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Foreword: Fundamental Research in Superconductivity *by P. M. Marcus, p. 2.*

Review of the Present Status of the Theory of Superconductivity *by J. Bardeen, p. 3.* Theory and experiment are compared for a number of phenomena in superconductors. While the agreement is generally good, there are some discrepancies for which there is no adequate explanation.

On the Influence of Free Path on the Meissner Effect *by K. U. von Hagenow and H. Koppe, p. 12.* The influence of impurities on the behaviour of a superconductor is computed by introducing a scattering potential and averaging over all positions of the scattering centers. This procedure only takes into account scattering and free path effects and neglects changes in the elastic constants and electron density due to actual impurities. Using perturbation theory, it is shown that the free energy and the static Meissner effect are not influenced by scattering.

Solutions of the BCS Integral Equation and Deviations from the Law of Corresponding States *by J. C. Swihart, p. 14.* The BCS integral equation has been studied for nonseparable interactions of the Bardeen-Pines form, $V(|\varepsilon\varepsilon'|)$. Numerical solutions were obtained using an IBM 7090 for a simple interaction of this form which included the effect of the Coulomb repulsion. The results for the ratio of the energy gap to the critical temperature and for the temperature dependence of the energy gap, the electronic specific heat, and the critical field in terms of the proper reduced quantities were rather insensitive to the form or strength of the interaction. This indicates that the BCS theory gives the law of corresponding states. The calculated ratio of energy gap to critical temperature varies with the ratio of critical temperature to the Debye temperature, and this variation is of the correct order of magnitude if the Coulomb interaction is included. The same model is used to study the isotope effect. With the plausible assumption that the Coulomb cutoff is independent of the ionic mass, there are deviations from the $M^{-1/2}$ law that are larger for small T_c/θ_D superconductors.

Nuclear Spin Relaxation in Superconducting Cadmium *by Y. Masuda, p. 24.* The nuclear spin-lattice relaxation time, T_1, in superconducting cadmium has been measured in the range of 0.37K to 0.6K. A field-cycling method was used. The results are explained by the theory of Bardeen, Cooper, and Schrieffer, and give another confirmation of the theory. The temperature dependence of T_1 in cadmium is identical to that in aluminum, which is surprising in view of the different crystal symmetry and band structure of the two metals.

Experimental Work on Superconductivity *by K. Mendelssohn, p. 27.* The high thermal conductivity in the superconductive state at low reduced critical temperatures has been used for the detection of metal imperfections, including those caused by radiation damage. A statistically disordered single crystal of Ta with 30% Nb has also been investigated. Work is described on specific heats, ultrasonic attenuation and on the behaviour of thin superconductive films. An experiment for observing quantization of persistent currents is described.

The Kapitza Resistance of Metals in the Normal and Superconducting States *by W. A. Little, p. 31.* A calculation has been made of the transfer of heat across a metal-liquid helium interface. In the normal state an appreciable transfer of energy occurs directly from the conduction electrons to the phonons of the fluid. Three mechanisms have been considered: the phonon-electron interaction within the metal, the modulation of the position of the interface and the phonon-electron interaction of the electrons which have tunnelled into the helium. All appear to be important. In the superconducting state each of these becomes ineffective at temperatures appreciably below the transition temperature and, consequently, the heat flow is reduced. The effect is sensitive to band structure and to the anisotropy of the energy gap.

Superconductivity and Electron Tunneling *by S. Shapiro, P. H. Smith, J. Nicol, J. L. Miles, and P. F. Strong, p. 34.* Experiments on the tunneling of electrons through a thin dielectric layer separating two superconducting metals are reported. Data are presented for the pairs Al-Pb, Sn-Pb, and In-Sn. Particular attention is paid to the form of the tunneling current vs voltage characteristics and to the changes observed as a function of temperature. Experimental details relative to the measurement techniques, the preparation of the samples, and the preparation of the dielectric layers are presented. An analysis of the problem is presented which is based on the simple, one-dimensional model of the electron energy spectrum of a superconductor given by the theory of Bardeen, Cooper, and Schrieffer. Close quantitative agreement is obtained between the results of the calculations and the observed characteristics.

Magnetic Field Dependence of the Superconducting Energy Gap in Ginzburg-Landau Theory with Application to Al *by D. H. Douglass, Jr., p. 44.* A theoretical calculation is given of the magnetic field dependence of the superconducting energy gap, using the Ginzburg-Landau theory. In addition to depending upon the size of the specimen, the field dependence of the energy gap depends quite strongly on the nature of the boundary conditions. For the usual case with the magnetic field equal on opposite sides of a film, the calculations show that for a ratio of thickness, d, to penetration depth, λ, less than $\sqrt{5}$, the energy gap goes smoothly to zero as the critical field is approached—a second-order phase transition. When $d/\lambda > \sqrt{5}$, the energy gap approaches a finite value as the critical field is approached—a first-order phase transition. Energy-gap

measurements for aluminum agree very well with these calculations. When one changes the boundary conditions so that the magnetic field is constrained to be zero on one side of the film, the theory predicts a very different behavior. For this case, at all thicknesses, the energy gap approaches a finite value as the critical field is approached—a first-order phase transition. An experiment involving cylindrical films is proposed to test this latter case. It is shown that in this proposed experiment these boundary conditions are appropriate for predicting the *current* dependence of the energy gap.

Dependence of the Energy Gap in Superconductors on Position and Magnetic Field *by M. Tinkham, p. 49.* A review is given of work concerning the decrease of the energy gap in superconductors when a magnetic field is applied. The absence of any observable effect in previous spectroscopic work is explained, and conditions for large effects are outlined. Experimental measurements on thermal conductivity and microwave absorption in films in a magnetic field are described. The results show that in thin films, the gap can be depressed continuously to zero, yielding a second-order phase transition. In thicker films, the gap can be only partially depressed before the transition, and the transition is of first order. These results agree with those obtained theoretically by Douglass from the Ginzburg-Landau-Gor'kov theory, and experimentally, by electron tunnelling. An attempt to generalize the Ginzburg-Landau-Gor'kov theory to cope with the case when $\varepsilon_0/kT \neg 1$ is then indicated. In this phenomenological theory, the normalized gap $\varepsilon(H)/\varepsilon(0)$ is taken as an order parameter ω, and the free energy is assumed to contain a term in $\xi_0{}^2|\nabla\omega|^2$, as well as a free energy density $f(\omega)$ and magnetic energy $\kappa(\omega)H^2$. Some success is found.

Far-Infrared Absorption in a Lead-Thallium Superconducting Alloy *by D. M. Ginsberg and J. D. Leslie, p. 55.* Preliminary measurements have been made of the absorption of far-infrared radiation in the surface of a bulk superconducting alloy composed of lead with 10.0 atomic percent thallium at 1.4K. The results indicate that the gap edge is quite distinct, in contrast to previous results of Richards and Tinkham on other alloys. The sharpness of the gap edge is thought to be characteristic of alloys which are homogeneous and have no trapped magnetic flux. Alloying narrows the observed gap width by about the same ratio as the critical temperature, and by an amount which is much smaller than that predicted by Suhl and Matthias from a simplified model. The subsidiary absorption maximum below the gap edge, which has been seen previously in pure lead, is also present in the alloy. This lends support to other evidence that it is not due to crystalline anisotropy.

Ultrasonic Attenuation in Superconductors *by R. W. Morse, p. 58.* A brief review is given of the ultrasonic attenuation in metals arising from direct interaction of the elastic waves and conduction electrons, and the physical variables on which it depends. The drop in attenuation of longitudinal waves on entering the superconducting state is in good agreement with BCS theory, the various factors combining to make the relative attenuation, α_s/α_n, depend only on the energy gap; the measurements give evidence, however, for gap anisotropy or the presence of more than one gap. Recent measurements at Brown by Claiborne of shear wave attenuation in single-crystal Al, are in good agreement with a theory based on the Boltzmann and London equations. The steep drop at T_c is produced by shorting out of electromagnetic waves by supercurrents; the residual attenuation results from the effects of collision drag.

The Magnetic Behavior of Superconductors of Negative Surface Energy *by B. B. Goodman, p. 63.* Abrikosov and the author have separately suggested that a new type of reversible magnetic behavior is to be expected in superconductors whose coherence length is small compared with their penetration depth. The treatments of these two authors are shown to lead to similar results for pure metals and to only slightly different results for alloys. The experimental evidence in favor of a new type of reversible magnetic behavior in superconductors is discussed.

Effects of Electron Concentration and Mean Free Path on the Superconducting Behavior of Alloys *by B. R. Coles, p. 68.* A brief review is given of the superconducting behaviour of solid-solution alloys. Intermetallic compounds are not considered but some reference is made to secondary solid solutions. Two topics are discussed: some factors affecting the transition temperature, and the role played by surface energy between normal and superconducting regions.

Surface Energy Effects at the Boundary between a Superconductor and a Normal Conductor *by H. Meissner, p. 71.* Films of tin ranging from 500 to 1400 Å in thickness have been prepared in pairs by vacuum deposition onto rotating cylindrical glass and metal substrates. The temperature dependence of the critical fields has been measured. The critical temperatures of the films on metal substrates are all depressed. Their critical fields at absolute zero, however, are usually not depressed but can be higher than those of the corresponding films on glass. This increase can be explained by a negative surface energy arising from a short mean free path of the superconducting electrons in an incidental oxide layer at the surface of the metal. Most of the films on glass had an abnormally small value of the critical field at absolute zero.

Some Elementary Theoretical Considerations Concerning Superconductivity of Superimposed Metallic Films *by L. N. Cooper, p. 75.* A microscopic theory of superconductivity of superimposed metallic films is proposed, based on the fact that the electron pair correlation function penetrates into a normal metal where the electron-electron interaction would not by itself produce a superconducting state.

Thermodynamic Consistency of Magnetic and Calorimetric Measurements on Superconductors *by D. E. Mapother, p. 77.* Comparison of the entropy and specific heats of normal and superconducting tin and indium as computed from critical field and calorimetric measurements shows excellent consistency. Salient features of the comparison are briefly summarized. Some implications of the recently reported specific heat anomaly for indium are discussed.

