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BIBLIOGRAPHY ON SERVOMECHANISMS

II. CLOSED-LOOP SYSTEMS

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BIBLIOGRAPHY ON SERVOMECHANISMS (CLOSED-LOOP SYSTEMS)

PREFACE

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SPECIALIZED SYSTEMS AND THEIR APPLICATIONS

AUTOMATIC AND MANUAL CONTROL

SPECIALIZED SYSTEMS AND THEIR APPLICATIONS

UNSPECIFIED SYSTEMS

499 MULTI-LOOP COMBINED CONTROL SYSTEMS.
M.V. Meerov
Avtomat.i.Telemek.,24(5),628-639,May,1963,U.S.S.R.
The author shows that absolute invariance in multi-loop control systems can be realized only in the case of combined systems, namely those in which the deviation control principle and the load control principle are used simultaneously: the invariance with - accuracy is realized if the contructed system structure is of the class of structures stable under unlimited increase of amplification coefficients.

SENSITIVITY IN SAMPLED-DATA SYSTEMS.
D.P. Lindorff
I.E.E.E.Trans Auto Control,AC-8(2),120-125,April,1963,U.S.A.
See item 523

500 SOME ASPECTS OF SAMPLING SCHEMES IN FEEDBACK CONTROL SYSTEMS.
E.I. Jury
Regelungstechnik, 11(3),98-107,March,1963,Germany.
The author classifies and enumerates the various sampling schemes arising in discrete systems, discussing simply the methods of analysis and synthesis usually employed. A detailed discussion of two important sampling schemes which appear in industrial and biological processes is introduced with particular emphasis on pulse-width modulated feedback systems and sampling frequency modulated control systems. The paper also includes six various applications of sampled-data systems, together with discussion of the theory developed in the course of such investigations.

FLIGHT CONTROL

501 HOW TO EVALUATE AUXILIARY POWER UNITS.
M. Voytish
Hydraul. & Pneumat.16(5),132-137,May,1963,U.S.A.
An auxiliary power unit (APU) usually provides means of guiding and controlling a missile after it has been fired: in the past, the main criterion for judging the APU was its useful output per unit of weight; now it is realized that the success of a missile weapon system depends not only on the APU's performance, but its performance as part of the weapon system. Evaluation of the APU must therefore take into account the overall mission objective, the weapon system chosen to accomplish that mission, the requirements this places on the APU, the methods used to fulfil these requirements, and the interaction of these methods on the remaining sub-systems of the weapon system.

OPTIMAL ROCKET-HEADING CONTROL SYSTEM
D. M'Cormack
Control Engng,10(6),85-89,June,1963,U.K.
See item 525

A UNIFIED APPROACH TO SYNTHESIS OF LINEAR SYSTEMS
P.P. Shipley
I.E.E.E.Trans Auto.Control,AC-8(2),114-120,April,1963,U.S.A.
See item 527

FLIGHT CONTROL

Position

502 FUEL MINIMIZATION IN FLIGHT VEHICLE ATTITUDE CONTROL.
W.H. Foy
I.E.E.E.Trans Auto.Control,AC-8(2),84-88,April,1963,U.S.A.
The problem of designing a single-axis rigid-body flight vehicle attitude controller to minimise control fuel consumption is formulated in the frame-work of system optimization theory. A performance measure consisting of the integral-square position and rate errors plus control fuel expended, with arbitrary relative weighting factors, is employed, and Pontryagin's maximum principle is invoked to show that the controller which minimizes this measure is of the bang-off-bang type. Calculations are presented, and an explicit design solution given for the problem of a minimum fuel space vehicle attitude control.

503 SYNTHESIS OF FEEDBACK CONTROLS USING OPTIMIZATION THEORY - AN EXAMPLE
F.J. Ellert, C.W. Merriam
I.E.E.E.Trans Auto.Control,AC-8(2),89-103,April,1963,U.S.A.
Illustrates the use of optimization theory in the synthesis of a linear time-varying feedback control by carrying out the design of an aircraft landing system, the method employed being the parametric expansion method. A number of different controls are synthesized by selecting different functional forms for the weighting factors appearing in the error index formulated from performance requirements: these controls are compared by presenting the landing trajectories of the aircraft.

PROCESS CONTROL (Manufactured articles and operational variables)

Position

504 ELECTRO-HYDRAULIC POSITIONER SIMULATION.
R.P. Auyang, G.N. Tsilibes
Instrum.Control Syst.,36(5),145-153,May,1963,U.S.A.
Details are given in this schematically illustrated article of a servo positioning system comprising an electrically operated pilot valve which controls a piston-actuated positioner: a block diagram illustrates the system and indicates how the electrically-operated pilot spool controls pressures which themselves control the piston actuator position to produce a feedback current. An experimental model of the system was constructed based on the results of analogue computer simulation, information from which was instrumental in producing good agreement between the mathematical and experimental models.

505 LASER MAY RIVAL GYRO AS GUIDANCE DEVICE FOR SEA, AIR, SPACE.
Elect.Engng,82(4),290,April,1963,U.S.A.
A new closed-circuit laser, developed by Sperry Rand Corp. U.S.A., may soon rival the gyroscope as an automatic guidance device for ships, planes, missiles and space vehicles. In operation, the laser produces two counter-rotating light-beams conducted through four helium-neon gas tubes positioned to form the sides of a square: four mirrors, three reflective and one partially transparent, fitted at the corners of the square bend the light beams around the ring; at one corner the two beams are picked-off through the partially transparent mirror and fed into a light-sensing device. When the turn-table assembly representing a space vehicle is static relative to the stars, the photodetector senses no difference in frequency between the light beams: the smallest rotation of the assembly, however, will cause one beam to travel slightly further than the other round the ring to close the circuit, thereby producing a
(continued)

505 (Contd.)

frequency variation in the beams proportional to the rate of rotation. This difference (actually a measure of rate) may then be used to re-direct the orientation or attitude of a vehicle to maintain its correct flight path. The laser will also measure the angular displacement with an accuracy equal to 0.00006 deg. on a compass.

