Bits

Many of the more enlightened (ahem!) of those in the computer field have realized for some time that not only are there problems which can be more effectively handled by analog means, and other problems which can be more effectively handled by digital means, but that there are also problems which cry out for a combination of these techniques.

In the past there has been much talk and some action (your Newsletter has mentioned some work by John Burke and others at JPL), but to the best of our knowledge it has concerned particular operations or special problems (e.g., the use of a digital multiplier in an otherwise analog setup, or the use of an analog integrator in a special-purpose digital computer). Progress has been hampered by the fact that proponents of each technique have been so busy in their own backyard that they have not had the time, or in many cases the inclination, to look over the fence and recognize their neighbor's good points, much less build a style so they could get together. Furthermore, an extremely accurate and incredibly fast interpreter was needed before they could actually work together effectively, and analog-to-digital and digital-to-analog conversion equipment accurate enough and fast enough has not in the past been available.

For these reasons we believe that the work reported under PIECES this month, and similar work by others, presages the most important advance in Simulation since the development of the electronic differential analyzer. Read all about it!

Got no THOTS this month - - - there are months like that!

Pieces

The Marriage of Figuresgalore

Sixty-five representatives of 21 organizations attended The Western Simulation Council meeting at the now-fabulous Ramo-Wooldridge Corporation (see illustration) on Thursday afternoon, 12 January, and were treated to an explanation of what might seem to many to be more like a shotgun wedding of the Martins and the Coys than an opera.

Pfeffer Describes a Large-scale Problem

After Norm Irvine (Aerojet-General Corp., Azusa, Calif., and the retiring chairman) turned his job over to Bill Waddell (Giannini DATEX Div., Pasadena, Calif., and the new Chairman of the Steering Committee of the Western Simulation Council), Irwin Pfeffer (Ramo-Wooldridge Corp., Los Angeles, Calif.) got the discussion under way, saying that R-W has a very special large-scale simulation coming up in the very near future, in which they are going to try to tie their 300-ampifier Electronic Associates' analog computer and their Remington-Rand ERA 1103A digital computer together to perform a three-dimensional simulation of tremendous proportions—the simulation of a weapons system (under development at Ramo-Woold-
ridge) which will perhaps require all 300 analog amplifiers and the entire 1103A, operating (they hope) in real time. The EPSO conversion equipment which they have on order is expected to do the tying, with 15 information channels in each direction. The requirements as to speed and accuracy are rather staggering.

Irwin referred to a block diagram which he had drawn on the greenboard. It showed that the missile is to be represented entirely by the analog computer. The simulation of autopilot, accelerometer, aerodynamics, and thrust characteristics will probably take about 200 amplifiers. The output of this section will be three components of missile body accelerations.

The kinematics of the system will be computed by the digital computer which will perform the necessary coordinate transformations and then solve the equations of motion by integrating the acceleration computed by the analog section. The three components of velocity and position thus made available are to be sent to the analog section on six of the information channels. In the actual system, missile velocities and positions are to be measured by a radar, which will also be simulated by the analog computer. Radar noise will be simulated by a noise generator and added to the velocity and position signals. The combinations will then be modified by the simulated radar dynamics to produce the analog of the velocity and position as measured by the radar.

The three components of velocity and three of position will be sent to the guidance computer, which is to be simulated by the 1103A. The guidance computer will first smooth the data (which has noise on it), then it will solve the guidance equations and generate commands. As there may be noise on the output calculations of the actual guidance computer, noise may have to be introduced in the simulation in a digital form.

In nature, kinematic equations are solved automatically and perfectly, so it will be necessary to do the best job possible on the digital computer. Therefore it is planned to solve these equations at least 100 times a second; perhaps 500 times a second.

Why Both Digital and Analog Techniques are Required

Dr. W. N. Schart (Convair-San Diego) asked, "Why do you do your

To this Irwin replied, "We don't know that we can. We hope to, but we might have to slow the problem down." One reason they wish to operate in real time is that it may be necessary to make quite a number of runs. Many hundreds of solutions may be required for any one statistical point.