The Temperature and Pressure Dependence of Critical Field Curves *by C. A. Swenson, p. 82.* A brief discussion is given of the analysis of recent critical field measurements. In particular, a negative volume coefficient of thermal expansion is predicted for tin in the superconducting state.

Mechanical Effects at the Superconducting Transition *by K. Andres, J. L. Olsen, and H. Rohrer, p. 84.* Work in Zürich on the difference in size and in expansion coefficient between the normal and the superconducting states is summarized. The volume dependences of the critical temperature and of the electronic density of states at the Fermi surface are discussed.

Variation of the Elastic Moduli at the Superconducting Transition *by G. A. Alers and D. L. Waldorf, p. 89.* Using an ultrasonic technique capable of measuring changes in the elastic moduli as small as one part in 10^7, the small modulus changes associated with the normal-to-superconducting transition have been measured as a function of both temperature and magnetic field. Single-crystal specimens of the cubic metals Pb, V, Nb and Ta were used and all their elastic moduli measured so that changes in the bulk modulus and Debye θ could be computed. The results showed that changes in the zero-point energy of the lattice can be far from negligible. Furthermore, the shear moduli are the most changed by the appearance of superconductivity.

First- and Second-Order Stress Effects on the Superconducting Transitions of Tantalum and Tin *by D. P. Seraphim and P. M. Marcus, p. 94.* The shift of critical field of a single-crystal wire under uniaxial tension is studied for Ta and Sn. For Ta the shift is nonlinear and gives both the first-order critical field-stress coefficient and a particular combination of second-order coefficients. By combining with other data, the three second-order constants are estimated. The smaller first-order coefficient of Sn is found to be considerably smaller than previous estimates. Both Ta and Sn are found to satisfy a similarity condition for the coefficients, but of a less restrictive form than usual. Similarity is used to predict the behavior of jumps in elastic constant moduli at the transition in Ta. The general formal theory of the first-and second-order coefficients is formulated and many special cases are given. The general thermodynamic relations at the transition between jumps in strain and elastic constants and the various coefficients, are derived. It is shown that BCS theory implies similarity.

Thermal Conductivity of Dilute Indium-Mercury Superconducting Alloys *by G. K. Chang, R. E. Jones, and A. M. Toxen, p. 112.* Thermal conductivities were measured for a series of polycrystalline alloys of indium containing 0.1 to 2.5 At.% mercury. Using theoretical models which relate the electronic thermal conductivity of a superconductor to its energy gap, the temperature and composition dependences of the energy gap have been calculated for these specimens. Estimates of the lattice thermal conduction were also obtained.

The Superconductivity of Some Intermetallic Compounds *by R. D. Blaugher, A. Taylor, and J. K. Hulm, p. 116.* The W-Os, Re-W, Re-Mo, Re-Hf, and Mo-Hf binary systems were investigated for superconductivity down to 1K. Several new superconducting regions were found with the most significant occurring in the primary and terminal solid-solution alloys. The occurrence of superconductivity in the β-phase field of the Re-Hf and Mo-Hf binaries indicates a possible explanation for the spurious superconducting effects sometimes observed in elemental hafnium.

High-Field Superconductivity in Some bcc Ti-Mo and Nb-Zr Alloys *by R. R. Hake, T. G. Berlincourt, and D. H. Leslie, p. 119.* Zero electrical resistance at unusually high magnetic field strengths has been observed in the bcc alloys Ti-16 a/o (atomic percent) Mo, Nb-12 a/o Zr, and Nb-25 a/o Zr. The maximum high-field zero-resistance current density, J_c, in these alloys appears to be a sensitive function of temperature, the degree of cold-working, and the orientation of the applied *transverse* magnetic field. For cold-rolled alloy specimens in an applied transverse field, J_c is a maximum or minimum, according to whether the field is set respectively parallel or perpendicular to the rolled face of the specimen. In Ti-16 a/o Mo the zero-resistance condition is observed in fields at least a factor 35 greater than the bulk material critical field as inferred from calorimetric data.

Anomalous Resistive Transitions and New Phenomena in Hard Superconductors *by M. A. R. Le Blanc, p. 122.* The value of the critical current (I_c)-critical field (H_c) of cold-worked Nb, Mo-Re and Nb-Zr wires at constant temperature is not a single-valued function of the field and current direction. The previous history of a specimen during an experiment plays an important role and a measurement of the critical field-critical current value can influence the response of the specimen to subsequent measurements. Anomalous resistive transitions are observed when I_c vs H_c curves are determined by proceeding from low to high fields which may not occur in measurements proceeding from high to low fields. Further, it is possible to condition a specimen to enable it to reach maximum values of the critical field and critical current. This phenomenon is also encountered in the operation of superconducting solenoids. The polarity of the field and current during this treatment is found to be significant. The effects of the rate increase of the current, of rotating the specimen in a transverse field, and of current density and temperature have also been studied.

Associative Memory with Ordered Retrieval *by R. R. Seeber and A. B. Lindquist, p. 126.* A basic associative memory utilizing cryogenic circuitry is described and its functions are compared with those of previously published associative memory descriptions. The ordered-retrieval sorting algorithm is described, along with its implementation by means of a ternary interrogating counter. A sorting example is given. The sorting efficiency is discussed and an efficiency formula is given. The required additions to the basic memory are outlined. Finally, some of the basic cryotron circuits are illustrated and their operation described.

Dual Programs *by P. Huard, p. 137.*

Domain Wall Creeping in Thin Permalloy Films *by S. Middelhoek, p. 140.*

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Some New High-Speed Tunnel-Diode Logic Circuits *by M. S. Axelrod, A. S. Farber, and D. E. Rosenheim, p. 158.* Several high-speed tunnel-diode logic circuits are presented which perform majority-type logic or majority-type logic with inversion, and make use of a multiphase sinusoidal power supply to obtain signal directivity. Laboratory results are presented which show operation of these circuits at a 125 Mc/sec pulse repetition rate with 2 nsec delay per logical decision. The circuits have also been operated at 250 Mc/sec.

A comparison which is made between these circuits and some of the tunnel-diode logic circuits previously reported in the literature reveals certain system advantages of the new circuits. Preliminary results of both analog and digital computer analyses of the systems of nonlinear differential equations which describe these circuits are presented. These results have been in excellent agreement with those found in the laboratory. A full serial binary adder is described which produces a carry output in 2 nsec and the sum output in 4 nsec.

Characterization of Tunnel Diode Performance in Terms of Device Figure of Merit and Circuit Time Constant *by L. Esaki, p. 170.* Tunnel diode oscillation, flip-flop switching and Goto twin operation have been characterized on the basis of numerical integration of a nonlinear differential equation representing transient behavior in the simplified, lumped equivalent circuit. The results have provided some information for the maximum utility of a tunnel diode having a given figure of merit. A useful relationship is given for single diodes, in which switching time vs external-circuit time constant L/R is shown for various device figures of merit. Another relationship is given for twin diodes in plots of cut-off frequency vs L/R. The study is then extended to the case of oscillator diodes.

Systematics of the Evoked Somatosensory Cortical Potential *by W. R. Uttal and L. Cook, p. 179.* This paper presents the results of a series of experimental studies in which a digital computer averaging technique was used to explore the dynamics of the electric response of the human somatosensory cortex evoked by pulse electrical stimulation of nerves in the wrist.

A nomenclature is presented for the typical components of the complex waveform which the authors consider to be representative of the evoked potential. The effects of stimulus amplitude, bilateral and bitemporal stimulation, and sleep on the evoked corticogram were investigated. Psychophysical studies were also carried out which complemented the evoked potential studies, and comparisons were made between the neurological and psychological data.

Charge Transport Mechanisms in the Transfer of Latent Electrostatic Images to Dielectric Surfaces *by R. M. Schaffert, p. 192.* The transfer of electrostatic charge patterns from one surface to another requires movement of electrical charges across very small air gaps. Gaseous electronics alone is not sufficient to account for charge transport across extremely small gaps. The concept of field emission is introduced as a supplementary mechanism of charge transport and as a source of primary electrons.

The Use of Triple-Modular Redundancy to Improve Computer Reliability *by R. E. Lyons and W. Vanderkulk, p. 200.* One of the proposed techniques for meeting the severe reliability requirements inherent in certain future computer applications is described. This technique involves the use of triple-modular redundancy, which is essentially the use of the two-out-of-three voting concept at a low level. Effects of imperfect voting circuitry and of various interconnections of logical elements are assessed. A hypothetical triple-modular redundant computer is subjected to a Monte Carlo program on the IBM 704, which simulates component failures. Reliability is thereby determined and compared with reliability obtained by analytical calculations based on simplifying assumptions.

Pseudo Division and Pseudo Multiplication Processes *by J. E. Meggitt, p. 210.* Some digit-by-digit methods for the evaluation of the elementary functions are described. The methods involve processes that resemble repeated-addition multiplication and repeated-subtraction division. Consequently, the methods are easy to implement and the resultant execution times are short.

Minimization Over Boolean Graphs *by J. P. Roth and R. M. Karp, p. 227.* This paper presents a systematic procedure for the design of gate-type combinational switching circuits without directed loops. Each such circuit (Boolean graph) is in correspondence with a sequence of decompositions of the Boolean function which it realizes. A general approach to functional decomposition is given and, in terms of a convenient positional representation, efficient tests for the detection of decompositions are derived. These results are

employed in the development of an alphabetic search procedure for determining minimum-cost Boolean graphs which satisfy any given design specifications.

Generalizations of Horner's Rule for Polynomial Evaluation *by W. S. Dorn, p. 239.* Polynomials are generally evaluated by use of Horner's rule, sometimes referred to as the nesting rule. This rule is sequential and affords no opportunity for parallel computation, i.e., completion of several of the arithmetic operations simultaneously. Two generalizations of Horner's rule which allow for parallel computation are presented here.

Schedules and, in some cases, machine codes for evaluating a polynomial on a computer with several parallel arithmetic units are developed. Some advantages of the generalized rules in sequential computations on a computer with a single arithmetic unit are presented.

Approximate Methods for a Multiqueueing Problem *by G. Schay, Jr., p. 246.* Two approximate methods are described and used to obtain the stationary distribution of the length of a queue which is a small part of a system of many queues. The methods are based on an analogy to statistical mechanics, and give simple approximate solutions of a problem whose exact handling would be extremely complex and would require much more information than is available.