Power

OBTAINING PRECISE INDUCTION MOTOR SPEED.
M.J. Campos-Costa
Control Engng,10(6),92-93,June,1963,U.S.A.
See item 512

507 PHASE-LOCK SYSTEM FOR THE GENERAL RADIO 1209-B OSCILLATOR.
H.G. Andresen
Rev.Sci.Instrum.,34(4),346-348,April,1963,U.S.A.
Describes the design parameter and performance of a simple automatic phase-control system for a GR 1209-B triode oscillator in which frequency modulation was achieved by varying the B+ voltage of the oscillator tube: consequently, the resonance circuit needs no modification, while the system will change neither the frequency range nor the calibration of the oscillator.

508 VOLTAGE REGULATOR COMPARISON CIRCUITS.
C.F. Young
Control,6(60),90-92,June,1963,U.K.
The three main problems in the design of an automatic voltage regulator in which the controlled voltage is compared with a reference are outlined as:- (1) achievement of satisfactory long-term accuracy, (2) very low efficiency of most reference circuits, (3) undesired delay (possibly followed by an oscillatory overshoot) which can occur between a change in generator voltage and the corresponding change in output from reference circuit. When a controlled alternating voltage must be refectified, it is difficult to remove the resulting ripple without introducing the third phenomenon referred to above: in one approach, described herein in detail, application of the circuit introduced by Boucherot and extensively developed by Steinmetz to the production of a poly-phase output from a single-phase supply, gives an arrangement with little power loss.

Pressure

ELECTRIC SIGNALS CONTROL WELDER'S AIR PRESSURE AND OIL FLOW.
C.H. Baillie
Hydraul.& Pneumat.,16(5),118-121,May,1963,U.S.A.
See item 513

509 REACTOR FLUID USED FOR HYDRAULIC CONTROL ACTUATOR.
Prod.Engng, 34(11),39-41, 27 May,1963,U.S.A.
Control-rod actuator modulates the power output of large atomic reactors: sealed within the reactor pressure vessel, the unit incorporates operating and safety features specified by the Atomic Energy Commission. The hydraulic control system uses low-level command signals (4 in.lb) to control the power piston that positions
(continued)

509 (Contd.)

the load: to withdraw the control rod from the reactor, the control sleeve is moved up, cutting off flow out of the control port, thereby inducing system pressure rise to force up the power piston. To hold the rod in a fixed position, control sleeve motion is arrested; a servo piston, linked to the power piston, continuing to move upwards until flow through the control port stabilises control pressure: in this condition, hydraulic pressure and load are balanced and the control rod or load holds without drift. For normal rod insertion, the control sleeve is moved downward increasing flow through the control port, decreasing system pressure and thereby lowering the power piston. Emergency insertion of the control rod to shut down the reactor is accomplished by opening 'scram' ports in the power piston cylinder; this drops hydraulic pressure beneath the piston to zero, allowing it and its load to drop instantly.

Quantity (include flow etc.)

ATOMATIC FORCE BALANCE CHECK WEIGHER.
P.A. Jassey
Radio & Electron.Engr.,25(5),429-431,May,1963,U.K.

510 AN AUTOMATIC FUEL METER.
L.A. Klimin, L.P. Gorin
Avtom.Prom., (1),29-30,Jan.,1963,U.S.S.R.
This article describes and illustrates the operating principles of a new, automatic fuel-metering device, suitable for both constant and fluctuating engine-operating conditions: no component wear or breakage was observed with the prototype in 15,000 measurement cycles, accuracy under constant engine-operating conditions being to within 0.2 per cent. In operation, the time taken to exhaust one or a series of specific volumes of fuel (variable within the range 0 - 300 cm.cub.) is measured.

FUEL MEASUREMENT IN FLIGHT VEHICLE ATTITUDE CONTROL.
W.H. Foy
I.S.A. Trans.Auto.Control,2(3),(2),84-88,April,1963,U.S.A.
See item 502

Selection (sorting, batching, etc.)

511 A COBBLE DETECTOR.
P.J. O'Donnell, R.F. Barron
Instrum.Control Syst.,36(5),302-306,May,1963,U.S.A.
During high-speed rod-mill rolling of steel, stock becomes occasionally diverted from the desired path, and since it is impracticable to stop the mill motors, the common practice is to shear the remainder of the billet into small, readily removable pieces as quickly as possible; this diminishes the amount of stock which would otherwise tangle or cobble. The cobble detector is a device which will detect when a cobble occurs and initiates shearing action automatically: the prototype machine described is digital in design and is almost completely fail-safe in its internal circuits, this being accomplished by the use of a redundancy technique.

Speed

CLOSED LOOP IMPROVES SYNCHRONOUS MOTOR CHARACTERISTICS.
W.J. Waffner
Control Engng,10(6),113,June,1963,U.S.A.

512 OBTAINING PRECISE INDUCTION MOTOR SPEED.
H.J. Campos-Costa
Control Engng,10(6),92-93,June,1963,U.S.A.

In the control system discussed, inverter frequency is commanded by a variable-frequency oscillator dependant, within limits, on the voltage supplied by a phase comparator through a low-pass filter: the comparator (a 0.5% bistable multivibrator) receives two signals, one from a rotating switch on the motor shaft, and one from the control oscillator or line frequency: the former sets the comparator, the latter re-sets it. Thus the multivibrator generates at a certain point, a rectangular pulse of amplitude E, the duration of which depends on the phase angle θ between rotor position and control signal; at synchronization, this pulse has a period of $2\pi/\omega_0$. The low-pass filter transmits only the d.c. component, attenuated by a factor K: thus, voltage V_1 has the value

$$V_1 = K \frac{2\pi - \theta}{2\pi} E$$

and a variation in θ causes a change in V_1 which determines the variable oscillator frequency.

513 ELECTRIC SIGNALS CONTROL WINDER'S AIR PRESSURE AND OIL FLOW.
G.H. Baillie
Hydraul. & Pneumat.,16(5),119-121,May,1963,U.S.A.

Winding the armatures of electric motors is facilitated by a machine which chooses the correct number of windings, controls winding speeds, indexes the armatures, and shuts itself off when they are wound. Such a machine must have a variable-speed arrangement for handling various size wires and maintaining constant linear speed irrespective of winding diameter: to meet these requirements, the system described has a pressure-adjustable air circuit and speed-adjustable oil circuit, both controlled and sequenced electrically.

506 VOLVO-HYDRIC: NEW AUTOMATIC GEARED TURBINE TRANSMISSION FOR COMMERCIAL VEHICLES.
S.O. Kronogard
S.A.E.Prep.,Automot.Engng Congr.,Jan.,1963,U.S.A.

