for a meeting of the Western Simulation Council on the subject of "Standard Simulation Circuits."

**Ehlers on Standard Equations**

Don Abrams (Convair, Pomona, Calif.), chairman of the Western Simulation Council, introduced Harold Ehlers (Autonetics) who presented a well-prepared paper which, with projected slides, described in mathematical and physical detail the work done by his group to standardize and mechanize certain frequently-recurring equations at Autonetics. Some details have had to be omitted from this writeup, but the objectives, methods, and results described should be of interest to all who are concerned with analog computation.

According to Harold, the early designers of the Simulation Facility recognized that they had two basic alternatives in the computer wiring. On the one hand, they could bring the computing element inputs and outputs to an adjustable wiring board and use the computer in a general-purpose manner. On the other hand, if it was decided to use the computer for a single purpose only, they could permanently wire the computing elements to solve this problem. In the latter case, particular
solutions would be obtained solely by adjustment of switches, potentiometers, function generators, etc. The Typhoon computer, constructed for the Navy by RCA, is to some extent an example of a special-purpose facility, designed specifically to solve three-dimensional aircraft flight equations. At first the computing components were not permanently wired, but later modifications have caused significant portions of this facility to be so wired. I believe that if the lessons that dictated the permanent wiring could be expressed by a single word, this word would be reliability.

As computer circuits become more complex, even the most skilled troubleshooter is hard pressed to locate a failure. And the time required to troubleshoot goes up markedly with the complexity of the problem. A ball-park figure for a problem containing 150 amplifiers might be one hour. This hour includes the time the operator is unaware that trouble exists, as well as the time required to locate and repair the failure. Intermittent types of failures or simultaneous failures can increase this time appreciably. On this basis a single failure per 8-hour work day would cause a reduction in operating efficiency of 12\%\%. Eight such failures would mean zero efficiency.

Consider the types of failures which can occur. In the first place there are failures of the electronic equipment—tubes, potentiometers, fuses, switches, resistors, capacitors, etc. An all-out attack has been made on such failures over the past several years with gratifying results. Even so, on a problem of 150 amplifiers and associated computing equipment, we can expect that one or two failures will occur in an eight-hour day. This leaves only about 80\% of the day for operating time and for other types of failures. On the Typhoon computer with 400 amplifiers it would not be unreasonable to expect that 50\% of the time would be used to correct equipment failures.

A second type of failure is induced by the human operator, who may construct a simulation circuit that doesn't behave as it was intended to, or may make an operational error in wiring, switch setting, or switching. Either a computer or operator error, undetected in the course of a study, might very well invalidate all the data obtained. Hence rigorous time-consuming checking procedures are generally adopted to establish an initial reliable reference solution. These checking procedures frequently consist of: (1) Complete static checks, (2) dynamic checks of portions of systems, and (3) over-all comparison of transient response with data obtained from digital computers.

The permanently-wired special-purpose computer has the advantage that the simulation circuits used are tested and proved, and temporary external wiring is reduced to a minimum with a consequent increase in wiring dependability. However, it has the distinct disadvantage of limited flexibility even on the specific problem for which it was wired.

The advent of the removable patchboard early in the development of the analog computer was a definite improvement. It allowed the storage of tested and proven circuits, but the new patchboard itself had to be very reliable. It has met this challenge of reliability, proof of which is the extensive use made of stored problems in all modern simulation facilities.

But has this method of problem storage eliminated any further need for progress in this direction? Is the efficiency of operation of a modern facility now determined purely by electronic component failures? Has circuit setup and checkout time been reduced to the point at which it represents a minor portion of the operating time? The answer to all of these questions is clearly NO!

Consider how the removable patchboard is used. An engineer studies the problem which requires investigation and writes the equations describing it. In this he may have a choice of several alternatives, any one of which will give the same final result.

Next he devises a simulation circuit for solving the set of equations. Several different engineers undertaking the same problem would quite probably end up with different circuits.

The problem is then wired on removable patchboards while off of the computer. The wiring is double-checked and the next phase of the problem, verifying the validity of the simulation circuits, begins. During this period circuit modification is made as required, scaling is adjusted, and the human errors are corrected. This phase usually consumes a substantial portion of the initial test period, after which the engineer has a proven simulation circuit. The prepitch boards can be stored and later used for any further tests of the same system with a minimum of preliminary checks, and without circuit modification.