Superconductivity and Ferromagnetism *by B. T. Matthias, p. 250.* The close relationship between superconductivity and ferromagnetism is discussed and illustrated; it is suggested that several mechanisms cause superconductivity and also ferromagnetism. Various rare earth alloys show simultaneous superconductivity and dilute ferromagnetism. Such dilute ferromagnetism does not occur, however, in the transition-metal superconductors. Striking differences in the effects of adding magnetic elements to transition-metal superconductors are traced to the presence or absence of localized magnetic moments; such occurrences show a dependence on electron concentration similar to superconductivity. Superconductivity in the transition and nontransition elements shows a simple dependence on valence electron concentration—but when such elements are mixed they interfere drastically.

Isotope Effects in Low Temperature Superconductors *by T. H. Geballe and B. T. Matthias, p. 256.* The critical temperatures of different isotopes of osmium and of zinc have been measured. The results are that Os has no isotope effect, while with Zn the critical temperature is proportional to $M^{-1/2}$. These findings, together with our previous work on ruthenium, are consistent with the statement that there is no isotope effect for the transition elements, whereas the full $M^{-1/2}$ effect exists for nontransition elements.

On the Influence of Free Path on the Meissner Effect *by D. C. Mattis, p. 258.*

Comment on "A Network Minimization Problem" *by M. Tideman, p. 259.*

A Theoretical Solution for the Magnetic Field in the Vicinity of a Recording Head Air Gap *by E. E. Francis and T.-C. Ku, p. 260.*

Application of Differential Interferometry with Two Polarized Beams *by C. Le Méhauté, p. 263.*

Comments on the Presence Function of Gazalé *by T. Rado, p. 268.*

Concerning the Possibility of a Cooperative Information Exchange *by M. Kochen and E. Wong, p. 270.*

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Rectification of Satellite Photography by Digital Techniques *by R. E. Mach and T. L. Gardner, p. 290.* Sample photographs from the TIROS I Weather Satellite have been successfully transformed into a Mercator projection using automatic digital techniques. Mathematical formulas expressing the relation between the photoplane and the Mercator projection have been derived, and a computer program has been written to efficiently manipulate a "digital photograph" in accordance with the formulas.

Multiple Input-Output Links in Computer Systems *by B. B. Tasini and S. Winograd, p. 306.* An algorithm is developed for the analysis and design of computing systems having a multiplicity of concurrent and independent information sources and a lesser number of input channels to the processing elements of a digital computer; the input-output links work simultaneously with the processing and computing elements of the system. Utilizing this algorithm, such problems pertaining to the amount of hardware and the interconnection of its components can be resolved. For an optimum system design, its parameters are subject to two major criteria, i.e., the amount of information transmitted to the central processing elements per unit time, and the degree of overlapping of input output operations with computing (or other processing operations) that can be attained. Part I of this paper is devoted to information sources of the sequential access, serial-by-character (or-bit) transmission class. Magnetic tape units are specifically dealt with. With minor modifications the method is applicable to other information sources of the same class. In Part I, three fundamental system configurations are discussed and results of computations are summarized. In Part II, information sources of the quasi-random and random access class are investigated within the framework established in Part I. Disk files were selected as a specific representative of the quasi-random and random access information sources.

Diffusion of Gas from a Liquid into an Expanding Bubble *by E. J. Barlow and W. E. Langlois, p. 329.* The growth of a bubble within a volume of isothermal viscous liquid containing uniformly distributed dissolved gas is considered. The problem of characterizing this growth-by-mass-transfer is reduced to an integro-differential equation for the bubble radius as a function of time, and a computer solution is obtained. The initial and final stages of growth are treated analytically.

Spin Absorption Spectra *by L. S. Brown, p. 338.* Spin systems exhibit a whole spectrum of absorption lines when in small constant external magnetic fields giving Zeeman energies comparable to internal interaction energies. With such small constant magnetic fields, power is absorbed from an alternating magnetic field at zero frequency, at the Larmor frequency, and at harmonics of the Larmor frequency, both for perpendicular- and parallel-field configurations. The calculation of this spectrum for spin systems in powdered materials is the main purpose of this paper. Both magnetic dipole-dipole and electric quadrupole internal interactions are considered and treated as second-order perturbations on the Zeeman interaction. The intensities of the two absorption lines that occur at the Larmor frequency and double the Larmor frequency are obtained for the parallel-field case. The intensity, frequency shift, and second moment of the Larmor line, and the intensities of the lines that occur at zero frequency and double the Larmor frequency, are obtained for the perpendicular-field case. The second-order calculation for powdered materials gives results which are identical within a constant factor for both dipole-dipole and quadrupole interactions.

An Experiment on the Effect of Particle Orientation on Peak Shift in Magnetic Tapes *by G. Bate, H. S. Templeton, and J. W. Wenner, p. 348.* One of the limiting factors in high-density recording on magnetic tape is the phenomenon of peak shift. With the NRZI code (flux change on a ONE, no flux change on a ZERO) this means that the reproduced signals from two successive ONES preceded and followed by ZEROS are separated in time by more than the natural bit period. The peaks in the signal output from the two ONES are thus shifted outwards. An experiment is described in which the peak shift is measured in particle-oriented tape as a function of the angle θ between the direction of recording and the direction of orientation. The dc hysteresis properties of the tape were also measured as a function of θ. It was found that the peak shift had a minimum when θ was approximately 65° for the tape and recording head used in this experiment. At this angle the remanence-coercivity was high, while the coercivity and the ratio of remanence to saturation intensity were low. Qualitative explanations of these results are offered and their significance is briefly discussed.

A "Logical Pattern" Recognition Program *by R. E. Bonner, p. 353.* A description is given of an IBM 7090 program which searches for "logical patterns" in a set of input samples. The program was tested on a character recognition problem, where it designed a recognition system whose error rate and hardware requirements are compared to those of a system designed by humans. This program is intended to be used as a research tool to discover certain kinds of patterns in data and as a step in the direction of automatic logic design for some character recognition problems.

Optical Mixing of Coherent and Incoherent Light *by A. W. Smith and N. Braslau, p. 361.*

Fluorescence of Europium Tungstate *by R. E. MacDonald, M. J. Vogel, and J. W. Brookman, p. 363.*

A Note on the Nature of RNA Codes *by S. A. Bernhard and W. L. Duda, p. 365.*

Partial-Switching Processes in Thin Magnetic Films *by W. Dietrich, p. 368.*

Direct Observation of Dislocation Loops in Arsenic-Doped Germanium *by G. E. Brock and C. F. Aliotta, p. 372.*

Electron Beam Microanalysis of Germanium Tunnel Diodes *by M. I. Nathan and S. H. Moll, p. 375.*

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Static Reversal Processes in Thin Ni-Fe Films *by S. Middelhoek, p. 394.* Magnetization reversal at an angle to the easy direction in Ni-Fe films was studied. The results, in contrast to the single-domain theory, show no coherent rotation, even for field directions in which the critical field for rotation is smaller than the critical field for wall motion. The actual reversal is initiated by rotation of the magnetization in bands formed in the film. New experimental studies show that the reversal is subsequently completed by wall motion. A qualitative discussion of the new observations and a review of previous work give a comprehensive picture of the static reversal processes in thin Ni-Fe films.

A Discrete Queueing Problem with Variable Service Times *by P. E. Boudreau, J. S. Griffin, Jr., and M. Kac, p. 407.* Methods from the theory of Markov chains are used to analyze a simple single-server queueing model. The model is of the sort that arises naturally in information-handling contexts, in that a discrete time basis is used, which matches the cyclic character of processors. Considerable generality is attained, in that no appeal is made to the exponential or other conventional forms for the probability distributions governing the number of arrivals per cycle and the service times.

The principal object of study is the queue length; the stationary distribution governing this quantity is calculated, along with various associated averages. The relation between the present method and the more usual continuous-variable

method is illustrated by the derivation of some of the classical equations from a limiting case of our model.

Analysis of Static and Quasidynamic Behavior of Magnetostatically Coupled Thin Magnetic Films *by H. Chang, p. 419.* When two superposed films exert fields on each other, their static and dynamic behaviors change. The following method or analysis is used to study the behavior: The stable states are found by minimizing the total free energy of the films. Then constant-field contours are plotted in the θ_1-θ_2 plane (θ's being the stable orientations of the magnetization vectors). In examining the plot, one can predict multiple stable states, switching, threshold, hysteresis, and the detailed paths of magnetization change as a function of applied field.

The solution is carried out by a numerical process which permits evaluation of the following effects: the variation of the degrees of symmetries of the anisotropy energies, the relative orientation between the films, the coupling strength, and the drive-line layout. An example is carried out in sufficient detail for illustrative purposes.

Coding for Logical Operations *by S. Winograd, p. 430.* The behavior of a computation system consisting of encoders, an unreliable logical operator and a decoder is investigated. It is shown that for almost all Boolean functions, coding each block of k input bits into a block of n bits such that all sets of s or less errors will be corrected requires that $n \geq (2s + 1)k$. This result suggests that the capacity (in the information theoretical sense) of such a computation system is zero.

Experimental Study of Electron-Beam Driven Semiconductor Devices for Use in a Digital Memory *by J. W. Horton, p. 437.* A novel method of electronic storage is proposed, in which an electron beam would be used to drive active and passive semiconductor devices to perform the functions of a digital memory, including those of nondestructive read-out and reset. Principally to ascertain what speeds and output signals might be currently obtained if the storage method were implemented, an experimental study was made of the response to a bombarding electron beam of commercial "four-layer" and surface-barrier diodes which could function in the proposed store respectively as storage diodes and read-out diodes. Data presented on the Shockley Laboratories' silicon 4N20D "four-layer" diode give the reduction of firing voltage caused by the bombardment as a function of beam current and bombardment duration. It is found that a beam current as weak as 0.2 μamp can fire a diode in 1/5 μsec. Three types of germanium surface-barrier diodes were studied for maximum speed of response to the bombarding beam current pulse and for charge multiplication. The "fastest" unit tested was a Philco 2N502 transistor modified for beam access to the base region by removal of the emitter dot. This unit could be bombarded to produce a 50 nsec pulse of 0.4 v peak across a 1000-ohm load. In the light of these data and of circuit and semiconductor device theory, a preliminary discussion is presented of the feasibility of a store providing a read-in rate of 5 megapulses/sec, a read-out rate of 15 megapulses/sec and a read-out signal ratio of stored ONES to stored ZEROES of 50 to 1.