This system is a fully-automatic geared transmission whose main elements are torque converter, simple planetary gear, and control system: the torque converter has one impeller and three turbines; one turbine serves as a rotating reactor: in operation, all elements rotate and transmit useful torque and power. Three forward phases of operation and one reverse, braking, and control system are described: a hill-holding and anti-creep arrangement is incorporated. In buses fitted with the transmission, improved acceleration, ease of handling, smoothness, and reduced noise and smoke have been reported: field tests indicate highly wear-resistant friction elements, and servicing is simple.

Temperature

514 THE CLOSED-LOOP CONTROLLED SYSTEM.
N.A. Anderson
Instrum.Control Syst.,36(5),126-130,May,1963,U.S.A.
A heat exchanger is one of the most elementary processes on which a three-mode controller can be justified. The action of a three-mode controller to control a heat exchanger is described in detail, including the effect of each element in the loop.

515 CONTROLLED TEMPERATURE OIL BATHS FOR SATURATED STANDARD CELLS.
P.H. Lowrie
Nat.Bur.Standards Tech.Note 141,Aug.,1962,U.S.A.
Two oil baths for the temperature control of saturated standard cells have been developed by the N.B.S. for operation at 28 C and 35 C respectively, short-term control to better than ± 0.001 C with day-to-day variations no greater than 0.002 C being achieved by the use of a mercury-toluene thermo-regulator incorporating a temperature anticipating device. The circulating system limits temperature gradients in the oil to less than 0.001 C across any 10-inch section: the baths include pre-heat and drain tanks as well as the main temperature regulated tank to facilitate the insertion and removal of cells and to minimize oil spillage.
(from J.Nat.Bur.Standards,67C(2),190,April-June,1963,U.S.A.)

NONLINEAR SYSTEMS

516 INTEGRAL REPRESENTATION OF ZERO-MEMORY NONLINEAR FUNCTIONS.
J.C. Hsu
Bell Syst.tech.J.,41(6),1813-1830,Nov.,1962,U.S.A.
Integral representation of zero-memory nonlinear functions offers promise as an analytical method for nonlinear control systems study. A review of work performed at Bell Laboratories and elsewhere on the use of these representations is presented, with particular emphasis on nonlinearities often encountered in feedback control systems. In general the integral representations are useful only insofar as the resulting expression can be readily evaluated. The use of Bennett functions systematized the formulation of these integrals: the numerical results of a large class of the integrals can then be given by the tabulated Bennett functions. A comprehensive bibliography is appended.
(from Electr.Engng.Abstr.,66(765),562,May,1963,U.K.)

Stability

517 THE STABILITY OF NONLINEAR SYSTEMS OF THE SECOND ORDER.
J.C. Gille and S. Wegrzyn
Bull.Acad.Polon.Sci.Ser.Sci.tech.,10(9),49-56,1962,Poland.
Demonstrates by rigorous mathematics and examples, using non-linear equations of the second order and a conveniently chosen Liapunov function, the previously postulated principle that a nonlinear relationship, in which the associated system is stable for all values of its variables, possesses unlimited stability.
(from Electr.Engng Abstr.,66(765),562,May,1963,U.K.)

ANALYSIS

518 DIVERGENT OSCILLATIONS AND THEIR EXCITATION IN CONTROL SYSTEMS WITH TWO SATURATION-TYPE NONLINEAR ELEMENTS.
E.A. Freeman, G.C. Barney
Proc.Instn Elect.Engrs,110(6),1096-1106,June,1963,U.K.
Control systems are considered which have two saturation non-linearities separated by a linear phase-advance network. Because of the high-pass-filter characteristics of the latter, distortion

(continued)

518 (Contd.)

produced by the first saturation element is amplified, and changes the gain given to the fundamental component by the second saturating element: it is shown that the change so caused produces a phase shift through the saturating elements; a joint describing function for the two elements is derived and used to predict sustained oscillations. These are found to be unstable, and once disturbed, diverge to infinite amplitude: methods of excitation are examined, and the amplitudes of step functions and sine waves which just excite divergent oscillations are determined. The power level of a noise signal which also excites a divergent transient, when applied to the input of the system, is not determined; analysis of the system when noise is injected into the second saturating element indicates, however, that noise has a stabilizing influence.

INTRODUCTION TO THE ANALYTICAL TREATMENT OF CONTROL PROBLEMS.
R.D. Lautenschlager
Elektrot.Maschin.(Aut.),79(20),505-513,15 Oct.,1962,Austria.
See item 531

519 ON LIMIT CYCLING CONTROL SYSTEMS.
A. Gelb, W.E. Vander Velde
I.E.E.E.Trans Auto.Control,AC-8(2),142-157,April,1963,U.S.A.
A class of limit cycling feedback control systems is investigated using a simple and practical analytic tool to determine input-output dynamic response characteristics. The nature of the dynamic response adaptivity of such systems is shown, and a model derived for the dynamic response characteristics of the amplitude of the limit cycle: experimental verification is given for each of the principal theoretical results.

520 METHOD OF INVESTIGATING AUTOMATIC CONTROL SYSTEMS CONTAINING LINEAR ELEMENTS WITH VARIABLE PARAMETERS.
TIL.1(b) N.T. Kuzovkov
U.K.A.E.A., DEG Inform.Ser.262(CA),1962,U.K.
(Translated from Vestnik Moscow Univ., Ser.Matemat.Mekh.Fiz. Khim,(6),1958,U.S.S.R.)
Automatic control systems exist which, besides containing constant-parameter elements, may also possess one or more whose parameters vary with time: very often these 'variable' elements are described by low-order linear differential equations, the coefficients of which are known functions of time. The study of a complicated system of automatic control consisting of a large number of 'constant' elements and one or more 'variable' elements, could be considerably simplified by replacing the variable- with constant- elements equivalent to them in some way: the stability and quality of control of the system could then be studied by ordinary (e.g. frequency) methods, developed for systems with constant parameters. It is obvious that, for any given fixed moment in time, replacement of a variable element by an equivalent constant one, is perfectly feasible: the present report presents the basis for the possibility of the above substitution, and puts forward a construction for the transfer function of this equivalent.

