January through March, 1959

IBM Technical Papers Published in Other Journals

Behavior of the Ferroresonant Series Circuit Containing a Square-Loop Reactor, R. H. Dennard, *Communication and Electronics (AIEE),* **40,** 903-911 (January, 1959).

An analysis is given for the behavior of the ferroresonant series circuit containing a reactor with 50% Ni-Fe grain-oriented core material. Consideration is given to several different kinds (or modes) of steady-state circuit response at fundamental as well as at subharmonic frequencies for both sinusoidal and square-wave applied voltages. Conditions are derived which are necessary for the stable existence of these modes, and methods are given for the study of the transient processes by which these various steady-state modes are attained.

The dynamic magnetomotive-force requirements of the unsaturated reactor and the differential inductance of the reactor during saturation are represented with suitable approximations. Core test procedures are described which supply this magnetic information.

Capture and Decay of μ-Mesons in Fe,† W. A. Barrett,* F. E. Holmstrom, and J. W. Keuffel,** *Physical Review,* **113,** 661-665 (January 15, 1959).

The mean life of μ-mesons in Fe has been measured using an improved cosmic-ray apparatus. A positive identification of the stopped muon was made using Cerenkov velocity selectors in the incident telescope. The 2.2-μsec background from positive muons was reduced a factor of 3 with a 3-layer sandwich of Fe and thin plastic scintillators, so arranged that electrons emitted in the target were mostly detected as such by the scintillators. The mean life is 196 ± 8 mμsec. By comparing this result with the electron-counting results of Lederman and Weinrich, the ratio of the decay rate of μ^- bound in Fe to the free μ^+ decay rate is found to be 1.15 ± 0.06.

†Work done at University of Utah.
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A Checklist of Intelligence for Programming Systems, R. W. Bemer, *Communications of the Association for Computing Machinery,* **2,** No. 3, 8-13 (March, 1959).

A remarkable variation exists in the degree of sophistication of various programming systems. A particular manifestation is the jungle of assorted devices for reproducing limited human decision procedures. An attempt is made here to begin a systematic classification of the various devices for educating the computer to take over the decision-making functions of one or many human operators, both those that have been demonstrated feasible to date and those that are highly desirable for the future.

Development of Ultra Low Loss Wollastonite Ceramic Insulation, B. R. Eichbaum, *Insulation,* **5,** No. 2, 19-24 (February 1959).

The development of several new high-frequency insulation ceramic compositions containing a large portion of the crystalline-phase wollastonite, is described. Many of these ceramic insulators have loss factors in the Grade L-6 (JAN 1-10) category. Techniques of preparation and evaluation are discussed.

A Direct Access Photomemory. Part I, Prototype Machine System, F. A. Litz, *Proceedings of the 1958 Western Joint Computer Conference,* pp. 50-53 (Published in March, 1959).

Research on a very large capacity, direct-access digital storage system using a unique self-developing photographic medium is described. A feasibility model with a 10^9 alphanumeric character capacity was completed. This machine was used as a carrier to determine the problems of photographic storage.

Direct Access Photomemory. Part II, System Considerations, A. J. Critchlow, *Proceedings of the 1958 Western Joint Computer Conference,* pp. 53-55 (March, 1959).

The design of a system to make optimum use of the characteristics of photographic storage as opposed to magnetic storage is discussed. Examples of possible applications and advantages and disadvantages of photographic storage for these applications are presented.

An Effect of Pulse Radiation on Transistors Packaged in a Moist Atmosphere, W. A. Bohan, M. G. Chasanov, and E. N. Schroeder, *Proceedings of the IRE,* **46,** 1953-1954 (December, 1958) (Letter to the Editor).*

This paper describes the results of a series of experiments on the effects of high-dose-rate radiation on transistors. Curves are included showing the variation of transistor collector to base leakage current (I_{co}) along a three-volt, 75-ohm load line, while simultaneously subjecting the transistor to a pulse consisting of a neutron and gamma ray radiation.

*Published during the period October through December, 1958.

Efficient Precision Current Regulator for High-Power Magnets, R. L. Garwin, D. Hutchinson,* S. Penman,* and G. Shapiro,* *Review of Scientific Instruments,* **30,** 105 (February, 1959).

Using paralleled power transistors driven by a transistor and a chopper amplifier, supplemented by a coarse feedback loop

to the generator field, we have regulated to $<0.001\%$ the field of an electromagnet requiring 80 amp at 200v. The dissipation in the regulator is 250w. The magnet current may be varied from zero to maximum by setting the reference potentiometer to the appropriate voltage, and sufficient protective measures are incorporated so that the circuit is not injured by misuse. The circuit is usable to perhaps a megawatt.