Residual Stress in Single-Crystal Nickel Films *by J. F. Freedman, p. 449.* Experiments are described which directly indicate the source, magnitude and direction of the residual stress on single-crystal nickel films evaporated on rock salt. A theoretical analysis using the five-constant magnetostriction equation shows how this stress affects the magnetic properties. X-ray diffraction studies indicate that the as-evaporated films exist in a highly strained condition, resulting in a tetragonal distortion of the cubic symmetry. The parameters of the unit cell are $a = b = 3.500 \pm 0.004$ Å in the plane of the film and $c = 3.546 \pm 0.002$ Å normal to the film. The stress causing this strain is elastic in character. When the film is floated off the rock salt, the parameter decreases to bulk unstrained Ni, $a_0 = 3.524$ Å.

The calculation using bulk elasticity data yields a planar compressive stress $\sigma = 1.0 \times 10^{10}$ dyne/cm^2, from differential thermal expansion between nickel film and NaCl substrate. This externally applied stress system influences the magnetic state of the film by contributing to the total energy of the system through a magnetoelastic interaction.

A Polarimetric Method of Measuring Magneto-Optic Coefficients *by H. B. Bebb, p. 456.* Formulas are established which allow polarimetric determination of the amplitudes and relative phases of the Kerr (and Faraday) coefficients for ferromagnetic metals. The results are valid only for oblique angles of incidence. Hence, the technique is most useful for measurement of thin films where the magnetization vector lies in the plane of the film.

Printed Cards for the Card Capacitor Memory *by J. W. Haskell, p. 462.*

Determination of Lattice Strain and Crystallite Size in Thin Films *by A. Segmüller, p. 464.*

Direct Observations of the Substructure Network in Iron *by W. L. Mitchell, C. Hays, and R. E. Swift, p. 467.*

A Note on Some Fundamental Parameters of Multiqueue Systems *by M. A. Leibowitz, p. 470.*

Effect of Initial Air Content on the Dynamics of Bubbles in Liquids *by J. T. S. Ma and P. K. C. Wang, p. 472.*

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Computer-Automated Design of Multifont Print Recognition Logic *by L. A. Kamentsky and C.-N. Liu, p. 2.* A computer program has been written to design character recognition logic based on the processing of data samples. This program consists of two subroutines: (1) to search for logic circuits having certain constraints on hardware design, and (2) to evaluate these logics in terms of their discriminating ability over samples of the character set they are expected to recognize. An executive routine is used to apply these subroutines to select a complete logic with a given performance and complexity. This logic consists of 39 to 96 AND gates connected to a shift register and a table look-up or resistance network comparison system.

The methods were applied to the design of recognition logics for the 52 upper and lower case characters of IBM Electric Modern Pica type font and lower case Cyrillic characters scanned from Russian text. In both cases when the logics were tested on data different from that used to design the logics, the substitution rate was about one error per thousand. A single logic was designed to read two different Cyrillic fonts. For this design, an error rate of one error per hundred characters was observed.

Several experiments are reported on a number of logics designed for typewritten data, and single- and two-font Cyrillic data. The performances of different recognition systems are compared as a function of the complexity of the recognition logics.

The Recognition of Handwritten Numerals by Contour Analysis *by E. C. Greanias, P. F. Meagher, R. J. Norman, and P. Essinger, p. 14.* A character recognition system has been developed for the recognition of handwritten numerals. This system uses a logically controlled cathode ray tube scanner to generate basic measurements that characterize significant features of the numeral shapes. A contour-follower procedure is used to control the scanner. In addition, special scanner subroutines initiated by feedback from the recognition logic are utilized. Character shape data are generated in a sequential form, which can be analyzed for recognition with an easily realizable logic.

An experimental model has been built that recognized 99.3% of numerals written by 45 subjects after 30 minutes of training. The error rate for these characters was 0.11%. The rejected character rate was 0.59%.

Increased Magnetic Recording Read-back Resolution by Means of a Linear Passive Network *by H. M. Sierra, p. 22.* It has been proven that the principle of superposition applies to a magnetic read-back waveform. Consequently, each pulse can be treated as an isolated transient, and a linear passive network can be used to reduce its width. In many cases this effective increase in read-back resolution would permit an increase in the operating density. The isolated read-back pulse is first approximated by a Gaussian curve. A second approximation is effected in the frequency domain, and a table of transfer functions is obtained. A network is designed using one of the transfer functions, and the solution is given an algebraic form. One particular case is illustrated numerically and the laboratory results are shown.

Anomalous Photoelectric Emission from Nickel *by I. Ames and R. L. Christensen, p. 34.* The photoelectric emission from a nickel ribbon has been observed as a function of temperature from 25° to 760°C, over a wavelength range from 2250 to 2530 Å, qualitatively confirming and extending Cardwell's earlier work. The yield increases with temperature at all wavelengths, with an upward bulge near the Curie point. Fowler-Dubridge analyses of the emission from the front face of the ribbon, which is found to contain mainly (111) facets after extensive outgassing, yield values of the work function ranging from about 5.07 ev at 25°C to about 5.20 ev at 760°C. Behavior below the Curie point may be consistent with the magnetization-squared dependence recently suggested by Wonssowski, et al.

Synthesis of Transfer Admittance Functions Using Active Components *by F. J. Hudson, p. 40.* A formal synthesis procedure is developed for active networks. The transfer admittance function is realized in parallel *RC* subnetworks, one of which contains a current-reversal negative impedance converter. This procedure offers several advantages over existing methods.

Investigations of the Electro-Optical Birefringence of Polydisperse Bentonite Suspensions *by M. J. Shah and C. M. Hart, p. 44.* Colloidal suspensions of bentonite were observed to undergo a negative electro-optical birefringence at low-voltage fields even in dilute suspensions, a phenomenon not reported earlier. Experimental results do not support a previous theory that the sign of birefringence is reversed because of various particle sizes. Although interaction between particles was found to augment this low-voltage anomalous behavior, we believe that in dilute solutions this behavior is caused by some inherent property of the bentonite micelle. This contention is supported by variation in the relaxation times in negative and positive birefringence regions, thus suggesting orientation on two different axes in the two respective regions.

Threshold Relations and Diffraction Loss for Injection Lasers *by G. J. Lasher, p. 58.* Mathematical expressions are derived for the minimum current density necessary to cause stimulated emission in injection lasers. A new type of diffraction loss for a thin light-emitting layer surrounded by light-absorbing material is calculated.

Directionality Effects of GaAs Light-Emitting Diodes: Part I *by G. Burns, R. A. Laff, S. E. Blum, F. H. Dill, Jr., and M. I. Nathan, p. 62.*

Directionality Effects of GaAs Light-Emitting Diodes: Part II *by R. A. Laff, W. P. Dumke, F. H. Dill, Jr., and G. Burns, p. 63.*

Electromagnetic Mode Population in Light-Emitting Junctions *by W. P. Dumke, p. 66.*

Paramagnetic Resonance of the Shallow Acceptors Zn and Cd in GaAs *by R. S. Title, p. 68.*

Determination of the Active Region in Light-Emitting GaAs Diodes *by A. E. Michel, E. J. Walker, and M. I. Nathan, p. 70.*

Room-Temperature Stimulated Emission *by G. Burns and M. I. Nathan, p. 72.*

CW Operation of a GaAs Injection Laser *by W. E. Howard, F. F. Fang, F. H. Dill, Jr., and M. I. Nathan, p. 74.*

Experimental Study of Human Factors for a Handwritten Numeral Reader *by M. N. Crook and D. S. Kellogg, p. 76.*

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Some New Classes of Cyclic Codes Used for Burst-Error Correction *by E. Gorog, p. 102.* A general theory of cyclic codes correcting a set of given types of errors is presented. Codes published by Abramson, Fire, Melas and others are accounted for in this theory, which also offers several new classes of codes. These new codes are competitive with existing ones. In burst-error correction, for certain message lengths they may be better since they may need fewer parity check bits.

The Lightly Loaded Foil Bearing at Zero Angle of Wrap *by W. E. Langlois, p. 112.* A method is developed for determining, to the first order, the deflection from a straight path of a perfectly flexible tape moving near a rigid cylinder. The case of a parabolic cylinder is considered.

Propagation of Torsional Disturbances in a Homogeneous Elastic Sphere *by Y. Satô, p. 117.* Localized torsional stress is applied on the surface of a homogeneous elastic sphere for a short duration of time. The propagation of the disturbance caused by this stress is calculated numerically by superposing the normal mode solutions. The phases of the body waves and surface waves are obtained.

A Method for Key-to-Address Transformation *by G. Schay and N. Raver, p. 121.* Techniques used in the theory of error-correcting codes are applied to solve the problem of addressing a large file. This novel approach to the file addressing problem is illustrated with a specific design to show feasibility. Its effectiveness is further illustrated by comparing test results obtained from a simulated calculation, which used typical data, against values calculated from an ideal model.

An Application of Coding Theory to a File Address Problem *by M. Hanan and F. P. Palermo, p. 127.* In this paper a file address problem is proved to be equivalent to a problem in coding theory. Results in coding theory can thus be used in solving this file addressing problem. It is shown, in particular, how the theory of Bose-Chaudhuri codes can be applied. A simple transformation from the input information to its address is given. This method can be easily implemented using either a computer or shift registers.

Magnetization of Uniaxial Cylindrical Thin Films *by H. J. Kump and T. G. Greene, p. 130.* An analysis is given of the magnetization of a cylindrical thin film exhibiting a uniaxial anisotropy in the circumferential direction. The magnetization and demagnetizing fields are derived for the cylinder where the magnetization is not uniform. The derivation is accomplished by dividing up the cylinder into a large number of uniformly magnetized, coaxial cylindrical regions in superposition and by integrating their individual contributions. Some applications of the derivation are shown for several specified field geometries. The technique of superposition may be applied to other film geometries.