Irwin was asked what sort of accuracy they expect to get from the acceleration measurement. "What is the validity of starting with a rough input and carrying out the computation with extreme accuracy?" To this cogent question, which has probably bothered all of us at times, Irwin gave the clearest answer we have heard. "The missile itself will be an analog device. Any accelerometer which might be in it is not likely to be more accurate as a piece of hardware than its representation on the analog computer. But the system will work in such a manner that even though the accelerometer may be no better than one part in several hundred, the actual accuracy that can be achieved by the guidance computer will be considerably better than that. So the analog computer will be used to represent the missile, while the digital computer will be used to represent the guidance computer. By hooking them up in this way, we will be able to actually simulate the accuracies of the system."

Hans Meissinger (Hughes Aircraft Co., Culver City, Calif.) offered one more comment on accuracy which may be achieved by using digital for kinematics and analog for dynamics. "In kinematics you often have to subtract large numbers to get small numbers. This operation must be per-
formed with extreme accuracy if the result is to be even reasonably accurate. This is difficult with analog—easy with digital.”

Norm Irvine asked, “Is there a reason for doing the data-smoothing in a digital form? Wouldn’t there be a lot gained by doing the smoothing on the other side of the converter?”

Pfeffer answered, “This is just the first way we thought of doing it. We may change.”

Jack Sherman (Lockheed Aircraft Corp., Van Nuys, Calif.) asked, “Aren’t you going to be performing some of your calculations twice? For example, to find your missile body accelerations won’t you have to get your missile body velocities and positions in analog form first?”

Irwin agreed, saying that yes, there will be a repetition of missile position and missile velocity in both the analog and digital machines, but that they will not be fed over.

“That’s what I mean; you will be computing this on two different machines,” Jack said. “Are you going to have any cross-comparison?”

Irwin replied, “A good point. We might have.” And then got a laugh by adding doubtfully, “If we have any channels left over.”

Gumbel observed, “The answer is No!”

Irwin returned to the subject of computing times. “The analog computer is by nature a real-time device, so there is no problem there. But some of the digital calculations have to be performed at the rate of hundreds of times per second. We believe that this will be possible if we use a great deal in programming and if the conversion equipment is so fast that it doesn’t impose any additional delay on the system.”

Programming With a Converter Clock

Irwin showed a diagram to illustrate what he meant by “care in programming.” The principle may be explained by assuming that there are some computations, for instance the kinematics, which the digital computer must repeat at a very fast rate, which we may assume to be 100 times per second. Call these the “A” computations. Other computations, like those of the guidance computer, may not be required so often, perhaps 50 times per second. Call these the “B” computations. Then some miscellaneous “C” computations may be required still less often, perhaps 25 times per second.

The read-in of analog information to the digital computer and the presentation of digital results to the analog computer by the conversion equipment, and to some extent the operation of the digital computer, are controlled by the converter clock, which in this example would be adjusted to produce 100 control pulses per sec.

On the first converter clock pulse of a cycle, all data from the converter will be read into the digital computer, which will proceed with all of the A computations, part of the B computations, and perhaps part of the C computations. On the next clock pulse the results of the A computations will be presented to the converter for conversion to analog signals, and all of the converted analog data will be read into the digital computer, which will make an A computation and then proceed to complete the B, and perhaps do some more of the C computations. On the next clock pulse A and B results are presented for conversion, the necessary data are read into the digital computer, and A, the first part of B, and perhaps some more of C are computed. Following the next pulse the computations of A, B, and C are all completed and the four-pulse cycle is repeated.

The program is fairly tricky and involves using the interrupt feature of the 1103A. In order to achieve the required speed, reading and writing times must be held down to hundreds of microseconds at the most. Actually the specs require that the conversion itself take place in the order of 100 microseconds. Slow conversion would seriously hamper the 1103A.

George West (Ramo- Wooldridge) pointed out that the interrupt feature of the 1103A was such that it was not necessary to pad (allow “slow-over” time) before each clock pulse but only at the end of a complete cycle. The longest time for any digital operation is 400 microseconds (for division) so if you happened to cut in at the beginning of such an operation you would have to wait until the instruction was completed. But there is no such uncertainty as to the time of sampling because that is controlled by the clock pulse.

Low on the EPSCO Conversion Equipment

After this system explanation by Pfeffer, Henry Low (Ramo-Wooldridge) took over to explain in some detail the operation of the EPSCO* conversion equipment which they expect to get. The electronic details are beyond the scope of this Newsletter*, but roughly the system consists of an absolute-value circuit, a comparator, a digital-to-analog converter, and a programmer. An analog signal ranging between −100 and +100 v is converted by the absolute-value circuit and compared to a converted digital value in the middle of the comparator range to determine the most significant digit of a 17-digit binary number. Depending on this digit, the analog voltage is next compared with another value in the middle of the remaining range interval to determine the next digit. This process is repeated until the analog voltage is digitalized to 17 places plus sign. Specifications require that the comparator be accurate to within 0.1% of full scale, or 1 millivolt, whichever is greater, and have a dynamic range of 1 to 100,000.