The most costly part of this process is the circuit development and checkout. Can the effort expended on this phase be substantially reduced or eliminated? If an analysis of the problems studied shows that many
use the same form of equations, then the answer is Yes! But in making the analysis we must remember that the equations for similar problems can be written in different forms, so the similarity may not be immediately evident; the physics of the problem must be studied.

In establishing the standard circuit, certain conditions must be satisfied. First, the various possible applications of the circuit must be determined, and the equations stated in the most efficient form for these applications. Compromises may have to be made, but application of this principle to flight-control problems has been accomplished with little difficulty. Second, the circuit must be independent of the physical size of the object being studied. This dictates that the equations must be normalized. Finally, the standard circuit must be available in such a form that its application can be readily understood by the engineer who will be using it.

The standard circuit bears the same relationship to the analog computer as the subroutine does to the digital computer. Each is a tested, proven, and frequently-recurring portion of whole programs. Standard circuits are applicable to all fields of simulation. As a specific example, consider a typical use—the simulation of aircraft flight-control systems.

A large percentage of the problems solved on the simulation facility of the Flight Control Department of Autonetics is concerned with the dynamic behavior of aircraft and automatic flight-control systems. Perhaps 75% of all our flight-control system studies can be grouped into the following categories:

1. Lateral perturbation
2. longitudinal perturbation
3. longitudinal trajectory
4. five-degree-of-freedom aircraft maneuvers
5. six-degree-of-freedom perturbation
6. six-degree-of-freedom trajectory
7. flare-out for landing.

The similar characteristics that distinguish these studies are:
1. The lateral-perturbation study included airframe simulation of the roll, yaw, and side-force equations with the aerodynamics represented as linear about a specified flight condition.
2. The longitudinal-perturbation study was similar to the lateral-perturbation study, except that airframe lift, drag, and pitching moment equations were simulated.
3. The longitudinal-trajectory simulation was used for missile studies in which the airframe accelerated or decelerated rapidly. The lift, drag, and pitching-moment equations defining the motion of the airframe in the longitudinal planes are simulated with the aerodynamic coefficients expressed as functions of Mach number.
4. The five-degree-of-freedom aircraft maneuver was studied on all high-speed fighter-type aircraft to determine the extent of the inertial cross-coupling that existed during high-speed maneuvers between the lateral and longitudinal planes. The lift, side force, and the three-moment equations were simulated with the aerodynamic coefficients generally expressed as functions of attack and sideslip angles.
5. The six-degree-of-freedom perturbation was used on both aircraft and missile studies when the investigation, among other things, was concerned with speed control. The three-force and three-moment equations were simulated assuming constant aerodynamic coefficients. Generally, the non-linearities associated with gyro signals were represented properly.
6. The six-degree-of-freedom trajectory study varied from the perturbation study only in that the aerodynamic coefficients were now represented as functions of Mach number. This simulation was employed principally in evaluating missile systems.
7. The flare-out-for-landing simulation was employed in evaluating automatic as well as manually operated landing systems for both airplanes and missiles. The lift, drag, and pitching moment equations were simulated, with aerodynamic coefficients expressed as functions of the angle of attack and nearness to the landing surface.

That part of the simulation which was similar from project to project was the airframe equations of motion. In the cases considered, the airframe represented from 50% to 85% of the total simulation circuit; therefore establishing standard circuits for the airframe represented an appreciable saving in circuit mechanization and checkout time.

Generally, the control system varied to such an extent that it appeared (at least for the present) to be a less fruitful area for circuit standardization. However, it should not be overlooked as an area for further investigation because, by using a subroutine approach, a repertoire of control systems might be devised that could be used in conjunction with the various airframe standard circuits described.

In considering standardization of the airframe equations of motion we should note that there are several separate axes systems which must be resolved:
1. Earth axes, which define the position of the aircraft with respect to the earth.
2. Airframe axes, which define the angular orientation of the aircraft in space.
3. Wind or stability axes, which define the aerodynamic forces and moments.
4. Gyro or inertial axes, which define the gyro signals.

A convenient method of presentation is to write the equations of motion with respect to the airframe axes and, by matrix methods, make the necessary transformation of forces and velocities to and from this axes system. However, each standard circuit must be considered individually, as the method of presentation of the equations which is most efficient for one application is not necessarily best for all.