A Liquid Scintillation Counter Using Anticoincidence Shielding *by G. J. Sprokel, p. 135.* A liquid scintillation counter with an active volume of one liter is described. The plastic anticoincidence shield reduces background by about 25 percent in the H^3 and C^{14} region. Photomultiplier noise is effectively eliminated by nanosecond coincidence circuitry. The tunnel diodes used in the coincidence arrangement also act as baseline or window discriminators. Counting efficiency for C^{14} solutions is 85 percent, limited mainly by light collection.

Fly's-Eye Lens Technique for Generating Semiconductor Device Fabrication Masks *by W. E. Rudge, W. E. Harding, and W. E. Mutter, p. 146.*

A Note on Extending Certain Codes to Correct Error Bursts in Longer Messages *by C. M. Melas and E. Gorog, p. 151.*

Nominal Clearance of the Foil Bearing *by H. K. Baumeister, p. 153.*

Line Widths and Pressure Shifts in Mode Structure of Stimulated Emission from GaAs Junctions *by M. J. Stevenson, J. D. Axe, and J. R. Lankard, p. 155.*

Threshold Current for *p-n* Junction Lasers *by J. L. Moll and J. F. Gibbons, p. 157.*

On the Direct Observation of the Substructure Network in Iron *by G. Koves and J. Pesch, p. 160.*

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A Circuit Packaging Model for High-Speed Computer Technology *by F. K. Buelow, F. B. Hartman, E. L. Willette, and J. J. Zasio, p. 182.* An exploratory model has been constructed in a study of packaging and circuit techniques for a high-speed computer technology. An Arithmetic and Logic Unit capable of processing 64-bit words in floating-point format was fully designed. From this design a nucleus system comprising 424 circuits and 1838 transistors was abstracted, built, and tested. In this model, a delay of 2.2 nsec per level of logic was achieved in worst-case paths. This figure includes the wiring and power driver delays.

Design of ACP Resistor-Coupled Switching Circuits *by D. H. Chung and J. A. Palmieri, p. 190.* Directly coupled logic circuits utilizing silicon transistors have been developed in the Advanced Circuit Program. Silicon transistors possess sufficient field gradient in the collector-base "diode" to permit high-speed operation under a forward-biased condition. Current-switching techniques provide the well-controlled voltage levels which permit operation in this region without sacrificing high speed. Operation in this region permits circuit simplification and low power dissipation.

A desirable state-of-the-art device is defined. Design techniques which result in a compatible set of logic circuits and power amplifiers are described. Germanium tunnel diodes are used in power driving and transmission line driving circuits.

In order to measure the delay times, a model with 424 circuits was subsequently built. ACP circuits (the name adopted for this circuit family) were found to perform two levels of logic in 3.2 nsec.

An Improved Tunnel Diode Memory System *by D. J. Crawford, W. D. Pricer, and J. J. Zasio, p. 199.* Beginning with a brief history of tunnel diode memories, this paper describes the factors leading to the present design approach. Array design criteria are discussed at length. Examples of engineering applications are given, including a cross-sectional model of a "scratch pad" memory for use with Advanced Circuit Program logic circuitry.

Transient Analysis and Device Characterization of ACP Circuits *by K. G. Ashar, H. N. Ghosh, A. W. Aldridge, and L. J. Patterson, p. 207.* Characterization of devices for high speed ACP (Advanced Circuit Program) circuits demands an accurate study of transients and switching delays. This paper describes (a) the large-signal transistor model evolved for the purpose of carrying out such an analysis; (b) methods of measuring device parameters with relevant theory; (c) computational techniques most adaptable; and (d) correlation between predicted and observed transients. Many new ideas in the development of the device model, measurements, and computational procedure are reported and could be used for any general circuit analysis.

A New Model for Error Clustering in Telephone Circuits *by J. M. Berger and B. Mandelbrot, p. 224.* This paper proposes a new mathematical model to describe the distribution of the occurrence of errors in data transmission on telephone lines. We suggest: a) that the statistics of telephone errors can be described in terms of an error probability depending solely on the time elapsed since the last occurrence of an error; b) that the distribution of inter-error intervals can be well approximated by a law of Pareto of exponent less than one; the relative number of errors and the equivocation tend, therefore, to zero as the length of the message is increased. The validity of those concepts is demonstrated with the aid of experimental data obtained from the German telephone network. Further consequences, refinements, and uses of the model are described in the body of the paper.

Digit-by-Digit Methods for Polynomials *by J. E. Meggitt, p. 237.* This paper presents a general system configuration for an arithmetic unit of a computer, which is used to solve polynomial problems efficiently. The technique is based on a digit-by-digit computation of the coefficients of the given polynomial, after the origin has been displaced systematically. Compared with standard techniques, the new scheme, closely allied with Horner's method, is similar in efficiency for polynomial evaluation and is superior for locating roots. The fact that the computed coefficients are related to the derivatives permits the systematic location of all real roots of a real polynomial.

Automatic Determination of Amino Acid Sequences *by S. A. Bernhard, D. F. Bradley, and W. L. Duda, p. 246.* A fundamental problem for biochemistry is the determination of the linear sequence of amino acids in proteins. This paper describes a computer-oriented logic for obtaining such determination. The logic applies successively stronger decision rules to extract the required information on the protein sequence.

Directional Coupling and its Use for Memory Noise Reduction *by G. F. Bland, p. 252.*

A Simple Active Equivalent to a Lattice Pulse-Slimming Filter *by P. D. Dodd, p. 257.*

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Nonlinear Wave Propagation in a Transmission Line Loaded with Thin Permalloy Films *by M. C. Gutzwiller and W. L. Miranker, p. 278.* This paper considers the propagation of waves in a transmission line loaded with thin permalloy films. Since the films are driven to saturation, the transmission line equations which are derived to describe the

wave propagation are nonlinear. The nonlinearity requires the use of shock wave analyses, and a derivation of the appropriate shock relations is included. The problems of a line loaded with a single film and a line loaded with a periodic array of films are both treated. The saturation front moving along a string of films is shown to be the shock front. The shock speed, which is determined in terms of the parameters of the circuit, is then the operational speed limit of a thin film memory.

A Theoretical Model for Separation in the Fluid Jet Amplifier *by Y.-O. Tu and H. Cohen, p. 288.* A theoretical study, based on the re-entrant jet model, is made of the growth of the separation region in the fluid jet amplifier. The flow is taken to be inviscid but dissipation of momentum is obtained by means of the re-entrant jet. The effect of control port pressure and wall angle on the size of the separation region is calculated. Several other versions of the model are suggested.

Prenucleation of Lead Films with Copper, Gold, and Silver *by R. H. Jeppesen and H. L. Caswell, p. 297.* Lead films evaporated onto thin nucleating layers of Cu, Ag, and Au were studied by the techniques of electron diffraction and electron microscopy. Elecuron micrographs indicated that films nucleated with Au become continuous much sooner than films nucleated with Ag or Cu. Examination of the diffraction pattern showed Au to be the only metal of the three to form an intermetallic compound with lead, indicating that compound formation aids in nucleation.

Analysis and Numerical Calculations of the Dynamic Behavior of Plane Pivoted Slider Bearings *by W. Stuiver and R. S. McDuffie, p. 303.* The dynamic behavior of plane, self-acting, pivoted slider bearings of infinite length is examined for the case of an incompressible lubricating film. The equations of motion for the slider are derived, with the lubricant force expressed in terms of the motion-coordinates and their derivatives and of the parameters that characterize the system. Equilibrium positions of the system are determined numerically and the stability of small motions in the neighborhood of these positions is examined. The nature of large motions is investigated by numerical integration of the equations of motion, and the transient behavior of the system is shown and discussed for some specific cases.

Automatic Correction of Multiple Errors Originating in a Computer Memory *by P. R. Daher, p. 317.* An error correction unit has been installed in an IBM RAMAC® 305 to demonstrate automatic correction of burst errors originating in a computer memory. Employing a cyclic code requiring two percent redundancy, the unit has successfully corrected all four-bit and most five-bit error bursts in a 100-character record stored on a defective disk. Details of the error correction unit and test results are presented; two special cases involving block length are also discussed.

A Data Display Subsystem *by J. E. Dammann, E. J. Skiko, and E. V. Weber, p. 325.* A cathode ray tube device is described in which up to 4000 flicker-free characters are displayed dynamically. The developmental system is designed to permit monitoring the display while data are inserted, deleted or corrected by means of a keyboard. This system uses a novel positioning method which combines electrostatic and magnetic techniques.

Nonlinear Absorbers of Light *by R. W. Keyes, p. 334.*

Tagging Techniques for Incorporating Microglossaries in an Automatic Dictionary *by G. O. Tarnawsky, p. 337.*

Automatic Step-Size Control for Runge-Kutta Integration *by R. M. Warten, p. 340.*

High-Speed Photographs of Laser-Induced Heating *by T. J. Harris, p. 342.*

Diffraction by a Finite Sinusoidal Phase Grating *by E. S. Barrekette and H. Freitag, p. 345.*

On a Queueing Problem Arising in Recirculating Memories *by G. Schay, Jr., p. 350.*

Further Results in Polynomial Addressing *by C. V. Freiman and R. T. Chien, p. 353.*

An Amendment to "A Theoretical Solution for the Magnetic Field in the Vicinity of a Recording Head Air Gap" *by T.-C. Ku, p. 355.*

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Speech Synthesis from Stored Data *by S. E. Estes, H. R. Kerby, H. D. Maxey, and R. M. Walker, p. 2.* The synthesis of speech by joining together segments derived from natural speech has not proven to be satisfactory with segments smaller than words, especially because of discontinuities in pitch and formant frequencies at the junctions. It appears that segmentation of the control signals for an analog synthesizer may avoid these difficulties. This paper describes an experimental system to investigate this method. A library of synthesizer control signals corresponding to subword segments of speech is now being developed. The equipment used to generate the library of control signals, as well as that used to synthesize connected speech from the library, is described.