Henry showed schematic electronic diagrams of the absolute-value circuit, the comparator, and the digital-to-analog converter, which caused a good bit of comment. In fact, in one amusing case Bob Leger (Convair) pointed out that a circuit would not work because it showed equal positive and negative feedback around an amplifier. Henry had sketched the circuits on an overgrown tablet, and when he wondered out loud “How do I get out of this?” someone brought down the house by suggesting “Turn the page!” **

After Henry turned the page and explained everything else to everyone’s apparent satisfaction, Bill Wad- dell asked for questions in general. Norm Irvine observed that they expect to compute the kinematics approximately 100 times a second. “This implies that you are thinking in terms of 50-cps information.”

Henry answered, “About 30. This conversion equipment is really about the peak of the state of the art—many vendors wouldn’t even touch our specifications.” Then turning to Bill Waddell—“That right?”

Bill’s enthusiastic “Absolutely true” drew understanding laughter. Dov Abramis (Convair-Pomona) wanted to know when they expected

* i.e., over your Ed’s head.

** Once your Ed. asked someone who should know how EPSCO accomplished the feats of conversion which they claim, and was told “They ain’t sayin’”. Couldn’t be they purposely throw Henry a curve!? 
Ramo-Wooldridge analog-computing facility features air-conditioning, engineered lighting, sound-absorbent ceiling, draperies—and 300 new EA amplifiers plus associated equipment.

the equipment, and was told some time in October.

Stan Rogers said they would have similar equipment delivered to Convair-San Diego in about two months, so he suspects that they will know before others how some of the things discussed will work.

McLeod wanted to know if anybody had seen any equipment which would meet these specifications actually in operation anywhere.

Henry said he had seen some devices that worked at much lower speed (laughter), and that Bob Bennett (Ramo-Wooldridge) had talked to someone at Lincoln Labs who has a device which is very fast, but that when he and Irwin Pfeffer were back there they tried to get to see it but couldn't even get into the lab (more laughs). There is one channel, he added, which is slated to go to Shell Development (Emeryville, Calif.). They don't have it yet. It isn't working yet. But they have been invited to go back to Boston to see it work!

Meissinger asked about the data-smoothing on the analog side, and was told that it will be left as a series of step functions.

Sherman asked Henry if he could describe the digital-to-analog smoothing circuit.

Henry explained that the current sources furnishing the analog voltages were pulsed on or off and would stay at that way until new information came in.

Returning to the subject of actual hardware actually working, Jim Marrin (J. B. Rea Co., Santa Monica, Calif.) said he didn't want to sound as if he was advertising, but that J. B. Rea has two devices operating in the field at the moment, and a third on the floor which isn't yet complete, but which should be ready for rent about the middle of February. The unit is on a par with the EPSCO equipment in many respects. It has been operating at 10,000 samples per second, but this rate can be stepped up to 100,000.

S. I. Klein (National Cash Register) asked whether or not they thought the 1103A would keep up with the converter.

Irwin passed the question to George West, who said that they didn't know because all of the equations are not yet written in final form. "Certainly if you should run all of the channels wide open to send numbers to the 1103A, it couldn't do much except perhaps add them and send them back. There would not be very much time to do computing. Running in true time will depend on how many computations have to be made at the fast sampling rate, how many at the slower rate. These questions are not yet answered. We will be able to make a good guess after some more experience with a current all-digital simulation problem."

About that time Irwin broke up the discussion by announcing that coffee and cookies awaited outside.

* * *

Coffee, Cookies—and R-W

After the coffee and cookies and the always-pleasant meeting with old and new friends during the break, we were shown into the (almost literally) plush R-W analog computing facility. The extent to which they have gone to provide ideal working conditions is far beyond anything we have seen so far: Separate air-conditioning systems for the room and the equipment; excellently engineered lighting; sound-absorbing material on the ceilings, and draperies completely covering all walls.