*At Columbia University.

Electron Spin Resonance of Acceptor States in Diamond, W. V. Smith, I. L. Gelles, and P. O. Sorokin, *Physical Review Letters,* **2,** No. 2, 39-40 (January 15, 1959).

The observation of an electron spin resonance spectrum in natural, unirradiated diamond is reported. The spectrum is thought to be due to aluminum impurities and reasons are given for this conclusion.

An Experiment in Mechanical Searching of Research Literature with RAMAC, F. E. Firth, *Proceedings of the 1958 Western Joint Computer Conference,* pp. 168-170 (Published in March, 1959).

This paper describes an experimental library-information retrieval system which can store and search about 25,000 documents on an IBM RAMAC 305.

Extreme Games with Three Values, J. H. Griesmer,* *Contributions to the Theory of Games,* Vol. IV, *Annals of Mathematics Study No. 40,* Princeton, 189-212 (1959).

In any fixed normalization, the set of n-person games can be represented by a convex polyhedron with the characteristic function of a game providing the coordinates of the corresponding point. A game is extreme if it is represented by an extreme point of this polyhedron. This paper discusses those extreme games in which the set of coalitions can be partitioned into three classes, each member of the same class assuming the same value when the game is normalized. As a preliminary, a method is given for deciding whether an arbitrary game is extreme or not. A set of homogenous linear equations is associated with the game, the game is extreme if and only if the solution set of this system of equations is $\{0\}$. Next, the set of extreme games with three values is characterized in two steps. First, conditions are imposed upon the partition of coalitions into winning, losing, and intermediate types. Second, a "chain" condition employed by Gurk is imposed to guarantee extremeness. One may interpret this condition as a "reluctance" on the part of intermediate coalitions to consider coalition changes.

To any game with three values, a linear graph may be associated by treating the intermediate coalitions as nodes and introducing edges between these nodes that correspond to disjoint coalitions. It is shown that a game with three values is extreme if and only if every node of the associated graph is part of a cycle with an odd number of edges, repetition of edges being allowed. The coefficient matrix of the system of inequalities defining the set of all n-person constant-sum games is next studied and properties of the system relating to the set of extreme games with two and three values are developed. Finally, discriminatory and finite solutions for these games are discussed; they exhibit the property that the minimal winning and minimal intermediate coalitions are most likely to form.

*Supported (in part) by the Office of Naval Research Logistics Project, Princeton University.

General Synthesis Procedure for Computer Control of Single-Loop and Multiloop Linear Systems (An Optimal Sampling System), R. E. Kalman* and J. E. Bertram, *Applications and Industry (AIEE),* **40,** 602-609 (January, 1959).

This paper is concerned with the problem of designing optimal systems for the control of a plant governed by a linear differential equation with constant coefficients. Control is exerted by means of piecewise constant signals which can change only at the "sampling instants." Optimality means here, as in some nonlinear problems, that the system achieves equilibrium with zero steady-state error from any initial state as quickly as possible.

The sequence of signals required for optimal control in this sense is ideally a linear combination of the state variables of the plant being controlled. In the simplest regulator problem, when all state variables are accessible, the optimal system is realized by a very simple multifeedback arrangement in which the only unconventional component is the sample-and-hold element. When some states are not accessible, when the plant includes time delays, and in some types of follow-up systems, the physical realization of optimal control requires real-time analog or digital computation. The requirements of machine computation for control purposes are derived here in a general way; the theory presented includes as special cases many commonly used methods for control system synthesis.

*Research Institute for Advanced Studies, Baltimore, Md.

Hot and Warm Electrons — A Review, S. H. Koenig, *The Journal of Physics and Chemistry of Solids,* **8,** 227 (January, 1959). (International Conference on Semiconductors, Rochester, N. Y., August 18-22, 1958).

There are two categories of problems relating to the study of hot and warm carriers; i.e., the situation in which the mean carrier kinetic energy deviates measurably from its equilibrium thermal value. The first of these relates to the manner in which a steady-state distribution is maintained. The pertinent work to date, both experimental and theoretical, is reviewed.

The second set of problems involves the phenomena which result from a non-equilibrium distribution, but that do not play a significant role in determining it. The velocity dependence of recombination cross sections, impact ionization of neutral impurities and enhanced thermionic emission are among these. The present experimental situation is discussed and related to what relevant theory exists for the various cases.

Information Storage and Retrieval Using a Large Scale Random Access Memory, J. J. Nolan, *American Documentation,* **10,** 27-35 (January, 1959).