THE PARTLY COMPENSATED NETWORK IN AUTOMATIC CONTROL SYSTEMS.
G. Fava
Elettrotecnica, 50(3),137-140,March,1963,Italy.
See item 538

ANALYSIS, ANALYSIS-SYNTHESIS

521 STEP PROCEDURE IN ANALYZING CONTROL SYSTEMS.
J.E. Valstar
Instrum.Control Syst.,36(5),132-137,May,1963,U.S.A.
The author presents eleven steps which can simplify the problem of analyzing a control system and determine its dynamic response: these are as follows:- draw a block diagram; trace the signal, add sources of disturbance; re-draw the diagram in signal-effect form; label paths between blocks with known signal units and ranges; identify response form for each block; compute the steady-state gain for each block and the loop; compute the frequency response curves for each block; plot total-magnitude and total-phase curves for the complete loop; find the ultimate proportional band and ultimate period; examine critical points on Bode chart to see that the chart is correctly drawn.

522 SYSTEM GAIN FROM SIGNAL FLOW GRAPHS.
S.H. Becker
Control Engng,10(6),83-84,June,1963,U.S.A.
Although the power of the signal flow graph method has been well recognized by circuit designers, its usefulness in the control field, in preference to block diagrams, has been appreciated by comparatively few. This article presents the basic definitions and rules for flow graphs, and shows how to construct and solve one for a Ward-Leonard system, finding open- and closed- loop gains directly from the flow graph.

TESTING FOR PLANT FUNCTIONS IN PRESENCE OF NOISE AND NONLINEARITY: 1 OUTLINING THE OVERALL PROBLEM.
F. Hennig
Control Engng,10(6),67-70,June,1963,U.S.A.
See item 556

ANALYSIS-SYNTHESIS

523 SENSITIVITY IN SAMPLED-DATA SYSTEMS.
D.P. Lindorff
I.E.E.E.Trans Auto.Control,AC-8(2),120-125,April,1963,U.S.A.
Examining the sensitivity of sampled-data systems to plant variations and load disturbance in terms of two fundamental configurations, it is shown that the sensitivity function of such a system containing no continuous feedback is theoretically limited if the plant possesses low-pass response characteristics. Since the limitation imposed by sampling can be removed by continuous feedback, consideration is given to a sampled-data system containing a continuous minor-loop feedback path. A sensitivity function is derived which measures the individual effectiveness of the inner and outer loops in de-sensitizing the system, thereby providing the basis for a realistic design approach: the sensitivity function is then applied to a design example.

SOME ASPECTS OF SAMPLING SCHEMES IN FEEDBACK CONTROL SYSTEMS.
E.I. Jury
Regelungstechnik,11(3),98-107,March,1963,Germany.
See item 500

SYNTHESIS

524 DESIGN OF OPTIMUM DYNAMIC CONTROL SYSTEMS FOR NONLINEAR PROCESSES.
C.L. Jones and others
Indus.Engng Chem: Fundamentals,2(2),81-89,May,1963,U.S.A.

A procedure for designing optimum dynamic control systems for single- and multivariable- linear and nonlinear processes by means of linear and nonlinear control elements is presented. It consists of a set of well-defined steps for establishing control system specifications, synthesis being effected by matching any given physical process or mathematical model with a sequence of control elements of increasing complexity in a nonlinear sense, each such choice, in turn, being optimized through steepest ascent determination of the values of the coefficients of the control function terms.

525 OPTIMAL ROCKET-HEADING CONTROL SYSTEM.
D. McCormack
Control,10(6),85-89,June,1963,U.K.

Observing that in most of the control system design techniques commonly used, a great deal is left to the designer, and that to meet some given performance, there are usually several possible solutions no one of which is the real optimum arrangement, the author remarks that even if the integral-square error is minimized, this may be accompanied by unnecessary saturation of the controlled system. He then refers to the optimization procedure developed by Chang Cf. 'Synthesis of Optimum Control Systems', McGraw-Hill,1962, based on two criteria; (a) minimization of the integral-square error, (b) limitation of the control effort. The author applies this method in the synthesis of an optimum heading control system for an unboosted vertically launched rocket, aerodynamic forces being neglected to simplify calculations, since the object is to demonstrate the suitability of Chang's procedure: it is a particularly suitable problem since the conventional technique, based on frequency-response with gain and phase-margin adjustments, will be seen to cause rocket-motor deflection limiting following certain disturbances.

526 A SELF-ORGANIZING CONTROL SYSTEM BASED ON CORRELATION TECHNIQUES AND SELECTIVE REINFORCEMENT.
VII.1(a) D.N. Streeter, K.S. Narendra
Cruft Lab.,Harv.Univ.,Camb.,Mass.,Tech.Rep.(359),20 July,1962,U.S.A.
P.114892

This report deals with control systems that exhibit a capacity to learn, in the sense of meaningful self-alteration based on experience, the relation between learning, adaptation and self-organization in control systems and in animals being discussed. A system capable of synthesizing its controllers without explicit knowledge of the process or the spectra of the inputs is described: this synthesis is based on the cross-correlation between a signal representing the desired output state, and the various components of the tentative input signal. The system, in a general way, exemplifies the principles of learning used by A.L. Samuel in programming a computer to play checkers; results of computer simulation of the system are presented. The report indicates the motivation and physical reasoning on which the system design was based, while results of computer simulation of a self-organizing system are presented to demonstrate the feasibility of the design.

SYNTHESIS OF FEEDBACK CONTROLS USING OPTIMIZATION THEORY - AN EXAMPLE.
F.J. Ellert, C.W. Merriam
I.E.E.E.Trans Auto.Control,AC-8(2),89-103,April,1963,U.S.A.
See item 503.

527 A UNIFIED APPROACH TO SYNTHESIS OF LINEAR SYSTEMS.
P.P. Shipley
I.E.E.E.Trans Auto.Control,AC-8(2),114-120,April,1963,U.S.A.
Given the transfer function of the process to be controlled, and contraints on desired closed-loop dynamics, the procedure presented yields an exact analytical solution for the transfer function of the required compensator without recourse to graphical techniques: suitable constraints include the specification of any or all closed-loop poles, and/or specification of the position, velocity, or acceleration constant. Design for specified rise time, overshoot, mean-squared error, etc., may be accomplished by using an iterative routine. The procedure is ideally suited for implementation by digital computer, and has been applied to a simulated adaptive flight control system which required that the entire compensator design procedure be executed by a computer alone.