Harold then described longitudinal-trajectory simulation in detail (too much detail for presentation here). Slides were projected which showed all the equations with definitions of all terms. Then he showed a diagram of the analog computer circuit for solving the equations, with an explanation of the symbology used and of operation of the circuit.

It was pointed out that variables shown in the circuit had a bar above them. The bar indicated that at that point in the circuit the voltage would equal 100 times the ratio of the variable to its predicted maximum value. This normalization procedure solves the scaling problem and enables the circuit to be used on different sizes and types of missiles and aircraft. In the standard circuit the gains are adjusted so that potentiometers are normally set at about 0.2. Analyses have shown that this generally provides adequate range for circuit adjustment.

To use such a standardized circuit the operator must compute an estimate of the maximum values of cir-
circuit parameters, as he would do normally in circuit scaling. These values are entered in a table which lists all parameters in the standard circuit for which maximum values are required. From this, a brown-line copy of the circuit is made to show the exact quantity of each variable at all points of the circuit.

Next, a table is completed listing circuit potentiometer settings as ratios of maximum values of circuit parameters. This operation is arithmetical and can be performed either by technical computer personnel from the listing of circuit maximums, or by a simple program on a small digital computer. This work completes preparation of the airframe portion of the circuit. When the simulation circuit for the control is added, the engineer is ready for the simulation study.

The foregoing technique accomplishes the following:

1. It reduces the time required to prepare the simulation circuit.
2. It provides tested and proven circuits for the airframe simulation.

But having developed a standard circuit, why should it be rewired each time it is used? Wouldn't it be more efficient to have it permanently wired so that only the non-standard part of the system need be rewired for each problem, especially if the standard wiring could be kept separate from the non-standard so that modification of the latter could be made readily?

**New Patchboard Design**

This line of reasoning led to a new computer patchboard design (Fig. 1). Fig. 2 shows that two levels of circuit wiring exist. The matrix of pins on the extreme left makes contact with the computing elements. Wiring for the standard circuit is contained within the etched circuit board. A complete matrix of contacts is attached to the etched circuit board; removable patch cords provide access to both the standard circuit and the computing elements not used within the standard circuit.

In the normal use of this board, the simulated control circuit, as well as minor modifications to the standard circuit, are wired externally with the normal type of patch cord. Only a small percentage of wires is changed from project to project and these wires are readily accessible.

Fig. 3 shows the wiring on a normal patchboard, and indicates the difficulty of making control circuit changes. Fig. 4 shows the same problem with only non-standard wiring exposed; we can see the ease with which control-circuit changes can be made using the new pre-patch panel.

Certainly a technique such as Harold described, which reduces set-up time, facilitates trouble-shooting, and increases reliability, is a real contribution to the simulation and analog computation art.

**Autonetics Simulation Facility**

After coffee and something of a smorgasbord of pastry, courtesy of Autonetics, Harold and his colleagues took us via two buses (these California aircraft factories are really spread out!) to their simulation facility.

The equipment is installed in a straight-line configuration in a rectangular room about 150’ long and 30’ wide. Air conditioning is provided by five units of 7½-ton capacity, which drive air through the computing racks and exhaust into the room. In addition, the room has its own air-conditioning system*.

The power to the computing system includes 60-cycle single-phase, 400-cycle single-phase, and 28 vdc. The 60-cycle power is provided by a transformer which is used exclusively by the computing facility and is capable of providing 200 kw of power. The actual power consumption is approximately 168 kw, 28 of which are required for operation of a Bendix Flight Simulator.

The ±100-volt reference for the facility is provided by a single unit, designed by New Jersey Electronics Company, which can supply five amperes of current. A twin supply is in a standby position to be used in case of failure of the operating unit. These units are used alternately so that the over-all operational hours on each is approximately the same.

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*Could this be proselyting propaganda?
A high-quality ground bus for the computer is provided by a copper tube of about 2 1/2 square inches cross-sectional area, which is connected to a pipe driven into the ground beyond the depth of local ground water.