The synthesizer is a transistorized terminal analog of the cascade type. The synthesizer control signals are originally derived from functions drawn on a transparent plastic belt with opaque tape and scanned by a CRT and photomultiplier. The control signal functions are varied until the speech segment being studied is satisfactory. The resulting control signals corresponding to the speech segment are then automatically digitized and recorded on punched cards for addition to the library. Connected speech may be generated by computer assembly of the synthesizer control signals corresponding to a sequence of speech segments. In the assembly of connected speech from the library segments, pitch and timing may be specified independently of the sequence of segments if desired.

Attenuation of a Magnetic Field by a Superconductor *by K. E. Drangeid, R. Sommerhalder, H. Müller, and H. Seitz, p. 13.* Observation of magnetic ac field penetration through superconducting tin films has led to the discovery of a 180° phase shift between the magnetic fields on either side of the film under favorable conditions. This result has so far been published only in a short note, and the present paper presents a detailed description of the experimental technique. A more quantitative discussion, with emphasis on the physical aspects of field attenuation in superconductors, will be published in a future paper.

On Some Clustering Techniques *by R. E. Bonner, p. 22.* The problem of organizing a large mass of data occurs frequently in research. Normally, some process of generalization is used to compress the data so that it can be analyzed more easily. A primitive step in this process is the "clustering" technique, which involves gathering together similar data into a cluster to permit a significant generalization.

This paper describes a number of methods which make use of IBM 7090 computer programs to do clustering. A medical research problem is used to illustrate and compare these methods.

A Vestigial-Sideband, Phase-Reversal Data Transmission System *by D. L. Critchlow, R. H. Dennard, and E. Hopner, p. 33.* A new method of carrier retrieval is described for a suppressed-carrier, vestigial-sideband data transmission system. Tests over voice grade telephone lines indicate that operation at 3000 bits per second (in some cases, 3600 bps) can be obtained reliably over private lines with simple adjustable equalization, whereas fixed compromise equalization will allow speeds up to 2400 bps over a large percentage of lines in the switched network. The possibility of higher speed operation using a multilevel data signal is demonstrated by tests at 6000 and 8000 bps over a carefully equalized private line.

Nondestructive Determination of Thickness and Refractive Index of Transparent Films *by W. A. Pliskin and E. E. Conrad, p. 43.* A simple nondestructive method of measuring the refractive index and thickness of transparent films on reflective substrates has been developed. The technique involves the use of a microscope equipped with a monochromatic filter on the objective and a stage that can be rotated so that the reflected light is observed at various angles. The film thickness, d, is given by $d = [\Delta N\lambda]/[2\mu(\cos r_2 - \cos r_1)]$, where λ is the wavelength of the filtered light, μ is the refractive index, and ΔN is the number of fringes observed between the angles of refraction r_2 and r_1.

This technique is especially suited for films thicker than one micron. Techniques are also described for obtaining accurate thicknesses of films less than one micron by the combined use of monochromatic filters and an interference pattern chart. These techniques can be used to determine film thicknesses ranging from several hundred angstroms to several microns with accuracies of 0.2% on films thicker than 2μ, and accuracies of tens of angstroms on thinner films. Since visual comparisons of color can be used fairly easily for film thickness determinations, the techniques were used to construct a color chart for thermally grown SiO_2 films up to 1.5μ thick.

Transmission-Line Response Using Frequency Techniques *by C. L. Bertin, p. 52.* Frequency-domain analysis of transmission-line pulse response is presented. A computer program is used to evaluate the response, using subroutines to describe the line characteristics and terminal conditions. The program is applicable to lines of any cross section in which the TEM mode of propagation exists. The line characteristics are obtained from either formula prediction or frequency measurements on small samples. Because of skin effects or complex geometry, these characteristics can be extremely difficult to calculate, and so an experimental procedure is adopted for determining these parameters. The computer-program results are compared to measured values.

A Fast, Digital-Indexed Light Deflector *by W. Kulcke, T. J. Harris, K. Kosanke, and E. Max, p. 64.*

A Note on a Class of Binary Cyclic Codes Which Correct Solid-Burst Errors *by A. D. Wyner, p. 68.*

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Foreword: The IBM System/360 *by A. L. Samuel, p. 86.*

Architecture of the IBM System/360 *by G. M. Amdahl, G. A. Blaauw, and F. P. Brooks, Jr., p. 87.* The architecture of the newly announced IBM System/360 features four innovations:

1. An approach to storage which permits and exploits very large capacities, hierarchies of speeds, read-only storage for microprogram control, flexible storage protection, and simple program relocation.

2. An input/output system offering new degrees of concurrent operation, compatible channel operation, data rates approaching 5,000,000 characters/second, integrated design of hardware and software, a new low-cost, multiple-channel package sharing main-frame hardware, new provisions for device status information, and a standard channel interface between central processing unit and input/output devices.

3. A truly general-purpose machine organization offering new supervisor facilities, powerful logical processing operations, and a wide variety of data formats.

4. Strict upward and downward machine-language compatibility over a line of six models having a performance range factor of 50.

This paper discusses in detail the objectives of the design and the rationale for the main features of the architecture. Emphasis is given to the problems raised by the need for compatibility among central processing units of various size and by the conflicting demands of commercial, scientific, real-time, and logical information processing. A tabular summary of the architecture is shown in the Appendices.

Solid Logic Technology: Versatile, High-Performance Microelectronics *by E. M. Davis, W. E. Harding, R. S. Schwartz, and J. J. Corning, p. 102.* A new microelectronics packaging technique, called Solid Logic Technology (SLT), utilizes silicon planar glass-encapsulated transistors and diodes, and graphic arts techniques for producing high-quality, passive components having tight tolerances. The result is a process permitting the low-cost realization of a variety of versatile, high-performance circuit modules.

The salient features of SLT are described: the unique form of the semiconductor devices, the module fabrication process, and some performance results. In addition, insight is provided to the range of components that my be fabricated with this technology, i.e., inductors, capacitors and high-power transistors. Examples are shown of specific high-speed, high-density and complex circuit packages.

Design of Serviceability Features for the IBM System/360 *by W. E. Carter, H. C. Montgomery, R. J. Preiss, and H. J. Reinheimer, p. 115.* This paper discusses the design of features that are intended to provide the IBM System/360 with a significant improvement in serviceability over that of previous systems. It was decided from the beginning to develop the System/360 as an integrated package of hardware, operational programs, and maintenance procedures.

The major problems to be solved in gaining this improvement and integration were (a) reducing the maximum duration of service calls; (b) reducing the median duration and mean duration of service calls; and (c) matching a single package of maintenance programs and procedures to a large variety of operational monitor programs and machine models.

These problems have been attacked by supplementing standard servicing facilities (both hardware and program) with (a) the ability to record automatically the complete, detailed, system environment at the instant of error discovery; (b) the ability to initialize the CPU to any arbitrarily specified state (either "legal" or "illegal"), to advance from this state by a specified number of machine cycles, and to compare the new state with a precomputed result state, much of this using circuits that are independent of those required for program sequencing; (c) a system of programs that can be integrated with the System/360 Design Automation to produce automatically the inputs, results, and location analyses that are required to exploit the capabilities described in (b); (d) a family of diagnostic monitor programs that attack directly the problem of matching maintenance procedures to machine models and operational monitor programs; and (e) a facility to retry failing CPU operations at the instruction level in the larger models, in addition to the usual retry at the program-segment level.

Solid Logic Design Automation *by P. W. Case, H. H. Graff, L. E. Griffith, A. R. LeClercq, W. B. Murley, and T. M. Spence, p. 127.* This paper describes the unique features of a set of IBM 7090 programs which provide design assistance to engineers who use Solid Logic Technology. These programs were applied in the design of the IBM System/360.

Instabilities of Current in III-V Semiconductors *by J. B. Gunn, p. 141.* A description is given of a newly discovered phenomenon which is observed when an electric field of a few thousand V cm^{-1} is applied to a homogeneous sample of *n*-type GaAs or InP. Above a well-defined threshold field, a time-dependent decrease in current is observed, which is largely independent of external circuit conditions. In long specimens this decrease is aperiodic, resembling random noise with a bandwidth of ~ 10^9 c/sec. In short specimens, coherent oscillations are observed whose period is equal to the transit time of electrons between the ohmic electrodes of the

structure. Frequencies over the range of 0.5–6.5 Gc/sec have been generated in this way, using experimental techniques which are described. Measurements of the efficiency of dc-to-rf conversion (from 1 to 2%), and of peak power outputs (up to 0.5 W), suggest that the new effect may have useful applications. Some diagnostic experiments are described and the results are discussed in terms of various possible mechanisms. Although the quantitative agreement with theory is poor it is concluded that the current instability may possibly be due to the amplification of lattice optical modes.

Evaluation of Spectrochemical Data Using Digital Techniques *by N. R. D. Åslund and B. T. Cronhjort, p. 160.* This paper describes how a digital computer was used in combination with an emission spectrometer to determine chemical compositions of some steels. A mathematical model describing the relations between the composition and the intensities of the spectral lines was derived and experimentally tested. Both overlapping and matrix effects were considered. The computer was also used to calibrate the instrument.

An Approach Towards Batch Fabricated Ferrite Memory Planes *by E. A. Bartkus, J. M. Brownlow, W. A. Crapo, R. F. Elfant, K. R. Grebe, and O. A. Gutwin, p. 170.* This paper describes a technique for the batch fabrication of ferrite memory arrays in which wire, previously coated with a thermoplastic, is formed into two orthogonally disposed sets of parallel wires. These grids are oriented between opposing molds having matched grooves filled with a fluid mixture of ferrite powder and thermosetting resin, in such a manner that one set of parallel wires coincides with the groove axes. After suitable curing this structure is released and heat treated to pyrolyze the organic materials and sinter the ferrite.

A yield study on 108 memory arrays produced in this manner resulted in a yield of 72.2% on pulse testing under simulated operating conditions and an over-all process yield of 36.1%. The paper concludes with a tabulation of electrical characteristics of the arrays and a brief discussion of the applicability of the technology to various modes of operation and its potential for high-speed (250 nsec magnetic cycle time) operation.

Some Theoretical Aspects of a Proposed Double Quantum Stimulated Emission Device *by P. P. Sorokin and N. Braslau, p. 177.* A double quantum stimulated emission device is proposed and some operating characteristics and relevant systems of materials are discussed.