STABILITY

CLOSED LOOP IMPROVES SYNCHRONOUS MOTOR CHARACTERISTICS.
W.J. Waffner
Control Engrg,10(6),113,June,1963,U.S.A.

DIVERGENT OSCILLATIONS AND THEIR EXCITATION IN CONTROL SYSTEMS WITH TWO SATURATION-TYPE NONLINEAR ELEMENTS.
E.A. Freeman, G.C. Barney
Proc.Instn Elect.Engrs,110(6),1096-1106,June,1963,U.K.
See item 518.

INTRODUCTION TO THE ANALYTICAL TREATMENT OF CONTROL PROBLEMS.
R.D. Lantenschlager
Elektro.Maschin.(Bud),72(20),505-513,15 Oct.,1962,Austria.
See item 531.

MULTI-LOOP COMBINED CONTROL SYSTEMS.
M.V. Meerov
Avomat.i.Telemek.,24(5),628-639,May,1963,U.S.S.R.
See item 499.

529 STABILISATION OF A VARIABLE QUANTITY WITH RESPECT TO A SINGLE VALUED REFERENCE.
D.H. Makow
Radio & Electron.Engr,25(5),417-427,May,1963,U.K.
Feedback control systems required to stabilize a variable value of the output in the presence of external disturbances use as a reference, a quantity which can be varied; for example, the required speed of a motor can be approached in the presence of load and supply voltage fluctuations using as a reference an output voltage of a potentiometer set to a corresponding value. This article studies a feedback system consisting of two interacting loops which stablize an output variable using a single valued reference: the deviation of the output quantity caused by an external disturbance depends on the equality of the two loops, and can be made to approach zero by suitable adjustment of system parameters. Results of the theory were confirmed experimentally using a system of two variable-frequency oscillators and a quartz crystal as a reference.

CONTROL THEORY

530 ADAPTIVE AND SELF-OPTIMIZING CONTROL.
R. Oldenburger
TIL.1(a) Univ.of Purdue,Mech.Engng Sch,Lafayette,Ind.,1 Feb.,1963,U.S.A. P.114306
The author proves that if an uncontrollable disturbance is followed by a sufficiently long controllable portion, and the disturbance is known in advance, there is one and only one best action of the controller that will yield a response optimum in every reasonable engineering sense, such as minimum time to equilibrium where the system error is zero, minimum area between the error curve and the time axis, minimum over- or under-swing etc. It is further proved that the control function optimum for ramps normally yields nearly optimum response to an uncontrollable disturbance followed by a one or two segment piecewise linear controllable section. An effort is being made to extend the proof to an uncontrolled disturbance followed by a piecewise linear controllable section composed of an arbitrary number of straight line segments: the new approach allows the system to be subject to an arbitrary disturbance while the controller brings it from its initial to its final form.

531 INTRODUCTION TO THE ANALYTICAL TREATMENT OF CONTROL PROBLEMS.
R.D. Lautenschlager
Elektrotechn.Maschinenbau,79(20),505-513,15 Oct.,1962,Austria.
An outline is given of the theory of closed-loop systems, particularly with respect to the relationship between amplitude/frequency and phase/frequency characteristics and its application to problems of stability.
(from Elect.Engng.Abstr.66(785),563,May,1963,U.K.)

532 THE MULTIPLE-INPUT MINIMAL-TIME REGULATOR PROBLEM: GENERAL THEORY.
J. Wing, C.A. Desoer
I.E.E.E.Trans Auto.Control,AC-8(2),125-136,April,1963,U.S.A.
This work considers a two-input linear time-invariant discrete system whose state transition equation is given by:-

$$x_{k+1} = Ax_k + Du_{k+1}$$

where:- A = n X n constant non-singular matrix; x_k is an n-rowed state vector of the system at t = kT; D is an n X 2 constant control matrix with columns d_1 and d_2; and u_{k+1} is a 2-rowed control vector with components u^1_{k+1} and u^2_{k+1}. The control vector u_{k+1} is restricted to be an admissible control i.e., $/ u^i_{k+1} / \leq 1$ for i = 1, 2 and k = 0, 1, ... The results are applicable to all discrete systems of the above form which are controllable by admissible controls irrespective of whether the eigenvalues of A are distinct or multiple, real, or occur in complex conjugate pairs. Furthermore, the theory is directly extendable to the case where D = n X m constant matrix and u_{k+1} is an m-rowed control vector; m > 2, subject to the admissibility constraint $/ u^i_{k+1} / < 1$, i = 1,2, ..., m.

OPTIMAL AUTOMATIC CONTROL FOR NONLINEAR PROCESSES.
L. Markus
Univ.Calif.,Dept Maths,Tech.Rep.(1),July,1961,U.S.A. P.113596
See item 543

533 SYSTEM UNITS AND AUXILIARY DEVICES FOR THE AUTOMATIC CONTROL OF DISCONTINUOUS PROCESSES AND OPERATIONS IN THE CHEMICAL INDUSTRY.
E. Pavlik
Regelungstechnik,11(3),107-113,March,1963,Germany.
A critical study of the definitions of open-loop and closed-loop automatic controls is followed by a discussion on the ways and means
(continued)

533 (Contd.)

which enable conventional controllers, developed for continuous processes, to be adapted for the special requirements of discontinuous processes. The author examines the meaning of the terms 'programme-controlled processes', 'self-controlled processes', 'feedforward plus feedback control' and 'feedforward only (pure open-loop) control', and surveys arrangements and units required for controlling and signalling purposes. Finally, the possibility of utilizing, for the control of discontinuous chemical processes, the experiences gained with machine tool control techniques which have already attained a high degree of development, is discussed.