A new approach to mechanized information retrieval utilizes large-scale random access memory, such as the IBM RAMAC magnetic-disk unit. Random access to any portion of the memory eliminates the need for scanning a complete file, as is necessary in other methods based on serial searching techniques. It is adaptable to a wide variety of coding schemes, including subject-heading lists, generic-specific classifications, and topological representation. Two or more different notations or coding schemes may be intermixed in the same system. Manual effort in preparing input data may be materially reduced through the use of automatic coding which utilizes a part of the memory to hold a cross-reference dictionary or conversion table. Typical operations are described using the IBM Type 305 RAMAC as the processing machine.

The Jacobi Method for Real Symmetric Matrices, H. H. Goldstine, F. J. Murray,* and J. von Neumann,** *Journal of the Association for Computing Machinery,* **6,** No. 1, 59-96 (January, 1959).

In this paper the authors have reviewed in considerable detail the existing classical techniques for finding the characteristic values of matrices and indicated possible difficulties with each of these techniques. They then proceed to a very complete and detailed statement of a procedure which was given by Jacobi for calculating the characteristic values of a symmetric matrix. This method is discussed fully and then its numerical counterpart is studied throughout the balance of the paper.

The end result of this analysis is to establish estimates for the amount of error introduced when the Jacobi procedure is applied to an actual calculation on a real machine. The primary purpose of the paper is to demonstrate the stability of the Jacobi procedure.

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**Deceased.

Low-Temperature Fluorescence Spectra and Crystal Field Splittings of Rare-Earth Activated SrS Phosphors, S. P. Keller and G. D. Pettit, *The Journal of Chemical Physics,* **30,** No. 2, 434-441 (February, 1959).

As a continuation of an earlier work, SrS phosphors, singly activated with rare-earth ions, have been excited with uv irradiation at 77°K. The resultant visible fluorescent emissions have been measured and correlated with crystal field splittings of energy levels. Energy-level diagrams are presented with possible term assignments. Where possible, comments are made about the symmetry of the activator sites.

A Magnetic Field Probe of High Sensitivity and Resolution, B. Kostyshyn and D. D. Roshon, *Proceedings of the IRE,* **47,** No. 3, 451 (March, 1959). (Letter to Editor.)

The construction of a high-resolution magnetic field probe employing the Hall effect in bismuth is described. The sensitive area of the probe is a square, 25 microns on a side. The minimum detectable fields reported were 0.02 oersted. Plots of remanent fields due to digital signals written on tape and drum surfaces are shown.

Measurement as a Design Tool, F. E. Fisher, *Machine Design,* **31,** No. 2, 105-112 (January 22, 1959).

Advantages of measurement are apparent in defining the system, trouble shooting, application of theory, accelerated experience, and application to other fields. The paper is concerned primarily with dynamic measurements, with the transducer as the key. Measurements of card and tape punches, keyboards, clutches, cam drives, magnetic tape transports, and relays can give results about such characteristics as acceleration, impact force, resonant frequency, momentum, torque, and contact bounce. These provide the raw material for development of impulse-momentum equations, stress calculations, spring mass simulation, et cetera. Several transducers are described in some detail. Also discussed are the means used to measure displacement, velocity and force.

Metastability in Niobate Systems, Arnold Reisman, Frederic Holtzberg and Melvin Berkenblit, *Journal of American Chemical Society,* **81,** 1292 (March, 1959).

Experiments are described which together with previous information[2] elaborate on one of the metastable equilibria in the interaction $K_2O-Nb_2O_5$. Quenched samples having an initial composition of 49.9 mole % K_2O were found to consist of fibrous insoluble and nondescript soluble fractions. The fibrous phase was found to contain $76.55 \pm .15$ mole % Nb_2O_5 corresponding to approximately $6K_2O \cdot 7Nb_2O_5$. On the basis of DTA and X-ray analysis, the recrystallized water-soluble fraction appeared to be identical to the $7 \cdot 6 \cdot 27H_2O$ compound reported in the early literature. It is believed that the metastable system 6:7-7:6 exists at the expense of the 2:3-1:1 and 1:1-3:1 fields, and that such behavior in intermediate composition ranges is directly related to deviations from model behavior and shows a possible extension of the ternary aqueous into the anhydrous system.

Meter Indicates Diode Reverse Recovery Time, R. Fekete, *Electrical Manufacturing,* **63,** No. 2, 103-107 (February, 1959).