Ruby Laser Q-Switching Elements Using Phthalocyanine Molecules in Solution *by P. P. Sorokin, J. J. Luzzi, J. R. Lankard, and G. D. Pettit, p. 182.*

The Crystal Structure of $CaPd_3O_4$ *by R. C. Wnuk, T. R. Touw, and B. Post, p. 185.*

An Existence Theorem for the BCS Integral Equation *by F. M. Odeh, p. 187.*

On Ordered Retrieval from an Associative Memory *by L. R. Johnson and M. H. McAndrew, p. 189.*

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Foreword *by P. J. Price, p. 214.*

Crystal Chemistry and Band Structures of the Group V Semimetals and the IV-VI Semiconductors *by M. H. Cohen, L. M. Falicov, and S. Golin, p. 215.* Some simple facts regarding crystal structures and semiconducting vs semimetallic behavior of the Group V elements and the related Group IV-VI compounds are summarized. The simple chemical interpretation of these facts (based on three perpendicular p-bonding orbitals) is reviewed. This picture is reinterpreted in terms of a simple pseudopotential band model, which provides a deeper basis for understanding the simple chemical notions. The results of various band structure calculations are presented in detail in order to make explicit the direct relation between band and bond pictures as well as between crystal structures and semimetallic vs semiconducting behavior. The calculations also provide information as to probable locations of valence and conduction band edges.

The Effective g-factor of Holes in Bismuth *by G. E. Smith, G. A. Baraff, and J. M. Rowell, p. 228.*

High Field Galvanomagnetic Effects in Bismuth *by J. J. Vuillemin, p. 232.*

Piezo-Resistance and Piezo-Hall Effect in Bismuth *by A. L. Jain and R. Jaggi, p. 233.*

Phonon Dispersion Curves in Bismuth *by J. L. Yarnell, J. L. Warren, R. G. Wenzel, and S. H. Koenig, p. 234.* Dispersion curves for phonons propagating in the trigonal direction in bismuth at room temperature and at 75K have been obtained in a neutron inelastic scattering experiment. Observed frequencies (units 10^{13} rad/sec) at 75K are as follows: at the zone center, $\omega_{TO} = 1.40 \pm 0.02$, $\omega_{LO} = 1.89 \pm 0.02$; at the zone boundary in the trigonal direction, $\omega_{TA} = 0.73 \pm 0.01$, $\omega_{LA} = 1.12 \pm 0.02$, $\omega_{TO} = 1.91 \pm 0.02$, $\omega_{LO} = 2.03 \pm 0.02$. At room temperature, the observed frequencies were about 1.5 percent lower. Data were also obtained for longitudinal phonons propagating in the binary direction at 75K. It is interesting to note that the splitting between the zone boundary frequencies for the optical and acoustic branches for each polarization is quite large. This splitting is difficult to understand if bismuth is thought of as a slightly distorted simple cubic lattice. The experimental results may be qualitatively understood if bismuth is considered to be made up of a series of double layers normal to the trigonal axis. The atoms in each double layer form a crinkled hexagonal net with strong, probably covalent, bonds between atoms. The

forces between atoms on adjacent double layers are relatively weak. This model is consistent with the easy cleavage of bismuth normal to the trigonal axis. Analysis of the trigonal dispersion curves in terms of a linear chain model indicates that there are significant forces connecting a given atom with atoms situated on the four planes on either side of it.

Transport Properties and Band Structure in Bismuth, Antimony and their Alloys *by J. J. Hall and S. H. Koenig, p. 241.* We shall interpret the galvanomagnetic properties of bismuth, antimony and the Bi-Sb alloy system in terms of bands of carriers known to exist in the pure semimetals. In our interpretation, the new carriers, presumed holes, observed by several investigators in antimony must have slightly warped oblate ellipsoidal energy surfaces to account for the galvanomagnetic data of Juretschke et al, rather than tilted ellipsoidal surfaces. These new holes, together with the well established holes in bismuth and the Shoenberg electrons in both bismuth and antimony, account for the anomalous Hall coefficients of antimony. Consideration of qualitative features of the nearly free electron model of Jones and Harrison suggests that a linear variation of the spatial potential upon alloying bismuth with antimony is sufficient to account for the considerable changes observed in the transport properties of the alloy system. This model also suggests that the conduction band minima in bismuth are located at different points in the Brillouin zone from those in antimony. Experimental support for these hypotheses is discussed.

Cyclotron Resonance and the Fermi Surface of Antimony *by W. R. Datars and J. Vanderkooy, p. 247.* A new series of cyclotron resonance experiments has been made on antimony which gave extended information on electron and hole cyclotron masses. Experiments were carried out with the magnetic field in the principal crystal planes of antimony at 1.5K and with 35 Gc/sec microwave radiation. The magnetic field of cyclotron resonance in certain regions was dependent upon the angle of tip of the magnetic field with respect to the metal surface. These effects were minimized by accurate alignment of the magnetic field along the sample surface. The carriers of two bands were observed. The cyclotron mass of one band, assumed to be the conduction band, was consistent with a tilted-ellipsoidal model for the energy surfaces. The cyclotron mass along the 1′ principal electron ellipsoid axis was measured from data in the binary-trigonal plane to be 0.215 m_0. The conduction band ellipsoids were found to have a tilt angle of 36° and mass tensor components: $m_{11} = 0.068\ m_0$, $m_{22} = 0.63\ m_0$, $m_{33} = 0.34\ m_0$, $|m_{23}| = 0.41\ m_0$. The data indicated three sets of warped ellipsoids for the valence band. The warped ellipsoids were found to have a tilt angle of 4° and mass tensor components: $m_{11} = 0.093\ m_0$, $m_{22} = 1.14\ m_0$, $m_{33} = 0.093\ m_0$, and $|m_{23}| = 0.082\ m_0$. The cyclotron masses of holes and the measurement of cyclotron resonance at limiting points of the Fermi surface indicated that the hole surfaces probably are deformed from an ellipsoid.

Growth and Transport Properties of Bi-Sb Single Crystal Alloys *by D. M. Brown and S. J. Silverman, p. 253.*

Energy Band Structure of Graphite *by J. W. McClure, p. 255.* The energy band structure of graphite is described in the region of the Fermi surfaces by the Slonczewski-Weiss model. The electron and hole Fermi surfaces are highly elongated and are aligned along the six Brillouin zone edges which are parallel to the trigonal axis of the crystal. The energy is a non-parabolic function of wavenumber and the Fermi surfaces are not ellipsoids. Galvanomagnetic, de Haas-van Alphen, and other experiments have established that: the band overlap is about 0.03 to 0.04 eV, the carrier densities of electrons and holes are each about 3×10^{18} cm^{-3} at low temperatures, the effective masses perpendicular to the trigonal axis are about 0.04 m_0 for electrons and 0.06 m_0 for holes, and the length-to-width ratio of the Fermi surfaces is about 12. The only important effect not included in the Slonczewski-Weiss model is the correlation of electron motion due to the coulomb interaction. Though this effect is expected to be important *a priori,* it is not yet clear if it causes important discrepancies between the predictions of the model and the experimental results.

The Fermi Surface of Graphite *by M. S. Dresselhaus and J. G. Mavroides, p. 262.* Recent magnetoreflection measurements in pyrolytic graphite have been interpreted using the magnetic energy levels obtained from the McClure-Inoue secular equation and the appropriate selection rules for interband transitions. Combining these results with those of the de Haas-van Alphen effect, the band parameters of the Slonczewski-Weiss model have been evaluated and the Fermi surface determined. The magnetoreflection experiment indicates considerable warping of the Fermi surface, particularly for holes. Further experiments to determine this warping more precisely are discussed.

Change in Fermi Surfaces of Graphite by Dilute Acceptor Doping *by D. E. Soule, p. 268.* The effect of doping graphite single crystals with the acceptor boron was studied in the dilute range from &ltequiv.0.1 ppm to 0.5% by measurements of the Hall effect and de Haas-van Alphen effect. The transition from a mixed electron and hole conduction in the narrow band overlap region (0.035 eV) to that of a single hole conduction produces a peak in the Hall coefficient that shifts to a lower boron concentration with a decrease in temperature. The increase in hole concentration is accompanied by a rapid decrease in mobility, demonstrating the importance of collision broadening. Preliminary de Haas-van Alphen results tentatively identify the major electron and hole Fermi surfaces by means of the period shift with increasing acceptor concentration. A *new,* very small ellipsoid-like Fermi surface was discovered. It is aligned along the hexagonal axis, having an anisotropy ratio of 9 with orbital masses of about 0.0023 m_0 for H *concat* C and 0.017 m_0 for H $\perp$ C. Analysis strongly indicates that this surface contains minority holes. Three of these surfaces are considered to be aligned

symmetrically like "outriggers" about the major hole surface, producing a total of six in the Brillouin zone. A comparison is made with the cyclotron resonance results and a possible interpretation of these minority Fermi surfaces is presented using the Slonczewski-Weiss band model.

STB Model and Transport Properties of Pyrolytic Graphites *by C. A. Klein, p. 274.*

Alfvén Wave Propagation in Bismuth: Quantum Oscillations of the Fermi Surface *by G. A. Williams and G. E. Smith, p. 276.* Alfvén wave propagation in single crystal bismuth has been studied as a function of magnetic field to 105 kilogauss for frequencies between 13 and 18 kMc/sec. Small deviations from a linear dependence of wave velocity on magnetic field are found and are interpreted as quantum oscillations in the mass density of carriers. Theory and experiment are compared for the magnetic field along a bisectrix axis and along a two-fold axis. Good agreement is found for the first case, but significant discrepancies exist for the magnetic field along a two-fold axis.

Infrared Reflectivity of Bismuth in the Quantum Limit *by L. C. Hebel, p. 284.*

Acoustic Plasma Waves in Semimetals *by A. L. McWhorter and W. G. May, p. 285.* The acoustic plasma wave suffers severe Landau damping for equal-temperature carriers obeying Boltzmann statistics, but can be relatively weakly Landau damped in semimetals if in the propagation direction the Fermi velocities and masses of the two carriers are very unequal. Only the carriers with the smaller Fermi velocity are important in producing collision damping since the other carriers store no appreciable momentum. Some results for many-valley semimetals like bismuth are given, together with a discussion of the problem of exciting and detecting this essentially neutral and longitudinal wave. Experiments undertaken to detect the acoustic plasma wave by transmission through thin wafers of bismuth at 10 Gc/sec have been unsuccessful thus far, but have revealed the existence of a higher velocity wave of weak amplitude that has not yet been identified. A discussion is also given of some magnetic quantum effects that should be associated with the acoustic wave.