COMPONENTS

THE DEVELOPMENT OF THE MASTER-SLAVE MANIPULATOR.
W.K. Curtis
Nuc.Sci.Abstr.,17(7),1401,15 April,1963,U.S.A.
See item 541

534 ELECTRO-HYDRAULIC SERVOVALVE.
S. Sajiki, M. Kimura, O. Seda
J.Mech.Lab.Japan,8(1),38-48,Japan.
Describes the construction and operation of a new electro-hydraulic servovalve used for numerically controlled milling machines, and involving position feedback with spool displacement equal to that of the flapper. Mathematical treatment of the valve is difficult for its nonlinearity, but may be taken as approximately linear by considering small variations from the neutrals for all variables. If the mass and viscous resistance of the spool are negligible, the output displacement of the spool against the input stroke of the flapper (i.e. the transfer function), may be represented approximately by a linear formula containing a first derivative of time: thus, the time constant T at supply pressure Ps = 50kg/cm.sq. is given as T = 0.0008 sec; this very fast response is in fair agreement with experiment. The transfer functions of hydraulic pistons, including heavy loads and elasticity of fluid lines and oil used, have also been obtained with reasonable agreement between theoretical and experimental formulas.

535 HOW TO CALCULATE RESPONSE TIME OF PILOT-OPERATED VALVES.
L. Dodge
Proi.Engng,34(11),25-31,27 May,1963,U.S.A.
A familiar sight in almost any hydraulic automatic control system is a four-way flow-control valve incorporating a solenoid pilot valve: how fast will they respond? The author observes that it is not just a matter of computing flow-rate through a known restriction: speed of response depends also on the characteristic force-vs-airgap curve of the solenoid; the shape, size, clearance and displacement of each spool, and the fluid viscosity. The method outlined in this article relates these parameters for the valve illustrated and can be applied to any other pilot-operated spool valve: a special technique is devised for a large spool valve actuated by a small auxiliary piston.

536 A LOW-FREQUENCY TRANSISTORIZED REVOLUTION COUNTER AND FREQUENCY METER.
D.F.J. Evans
Instrum.Control Syst.,36(5),395-396,May,1963,U.S.A.
Circuits for a transistorized tachometer and a frequency meter, covering the ranges 10 to 100 rev/sec and 20 to 200 c/s respectively,
(continued)

536 (Contd.)

are described, both being based on monostable circuits: each instrument displays its results on a linear scale using a moving-coil meter, the frequency meter requiring an input voltage of 15mV r.m.s. Both circuits, which are extremely simple, may be modified to alter their frequency ranges.

537 MINIATURE SERVO VALVE.
Control Engng,10(6),133,June,1963,U.S.A.
Working with all known hydraulic fluids and most fuels and gases, and weighing less than 7 oz, this servo valve positions loads that are common to air- and space- craft control systems. By using mechanical feedback, flow control is directly proportional to input signal: the unit has a flow capacity of up to 2.9 gal.per min. at 4000 p.s.i. through a range of -65 to + 450 F. Produced by Power Equipment Division, Lear Siegler,Inc,Ohio,U.S.A.

538 THE PARTLY COMPENSATED METADYNE IN AUTOMATIC CONTROL SYSTEMS.
G. Fava
Elettrotecnica,50(3),137-140,March,1963,Italy.
Presents an analysis of the operation of a partly compensated metadyne for a machine supplying a resistive and inductive circuit, and for a machine used as rotating amplifier in a Ward-Leonard system: the effects of this machine on the automatic control circuit in which it is inserted are considered.

539 SERVO AMPLIFIER.
Hydraulics & Pneumatics,16(5),138,May,1963,U.S.A.
This fast-response, high natural frequency amplifier drives servo valves in hydraulic or pneumatic systems. Designed for rack or bench mounting, it includes its own power supply, permits the use of potentiometers, synchros, variable-reluctance devices etc. in a system, while socket allows the addition of plug-in networks. Quiescent output current is 8 - 22 ma, adjustable; differential current is 0 to nearly twice quiescent current, while dither frequency is adjustable from 100 to 400 c.p.s. Available from:- Aerospace Division of American Brake Shoe Co.,Oxnard,Calif.

540 A SHUNT-LOADED MAGNETIC AMPLIFIER.
E.W. Manteuffel, T.A. Phillips
Elect.Tech.,71,112-116,April,1963,U.S.A.
The output voltage of a new type of magnetic amplifier is controllable in amplitude rather than variation of pulse width, controlled rectifiers gated from small saturable reactors being used in a circuit similar to that of a magnetic stabiliser. The major area of application is in the field of accurately regulated power supplies.

541 A STUDY OF HIGH-PERFORMANCE SERVOMECHANISMS.
J. Henry-Baudot and J. Gillonnier
Automatisme,7(11),446-452,Nov.,1962,France.
Using the "power rate" figure of merit $P_s = T^2/J$, various motors are compared. Particularly as regards weight, the best performance is given by disc-armature motors: a special model, weighing about 5 kg, has a P_s of more than 300 kw for a duty cycle of 4% and a maximum "on" time of 300 ms; the temperature rise does not exceed 75 deg.C above ambient. Schematic diagrams of suitable servosystems to drive the motor, and circuits of the electronic sections, which use transistors and controlled silicon rectifiers, are given.

SYSTEM UNITS AND AUXILIARY DEVICES FOR THE AUTOMATIC CONTROL OF DISCONTINUOUS PROCESSES AND OPERATIONS IN THE CHEMICAL INDUSTRY.
E. Pavlik
Regelungstechnik,11(3),107-113,March,1963,Germany.
See item 533

USE OF MODELS

DESIGN OF OPTIMUM DYNAMIC CONTROL SYSTEMS FOR NONLINEAR PROCESSES.
C.A. Jones and others
Indus.Engng Chem: Fundamentals,2(2),81-89,May,1963,U.S.A.
See item 524.

ELECTRO-HYDRAULIC POSITIONER SIMULATION.
R.P. Auyang, G.N. Tsilibes
Instrum.Control Syst.,36(5),145-153,May,1963,U.S.A.
See item 504.

HISTORICAL

542 THE DEVELOPMENT OF THE MASTER-SLAVE MANIPULATOR.
W.K. Curtis
Nuc.Sci.Abstr.,17(7),1401, 15 April,1963,U.S.A.
A great deal has been written about handling cells and remote operations in which the master-slave manipulator has been used; enough, in fact, to have stimulated considerable interest in these machines. Little has been written, however, of their construction and function: this brief review will help to put these interesting devices in their proper perspective.

543 OPTIMAL AUTOMATIC CONTROL FOR NONLINEAR PROCESSES.
L. Markus
TIL.1(a) Univ.Calif.,Dept Maths,Tech.Rep.(1),July,1961,U.S.A. P.113596
Comprises notes for four lectures on automatic control presented by the author to a joint seminar of the Mathematics and Electrical Engineering departments of the University of California, Berkeley, U.S.A., in July, 1961. The topics covered concern existence of optimal controls, domains of controllability, extremal and relay properties of optimal controllers, and synthesis of such controllers.