Oh yes, and the computing equipment! About 300 new EA amplifiers and associated equipment arranged in the form of 3 L's* backing three corners of the room. (S'matter with that other corner, boys? Let's not be chintzy.)

Well, we thought that was the grandest till we walked next door to see the 1103A and were dismayed to find deep wall-to-wall carpeting there! However, we felt better when Jack Sherman explained that digital equipment has a way of dropping digits and, as digits are fragile, the carpet was to prevent any breakage.

*One of the L's was straightened out for the picture at the top of this page.

Information
(Without Theory)

We have a letter from Gomer L. Davies, President of the Davies Laboratories, 4705 Queensbury Road, Riverdale, Maryland, enclosing information on their Magnetic Tape Time-Delay Simulator (Dead Time Simulator) which sounds as if it might be a handy gadget to have around. But Gomer (perhaps pointedly) mentions no price, so "Quien sabe?"

Basically the equipment consists of a tape mechanism servo-driven at a speed proportional to one input signal while another signal is pulse-width modulated and recorded on the tape to be played back subsequently and demodulated to give a voltage varying ±1 v from 5 volts, the variation being proportional (within 1%) to the original signal and delayed by from 1 to 10 seconds (or with additional equipment up to 2 minutes).

We also have a letter from Everett T. Sprague, Business Manager of Control Specialists, Inc., 115 E. Arbor Vitae, Inglewood, Calif., telling us of their Desk Model Analog Computer "designed primarily for equipment simulation and the solution of linear differential equations, but capable of simulating certain nonlinearities, (such as threshold and hysteresis) often found in physical systems."

* * *

If you want more info, we urge that you read "What Automation Means to America" by Carroll W. Boyce in Factory, September 1955, because this is the most lucid article we have read on "why industry must automate." And if you wonder why this Newsletter is concerned with automation, we will point out that the same computer techniques which make possible simulation as we practice it today also make the difference between mechanization and automation.
You Are Invited

The Chairman of the various Simulation Councils often receive letters from men who want to come to the Council meetings, and who ask permission to do so. This is not necessary. The Councils are informal groups; all who wish to come may do so at any time; no advance permission is required. Anybody interested in simulation technique is not only cordially invited to attend any of the Simulation Council Meetings but is urged to do so. We need your thoughts. To help you know what to expect, some brief program notes will be included in each calendar item in the future.

Western Simulation Council
Date: 8 March 1956
Place: Firestone Tire and Rubber Company, Guided Missile Division, 2525 Firestone Boulevard, Los Angeles, Calif.
Subj: Electro-mechanical (servo) vs. electronic multiplication—resolution—function generation.
Clearance: No clearance will be required for the discussion part of the meeting, but Security Clearance of Confidential will be required for the tour of missile facility which will follow.

Midwestern Simulation Council
Date: 19 March 1956
Place: Cincinnati Milling Machine Company, Cincinnati 9, Ohio.
Subject: "Mathematical Formulation and Transfer Functions"; Tentative speakers: Larrow (University of Michigan); Hamer (Electronic Associates); Robinson (Wright Air Development Center)
Discussion will emphasize (1) Mathematical formulation or direct formulation? (2) How to set up transfer function most effectively? (3) Are you simulating or computing?

Eastern Simulation Council
Date: March 23, 1956
Place: Waldorf-Astoria Hotel—New York City
Host: Mid-Century Instrument
Subject: Function Generation


Electronic Measuring Instruments, by E. H. W. Banner. 1955. Macmillan Co., New York 11, N. Y. 395 p. $8.50. 9 in. Survey of electronic measurement for very high and very low values, for remote indication, and for increased accuracy. Intended for the instrument engineer, the user of instruments, and the student with some knowledge of electronics.


Basic Synchros and Servomechanisms, by Van Valkenburgh, Nooger & Neville, Inc. 2 v. c1955. John F. Rider, New York 13, N. Y. 137–121 p., unbound. $5 (82.75 each). 9 in. "The text of this—course, as currently taught at Navy specialty schools, has now been released for civilian use." Features large pictures on elements and fundamentals.

Mathematics of Engineering Systems (Linear and Non-linear), by Derek F. Lawden. [1954.] John Wiley & Sons, New York 16, N. Y. 380 p. $5.75. 9 in. Presents a number of mathematical methods which may be used to analyze the behavior of various "physical systems" such as electronic amplifiers and oscillators, electric circuits, servomechanisms and regulators.