This meter technique is intended to eliminate the need for an oscilloscope when measuring the reverse recovery time of large quantities of diodes. Methods now in use require an oscilloscope, with the drawback that both the instrument and the operator's judgment are sources of error. Although the oscilloscope does allow the transient response of the diode to be observed, it is not suitable for measuring a large number of diodes by automation. The meter technique described here has been designed specifically for semiconductor diodes, but it could be used for other transient response measurements. The article discusses the system, including pulse generator, recovery circuits, wide-band amplifier, cathode follower, voltage-comparator circuits, and the metering circuit. Three typical voltage-comparator circuits are analyzed in detail.

Mirror-Image Cams, D. C. Allais, *Machine Design,* **31,** No. 2, 136 (January 22, 1959).

Production is simplified and accuracy increased in a complementary cam system by designing both cams for back-to-back machining.

Numerical Analysis for Design of Electron Guns with Curved Electron Trajectories,* Iwao Sugai, *Proceedings of the IRE,* **47,** No. 1, 87 (January, 1959). (Letter to Editor.)

Based on Slater's works on linear magnetrons, configuration of electrodes was determined numerically using the IBM 650 computer. These electrodes produce the Brillouin flow of electron beam for M-type carcinotrons.

*Work done at Polytechnic Institute of Brooklyn.

On the Theory of Strong-Field Conduction, P. J. Price, *Journal of Physics and Chemistry of Solids,* **8,** 136 (January, 1959). (Proceedings of the 1958 International Conference on Semiconductors, Rochester, N. Y., August, 1958).

For conduction in a finite constant electric field, an electron *differential mean free path* (giving the change in current when a small steady disturbance is imposed) may be defined as the time integral of the electron velocity, *relative to its final mean value,* averaged at each instant over the ensemble of "paths" by which the specified initial definite state evolves to the final steady distribution. This mean free path satisfies (as a function of electron state) a linear inhomogeneous equation which contains the drift velocity explicitly, and for which a well behaved solution should exist only if this is given its

correct value: The drift velocity has the role of eigenvalue in the equation. The eigenvalue feature is verified for the familiar case with spherical symmetry and acoustic-mode scattering. The resulting "eigenfunction" (the differential mean free path) is used to obtain results for the Hall effect and for diffusion.

Optimum Block Length for Data Transmission with Error Checking, F. B. Wood, *Communication and Electronics,* **40,** 855-861 (January, 1959).

The efficiency of a block-checking system of data transmission, in which an answer-back block-checking signal is provided to acknowledge each block of characters, or to ask for a repeat if an error is detected, is investigated. Curves of data-transmission efficiency, as a function of the number of characters in a message block, are shown to have sharper peaks as the distance and error probabilities have increased. For comparison, efficiency curves are plotted for a 7-bit single-error-detecting code and for a 10-bit single-error correcting code. A family of curves of optimum block length is given for different probabilities of error and different reply times.

Possible Modifications to the International Algebraic Language, Julien Green, *Communications of the Association for Computing Machinery,* **2,** No. 2, 6-8 (February, 1959).

Several proposals are listed for increasing the power of the IAL. They consist mainly in generalizing the definitions given in the "Preliminary Report—International Algebraic Language" without restricting the original language. The major proposals were: (1) Allowing the use of Boolean variables or expressions in an arithmetic expression; (2) Adding a new loop-control statement to include the ability to modify several variables simultaneously (called *parallel recursion*); (3) Generalizing the loop-control statement to give the programmer greater flexibility in stating the termination of the recursive process. Seven examples are shown coded as an illustration of the language.

Precise Determination of the Muon Magnetic Moment, R. L. Garwin, D. Hutchinson,* S. Penman,* and G. Shapiro,* *Physical Review Letters,* **2,** No. 5, 213 (March, 1959).

The magnetic moment of the μ-meson has been determined by a magnetic resonance method to an accuracy of 0.01% by the use of a stroboscopic method.

*At Columbia University.

The Present Status and Anticipated Progress in the Field of Insulating Materials, T. D. Callinan, *Communication and Electronics (AIEE),* **41,** 22-28 (March, 1959).

Solutions to three problems in electrical insulation are sought by many chemists, physicists and electrical engineers. They are (a) the aging and deterioration of insulants, (b) the loss of electric strengths in materials at radio frequencies and (c) the "fatigue" of ferroelectrics in service. This paper shows how the solution of these problems will result in progress for the electric power, the telecommunications and the automatic detection and control industries.

The Properties of Electrons Heated by Microwave Fields in N-Type Germanium, T. N. Morgan, *International Journal of the Physics and Chemistry of Solids, Supplement,* **8,** 245-249 (January, 1959).