INSTRUMENTS ASSOCIATED WITH SERVOSYSTEMS

544 THE DEVELOPMENT OF A CONDITIONAL PROBABILITY COMPUTER FOR CONTROL APPLICATIONS.
TIL.1(a) H.C. Ratz, G.H.M. Thomas
Univ.Saskatch.,Elect.Engng Rep.62R13,Nov.,1962,U.S.A. P.113515
A special purpose computer has been constructed which continuously measures time-weighted frequencies of binary patterns, and from these deduces certain conditional probabilities which provide the basis for making control decisions: it has been applied to the control task of optimizing a process simulated by an analogue electrical network. Experimental results show that the computer remains useful in the face of considerable interaction among the control variables, information being processed into a form that facilitates control, while the procedure provides for continuous adaptation to changing characteristics of the response surface.

545 DYNAMIC FREQUENCY METER.
P. Wood
Electronics,36(18),26,3 May,1963,U.S.A.

In this instrument, which gives a continuous 6-digit display of frequencies between 250 c.p.s. and 16 Kc without the normal sampling period, the unknown frequency input is converted to a pulse train fed to the add input of a reversible counter: the subtract input is obtained from a binary rate multiplier comprising a binary scaler to which is applied a fixed-frequency pulse train. Scaler outputs are fed to gates controlled by the counter stages. Combined, the gate outputs give a pulse train whose mean rate equals the product of the fixed frequency and the contents of the counter: when the mean rates applied to the add and subtract inputs become equal, the number held by the counter represents the input frequency.

546 FATIGUE MACHINE SIMULATES RANDOM LOADS.
Engineering,195(5066),698-699,24 May,1963,U.K.

A new fatigue testing machine, developed by Dowty Rotol Ltd., Gloucester can undertake tests either to a programme or a random record taken from a component in service: the first machine of this type has been delivered to the Loughborough College of Technology. To provide the high degree of accuracy claimed (± 1 per cent), feedback techniques are employed: by the provision of a carrier system, a continual correction of force error is effected, and detected by a load cell employing an inductive pick-off, the output of which is combined with the control signals and returned to the amplifier input to close the feedback loop. The load cell feedback signal is provided by a differential inductance pick-off arranged so that it measures the deformation of a proof ring type elastic member: precise ratios of the pick-off-carried supply are injected into the feedback loop to provide control of the static load; the dynamic load is similarly controlled, except that in this case a digital technique is used to build up the required sinusoids from linear staircase functions of progressively changing slope.

547 A FOUR-CHANNEL TRANSISTORISED CONSTANT-TEMPERATURE HOT-WIRE ANEMOMETER.
E.J. Cooper
Instrum.Control Syst.,36(5),390-394,May,1963,U.S.A.

This instrument is designed for use with a 0.0005-in. diameter wire probe having a resistance of approximately 10 Ω ; with slight modification, it will also feed any hot-wire or hot-film probe which requires a heating current of up to 500mA and a maximum input to the hot-wire bridge of 15V. The frequency response of the instrument, which depends on the size of the wire used, is 3dB down at 500c/s for the diameter of wire quoted above, with a mass velocity of approximately 1 lb/sec.ft.sq: using a standard probe, it will measure mass velocities up to 350 lb/sec.ft.sq; resolution is set by the ripple on the output and is equivalent to a turbulence of around 1 per cent.

548 THE RECORDING ON PUNCHED FILM OF THE CONTINUOUSLY CHANGING BINARY CODED OUTPUT FROM SHAFT DIGITISERS.
TIL.1(b) R.P. Parkiss
R.A.E.Tech.Note Aero.2880,March,1963,U.K.

Describes a recording system which enables the coded output from a number of rotating shaft digitisers to be stored simultaneously and then recorded serially on punched 35-mm film, the process being repeated continuously at a rate of 15 digitiser outputs per second. The equipment, which was developed to record data from a wind tunnel model, the attitude of which was slowly changing, is also of use in testing the response of servo systems. It is to be adopted as a standard facility for the R.A.E. 15 x 16 inch intermittent tunnel.

A SELF-ORGANIZING CONTROL SYSTEM BASED ON CORRELATION TECHNIQUES AND SELECTIVE REINFORCEMENT
D.N. Streeter, K.S. Narendra
Cruft Lab.,Harv.Univ.,Camb.Mass.,Tech.Rep.(359)20 July,1962,U.S.A.
P.114892

See item 526.

549 SENSITIVE AUTOMATIC TORQUE BALANCE FOR THIN MAGNETIC FILMS.
F.B. Humphrey, A.R. Johnston
Rev.Sci.Instrum.,34(4),348-352,April,1963,U.S.A.
Automatic servo force balancing techniques using a photo-electric pick-off have been applied to a fused-silica torsion fibre suspension system in the balance described for studying the magnetic properties of thin ferro-magnetic films. An appropriate set of coils provides the magnetic field H; since the torque on a sample is given by M x H = L, measurement of torque affords a means of studying the behaviour of the magnetisation M. Examples are given of the measurement of the saturation and remanent magnetization, anisotropy constant, and coercive field on a film 35 angstroms units thick, from which data, the anisotropy field and the squareness are calculated: observations of rotational hysteresis loss are also discussed.

550 SPECIAL COMPUTER INTEGRATES RAINFALL.
R.T.H. Collis
Electronics,36(21),24 May,1963,U.S.A.
The integrator is a simple special purpose relay computer which automatically samples the output of a standard WSR-57 weather radar. The data are processed in digital form and displayed on a series of electro-mechanical counters arranged in a grid set on a map showing the area covered: counters show the rainfall in inches accrued at each point since time of re-set. Five incremental readings per hour are obtained, the integrator taking over the radar every twelve minutes to ensure its correct operation, the antenna scanning in PPI fashion at a predetermined rate and elevation.