There are a total of 464 EA operational amplifiers. Of these, 356 are independent amplifiers with 160 capable of being used as integrators; 36 amplifiers are associated with servo resolvers; 48 are used with the electronic multipliers; and 24 are wired as relay amplifiers. However, all of the amplifier terminals are brought out to the patch bay so that if they are not used in the special-function application they can be used as isolation amplifiers. This equipment also includes 12 precision dual-channel resolvers; 10 channels of time-division-type dual-product electronic multipliers; and 40 servo multipliers, each with five multiplier potentiometers. Fifteen of the servo multipliers have four of the potentiometers with 17 tap points which are brought out to a special unloading control panel. Each of these servos with the tapped potentiometers provides a capacity to generate 80 functions of a single variable.

The Bendix Three-Dimensional Flight Simulator includes, in addition to the three-axis flight table, 78 d-c operational amplifiers, time-division-type electronic multipliers with a total capacity of 15 products of five independent variables, and modulators and demodulators for conversion of signals to and from the flight table.

The recording equipment contained within the facility includes eight Offner 6-channel recorders, two Brush 6-channel recorders, two Electronic Associates 30" x 40" 2-armed vertical plotting boards, one Electronic Associates 30" x 40" single-arm horizontal plotting board, and 10 Moseley 11" x 17" flat-bed-type plotter/curve followers.

This equipment has been used for (1) training of pilots for missile flights, (2) development of flight-control and navigation systems, (3) investigation of airframe structural dynamic loads. In the course of development of the flight-control and navigation systems, the simulation circuitry provided for tie-in of the flight-control system hardware, the AN digital computer, and a full-scale mockup of the hydraulic systems in both planar and three-dimensional simulated flights. The simulation of the flight with the flight-control system hardware involved the use of rate and attitude gyroes mounted on the flight table. The pilot, training, on numerous occasions, was carried out on a three-dimensional basis in which the aerodynamic coefficients were generated as functions of Mach number as well as of other variables. Cockpit simulation was and is being employed extensively. Numerous simulation studies of rocket engines and nuclear reactors also have been performed.

The Flight Control Simulation Facility equipment is operated on both an open- and closed-shop basis, although the closed-shop approach is preferred. Continual changes and improvement of the computing facility are taking place and the computing consoles are not identical in detail; experience has shown that skilled operators, who are constantly associated with the equipment, can get the most out of it.

Information (Without Theory)

As pointed up elsewhere in this issue of I&A, this is the thirtieth anniversary of their publication. Certainly congratulations are in order. The I&A circulation of 26,000 attests to the value of the magazine to instrumentation and allied fields. This is also the fiftieth Simulation Council Newsletter, the last 22 of which have been published by I&A. Your Editor, in offering his congratulations, would like to add that he has never enjoyed a better business relationship. Both Richard Rimbach, the publisher, and Milt Aronson, the editor, have meticulously kept their part of every agreement—written, oral, or implied. Of greatest interest to my readers is one of the first: That they would not attempt to influence the contents of the Newsletter in any way. However, admitting that some professional influence might give you a better Newsletter, I am glad to be able to report that no one connected with I&A has ever commented on what does or does not appear in the Newsletter. Mmmm—wonder if they read it!

Computer Events

Central Simulation Council Meeting
Date: 3 February 1958; 2:00 PM
Place: Monsanto Chemical Co., Lindbergh and Olive Street Road, St. Louis 24, Mo.
For information write Theodore J. Williams, Research and Engineering Div., Monsanto Chemical Co., Lindbergh and Olive Street Road, St. Louis 24, Mo.
Subject: Four papers on process uses of analog computers will be given.

1958 High-Speed Computer Conference
Dates: 12-14 February 1958
Place: Louisiana State University, Baton Rouge, Louisiana
For information write Dr. Billie Townsend, Mathematics Department, Louisiana State University.

Eastern Simulation Council Meeting
Date: 17 February 1958
Subject: Applications of Large-Scale Simulators, Including Environment
Schedule: Steering Committee 10 AM; Tour of facilities 10 AM; Study Groups 11 AM; Technical Sessions 1 PM.
For information contact Hideo Mori, Hydel, Inc.; Robert Yaeger, Electronic Associates.

Western Joint Computer Conference
Date: May 1958
Place: Los Angeles, California

1958 National Simulation Conference
Place: Dallas, Texas
The conference will be sponsored by the IRE Professional Group on Electronic Computers and the Dallas Section of the IRE. For information write Louis B. Wadell at 3905 Centenary Drive, Dallas 25, Texas.