When an alternating electric field of low intensity is used to modulate the dc current flow in a semiconducting sample,[1] the current change is proportional to the square of the applied field and depends upon its frequency. For short relaxation times, τ, and low frequencies, ω, such that $\omega\tau << 1$, this dependence is not important. For electrons in germanium it becomes important for microwave frequencies above about 50 kmc at room temperature and above 5 kmc at liquid-nitrogen temperature. Calculations of the perturbed distribution function and of the resulting conductivity changes have been made with the help of the IBM 704 computer at Poughkeepsie for the frequency and temperature ranges of interest. It is found that the changes in current flow arise from two terms differing in their dependence on frequency. One represents the current produced by a change in the average dc conductivity. The other represents an average value of the microwave current produced by an ac conductivity variation in phase with the microwave field. The results of these calculations will be compared with measurements performed at frequencies from 8 to 35 kmc between 77° and 300° K.

[1] T. N. Morgan, *Bull. Am. Phys. Soc.,* Ser II, **2,** 265 (1957).

Reliability Engineering in the Commercial Data Processing Field, F. J. Roehm, *Compendium of Maintainability Symposium,* conducted by the National Security Industrial Association Maintenance Advisory Committee, (February, 1959).

This paper presents the reliability engineering organization of the Data Processing Division in IBM. The structure, objectives, and implementation of the program are discussed.

A Simple Continuous He^3 Refrigeration System, H. A. Reich and R. L. Garwin, *Review of Scientific Instruments,* **30,** 7 (January, 1959).

A simple continuous He^3 refrigerator which uses a minimal amount of gas (80 cc STP) has been built. Temperatures below 0.5°K may be attained for as long as He^4 remains in the cryostat. Commercial components are used throughout.

Single Crystal CdS as Soft X-Ray Detector, H. Cole and Brother Brian Henry,* *The Review of Scientific Instruments,* **30,** No. 2, 90-92 (February, 1959).

A discussion of how photoconductivity in certain selected single crystals of CdS, by comparison with conventional Geiger-type counters, affords a fairly sensitive and inexpensive detector for simple X-ray spectrometry.

*Physics Department, Marian College, Poughkeepsie, N. Y.

Some Properties of Spin Generators, R. J. Blume, *Review of Scientific Instruments,* **30,** 41 (January, 1959).

A spin generator is an electronic oscillator whose frequency is directly controlled by the Larmor precession of nuclei in a bulk sample placed in the feedback path of the oscillator. The type described by Hershberger and by Schmelzer consists

of two precisely orthogonal-tuned rf coils surrounding a stationary sample in a magnetic field which is orthogonal to the axes of the two coils. One coil drives the input of an amplifier, whose output in turn drives the second coil. Regenerative coupling of the output to the input of the amplifier, which can result in oscillation, occurs only at the resonance frequency of the nuclear spins, owing to the orthogonality of the coils.

The foregoing scheme is troubled by saturation of the resonance in the stationary sample and by difficulty in eliminating all non-nuclear coupling between the two coils. While saturation may be avoided by the use of a flowing sample, spurious inductive coupling remains. However, if the two coils are physically separated by a short distance and are shielded, and if the sample flows between them as in Fig. 1, a practical rf oscillator may be obtained. The scheme in Fig. 1 was proposed by the author and independently by Skripov, who has developed a fast-acting earth's field magnetometer of this type.

Theory of Electron-Phonon Interactions, G. D. Whitfield, *Physical Review Letters,* **2,** No. 5, 204 (March, 1959).

The theory of the interaction of electrons and acoustic phonons in nonpolar crystals has been formulated in terms of a new set of basis states, whose wave functions are essentially Bloch functions that deform with the lattice. The major part of the interaction may then be calculated in terms of the strain tensor rather than the displacement of the lattice. A result of the theory is a generalization of the deformation potential theorem.

Transistorized, Crystal-Controlled Marginal Oscillator, R. L. Garwin, A. M. Patlach, and H. A. Reich, *Review of Scientific Instruments,* **30,** 79 (February, 1959).

A simple, crystal-controlled, transistorized marginal oscillator magnetometer has been built. It is self-contained except for an oscilloscope and modulation power supply. Circuit and construction details are given.

Variation of Valence State of Eu in SrS Phosphors, S. P. Keller, *The Journal of Chemical Physics,* **30,** No. 2, 556-560 (February, 1959).

Phosphors containing SrS as the base material and 0.04% Eu as the activator were prepared in various reducing or oxidizing atmospheres. Firings in reducing atmospheres produced divalent Eu, and firings in oxidizing atmospheres produced decreasing amounts of divalent Eu and increasing amounts of trivalent Eu, depending on the degree of oxidizing character of the atmosphere. The relative amounts of the two valence states were determined by observing the fluorescent emission and by measuring the paramagnetic resonance absorption of the samples.