551 TRAJECTORY TRACER FOR CHARGED PARTICLES WHICH INCLUDES MAGNETIC FIELDS AND SPACE CHARGE.
T. Van Duzer
Rev.Sci.Instrum.,34(5),558-567,May,1963,U.S.A.
Presents the theory and design of an analogue system for computing trajectories of charged particles in electron and ion guns, where the effect of space charge and magnetic fields is important. The magnetic fields considered satisfy Laplace's equation, being simulated by specifying boundary conditions on the magnetic scalar potential. A special tank for obtaining accurate results on a thin annular beam is described: a precision analogue computer solves the equations of motion with the fields measured in the tanks and controls servomechanisms which move the field-sampling probes along the trajectory. Results for high-perveance electron guns are compared with beam sampling measurements on actual guns.

552 TRANSISTORIZED AUTOMATIC DATA RECORDING FOR COSMIC-RAY DETECTORS.
K.F. Richard, U.R. Rao, W.B. Smith
Rev.Sci.Instrum.,34(5),504-509,May,1963,U.S.A.
This system, developed to provide more reliable instrumentation for the cosmic-ray physicist, includes a counting rate integrator, a memory circuit, an electronic clock, and a serial-to-decimal converter. Besides reliability, small size, and low power consumption, the system can give both BCD and decimal output which are automatically punched on IBM cards.

553 ULTRAVIOLET RECORDING MICROSPECTROPHOTOMETER.
G.N. Wagener, C.G. Grand
Rev.Sci.Instrum.,34(5),540-544,May,1963,U.S.A.
Describes the design and operating principles of a scanning and integrating microspectrophotometer for studying the absorption of tissue cells in the wavelength region 2200 to 7000Å: the instrument can be used in three modes; as a double beam system in which the two beams are derived in the image plane of the microscope using a two-hole aperture plate, as a scanning integrator, and as an uv photomicroscope.

554 OBTAINING THE INTERNAL JUNCTION CHARACTERISTICS OF A TRANSISTOR FOR USE IN ANALOGUE SIMULATION.
S.B. Geller
IRE Trans Electron.Computers,EC-11(5),709-710,Oct.,1962,U.S.A.
A technique is described for making the internal base-to-emitter junction characteristics of an alloy junction transistor available to an analogue computer simulation process: this is accomplished with an active feedback network that continuously compensates for the internal voltage drop across the extrinsic base-spreading resistance at all base current levels.

MATHEMATICS

555 ASSESSING CLOSED-LOOP FREQUENCY RESPONSE.
A.G. Bogle
Control. 6(60),83,June,1963,U.K.
When a Nyquist diagram is drawn showing the open-loop gain G and open-loop phase ϕ, it is possible to assess readily the closed-loop response of the system in respect of both gain and phase, by reference to the M-circles and α-circles as described in standard texts: while the Bode diagrams are more convenient, auxiliary reference to the Nichols chart is necessary, with the attendant disadvantage of apparent complexity due to the rectangular log G and ϕ co-ordinates. The same information may be given from a self-drawn chart by adopting a polar grid of log G-circles and ϕ-radii, intersecting one of log M-circles and α radii, the diagram being directly derived from the Inverse Nyquist one, on which loci of constant M value are circles with $(-1, j0)$ as centre and radius $1/M$, while loci of constant α are radial lines from the same centre. Since loci of constant G are also circles centred at the origin and of radius $1/G$, and loci of constant ϕ are radial lines from the origin, it only remains to label the two sets of circles with appropriate decibel values, and a workable equivalent of the Nichols chart has been drawn.

DESIGN OF OPTIMUM DYNAMIC CONTROL SYSTEMS FOR NONLINEAR PROCESSES.
C.A. Jones and others
Indus.Engng Chem: Fundamentals,2(2),81-89,May,1963,U.S.A.
See item 524.

FUEL MINIMIZATION IN FLIGHT VEHICLE ATTITUDE CONTROL.
W.H. Foy
I.E.E.E.Trans Auto.Control,AC-8(2),84-88,April,1963,U.S.A.
See item 502.

METHOD OF INVESTIGATING AUTOMATIC CONTROL SYSTEMS CONTAINING LINEAR ELEMENTS WITH VARIABLE PARAMETERS.
N.T. Kuzovkov
U.K.A.E.E., DEG Inform.Ser.262(CA),1962,U.K.
See item 520.

MATHEMATICS, TESTING (Equipment, techniques, results)

A METHOD OF SOLVING NONLINEAR SYSTEMS.
B.L. Deekshatulu
Control Engng,6(60),93-96,June,1963,U.K.

THE MULTIPLE-INPUT MINIMAL-TIME REGULATOR PROBLEM: GENERAL THEORY.
J. Wing, C.A. Desoer
I.E.E.E.Trans Auto.Control,AC-8(2),125-136,April,1963,U.S.A.
See item 532.

OPTIMAL ROCKET-HEADING CONTROL SYSTEM.
D. M'Cormack
Control Engng,10(6),85-89,June,1963,U.K.
See item 525.

TESTING (Equipment, techniques, results)

HOW TO CALCULATE RESPONSE TIME OF PILOT-OPERATED VALVES.
L. Dodge
Prod.Engng,34(11),25-31, 27 May,1963,U.S.A.
See item 535.

HOW TO EVALUATE AUXILIARY POWER UNITS.
M. Voytish
Hydraul.& Pneumat.,16(5),132-137,May,1963,U.S.A.
See item 501.

THE RECORDING ON PUNCHED FILM OF THE CONTINUOUSLY CHANGING BINARY CODED OUTPUT FROM SHAFT DIGITISERS.
R.P. Purkiss
R.A.E.Tech.Note Aero.2880,March,1963,U.K.
See item 548.

556 TESTING FOR PLANT TRANSFER FUNCTIONS IN PRESENCE OF NOISE AND NONLINEARITY: 1 OUTLINING THE OVERALL PROBLEM.
T. Hennig
Control Engng,10(6),67-70,June,1963,U.S.A.
In this series of articles attention will be directed to the problem of determining transfer functions, and errors in them, that arise when techniques intended for noiseless linear systems are applied to noisy systems containing elements that are slightly nonlinear. Particular emphasis is placed in how the errors involved in determining experimental transfer function depend on the choice of perturbation signals for the input and on the methods of analysis of the input and output signals. In this first article, the author discusses briefly perturbation signals, methods of analysis, systems with noise systems with nonlinearities, and test and analysis techniques.

AUTHOR INDEX

Ref:- ¤ indicates co-author(s)

Ref:- × indicates co-author(s)