Effect of the Self-Magnetic Field on Galvanomagnetic Effects in Bismuth *by S. Tosima and R. Hirota, p. 291.* The magnetoresistance and the Hall coefficient for pure bismuth at 77K have been calculated to the second order in the self-magnetic field, i.e. current density. The calculations show that the observed dependence of the galvanomagnetic effects on the current density at high currents can be qualitatively explained by the self-magnetic field. However, to obtain quantitative agreement it is necessary to include the contribution of diffusion currents in the calculation. The theory for the self-magnetoresistance, including diffusion, has been carried out for the pre-pinch regime of currents. The resulting curve for the self-magnetoresistance agrees well with the observed one if the scattering times between ellipsoids are taken to be of order 10^{-9} sec (assuming that the diffusion effects are not dominated by the surface, i.e. that the surface-recombination velocity is sufficiently small).

Non-Ohmic Conduction in Bismuth *by W. Schillinger, p. 295.* The experimentally determined I-V characteristics at large currents at 4.2K, 77K, and 300K have been found to be nonlinear in both single crystal and wire samples of bismuth. A theory has been formulated which includes self-magnetoresistance, a redistribution of carriers (pinch) and bimolecular bulk and surface recombination. Very little information exists, either experimentally or theoretically, with regard to these recombination mechanisms. A program has been written to numerically solve the equations for various values of the electron-hole recombination time and surface velocity. It is found that the I-V characteristics are dominated by the self-magnetoresistance and vary only slightly for a wide range of the generation-recombination parameters.

Linear and Nonlinear Methods in Pattern Classification *by H. J. Greenberg and A. G. Konheim, p. 299.* The problem of pattern classification has two highly interactive aspects: (1) the selection of numerical measurements to 'represent' the patterns, and (2) the specification of an algorithm to identify patterns, based upon the numerical values of these measurements. The present paper presents the mathematical framework for one attack upon these problems and gives results obtained in some experiments in character recognition.

Magnetically Controlled Variable Logic *by E. G. Newman and L. F. Winter, p. 308.* Magnetically controlled multipurpose logic provides a great flexibility and compactness. A matrix consisting of 2^n saturable magnetic elements for n variable inputs is controlled by an adjacent magnetic pattern recorded on a magnetic medium, which determines the logical function to be performed. Since 2^{2n} magnetic patterns enable the performance of 2^{2n} logical functions, great flexibility of system operation is possible. The selection of the required magnetic materials is described.

Application of the basic system to several special purpose machines is shown. In particular, the design of a computer using microprogramming techniques is described, and the application of this system to various serial and parallel computer operations is discussed.

A New Digital Method of Bit Synchronization Derived from an Analog Theory *by A. J. Anello, A. C. Ruocchio, and W. D. Van Gieson, Jr., p. 318.* This paper discusses a new method of bit synchronization derived from an analog theory to solve the problems involved in receiving a serial train of bits from a remote data communication source. Test results show that accurate frequency and phase information can be derived from the received serial data. The Analog Derived Clock to accomplish this bit synchronization is described, and

applications in two-wire (half duplex operation) and four-wire (full duplex operation) communication systems are discussed. Speeds up to 2 Mc/sec using existing digital circuit technology were achieved. The special advantage of the Analog Derived Clock over present clocking techniques is an increase in speed and a reduction in circuitry.

Simulation of a Hydraulic Actuator *by A. H. Mitchell and K. L. Johnson, p. 329.* A simple mathematical model of a hydraulic actuator is formulated, and the differential equations describing the model are derived. Experimental data and a computational solution of the model are determined. Results correspond favorably with oscilloscope velocity traces; hence the model could serve a useful purpose in mechanical design.

A Note on the Resonant Modes and Spatial Coherency of a Fabry-Perot Maser Interferometer *by G. J. Y. Fan, p. 335.*

Analysis of a Nondegenerate Two-Photon Giant-Pulse Laser *by R. L. Garwin, p. 338.*

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Surface Effects on Silicon: Introduction *by D. R. Young and D. P. Seraphim, p. 366.*

Space-Charge Model for Surface Potential Shifts in Silicon Passivated with Thin Insulating Layers *by J. E. Thomas, Jr. and D. R. Young, p. 368.* Semipermanent changes in the semiconductor surface potential occur in insulator-covered semiconductors when external fields are applied for long times, particularly at elevated temperatures. An attempt to explain these changes in terms of the charging and discharging of interface states leads to conclusions that disagree with many of the experimental facts. Specifically, the semipermanent effects of interface-state charges can always be overcome by the application of a field smaller than that which is used to induce the effect, and of the same sign, while the experiments described in the accompanying papers generally show that a field much larger than the inducing field, and of the opposite sign, is required to return the insulator covered surface to its initial status. The accumulation of space charge in the insulating layer can give rise to very large fields at the semiconductor surface that persist after the removal of an external inducing field. The size and sign of such space-charge fields agree with the experimental observations. Measurements made after treatment at temperatures above 125°C show that the surface of silicon passivated with silicon dioxide can become strongly *n*-type as a result of such a positive space-charge layer formed at the interface. A model is presented based on the concept that this space charge arises from oxygen vacancies in the silicon dioxide. It is suggested that the improvement resulting from the use of phosphorus pentoxide on the outside surface is due to the elimination of vacancies by the oxidizing action of the phosphorus pentoxide.

Stabilization of SiO_2 Passivation Layers with P_2O_5 *by D. R. Kerr, J. S. Logan, P. J. Burkhardt, and W. A. Pliskin, p. 376.* Measurements are reported on the stability of planar, *npn* silicon transistors with and without a phosphosilicate glass layer over the SiO_2 passivation layer. The phosphosilicate layer forms during the emitter diffusion from a P_2O_5 source, and the data show that, to insure stability, it must not be removed in subsequent processing steps. The units tested were of conventional geometry except for a gate electrode over the base region, which provided additional information on the surface condition. The transistors were subjected to temperatures of 150° and 200°C with either gate-bias or junction reverse-bias. Production transistors, without gates, which had failed on life test were shown to have no phosphosilicate layer because it had been removed by excessive etching during fabrication. Additional evidence for the stabilization by P_2O_5 has been obtained using metal-oxide-silicon capacitors with and without P_2O_5 treatment of the SiO_2 layer. Both dc conduction through the insulator and stability of the capacitance-voltage characteristic were measured. These experiments suggest that the transistor degradation with unstabilized SiO_2 is caused by an accumulation of positive space-charge in the silicon-dioxide. This charge accumulates when an electric field (directed toward the silicon) is applied to the SiO_2 at temperatures in the range of 150°C.

Effect of Temperature and Bias on Glass-Silicon Interfaces *by D. R. Kerr, p. 385.* New technologies for deposition of thin glass films on silicon substrates have generated interest in the resulting glass-silicon interface potentials and the interface stability under conditions of bias and temperature that might be experienced in device operation.

Experiments are described which show accumulation of space-charge layers at glass-silicon interfaces under combined conditions of electric field applied normal to the surface, and elevated temperature. The glasses studied are lead-alumino-borosilicates and zinc-alumino-borosilicates and were applied in films several microns thick by sedimentation techniques. Measurements were made on metal-glass-silicon capacitor structures. The silicon at the interface may be shifted strongly *n*-type or strongly *p*-type, depending on applied field direction, during a heating cycle of a few minutes. Surface charge densities up to 10^{13} electronic charges/cm^2 have been observed. The temperatures required for such shifts vary over the range 100° to 300°C, depending on glass composition. Conductivity through the films during the combined bias-temperature treatment is compared with interface charge build-up. The data suggest a mechanism in which the bias-temperature combination causes movement of ions (possibly sodium) with a resultant build-up of space charge in the glass near the interface. The long-term stability of this "locked-in" charge indicates that interface potential with the more stable glasses may be permanently tailored to a desired value by bias-temperature treatment.

Electrode Control of SiO_2 Passivated Planar Junctions *by P. P. Castrucci and J. S. Logan, p. 394.* Electric fields have been applied to the surface over a planar silicon junction by means of a metallic control-ring electrode on the oxide surface. Capacitance measurements have indicated that a large, positive, immobile charge is present at or near the interface between the silicon dioxide and the silicon. An improvement in breakdown voltage occurs when the control ring is biased negatively, producing a field that opposes the field of the immobile charge. Positive control-ring voltages are shown to produce very large junction leakage currents. The leakage current is shown to be sensitive to a high-temperature reverse bias treatment and a model for this effect is suggested. Transistors with base contracts that extend over the oxide-protected collector junction are shown to have higher breakdown voltages than do those that lack the base electrode extension. This effect is consistent with the improvement in breakdown voltage found in control-ring diode measurements.

Electrochemical Phenomena in Thin Films of Silicon Dioxide on Silicon *by D. P. Seraphim, A. E. Brennemann, F. M. d'Heurle, and H. L. Friedman, p. 400.* A study has been made of the effect of chemical additives and of annealing and electrical biasing procedures upon the state of charge of silica films grown on silicon. A model, proposed to account for the observations, is based on the assumption that phosphorus, aluminum, and boron, when present, substitute for Si in SiO_2. The resulting species may be represented as PO_2+, PO_2-, AlO_2-, or BO_2-. The mobile charge carrier in the silica under the conditions investigated here is assumed to be an oxide-ion vacancy. Under certain conditions electrolysis is accompanied by deviations from Faraday's laws and changes the net charge in the oxide; under other conditions only the charge distribution in the oxide is changed. The experiments leading to the development of the model, which were done with metal-oxide-silicon structures, have been supplemented with experiments with field effect transistors. Field effect transistors of the *n-p-n* type have been made to operate in the enhancement mode.

Carrier Surface Scattering in Silicon Inversion Layers *by F. Fang and S. Triebwasser, p. 410.* The field effect surface-channel conductance and transconductance of both *p*-type and *n*-type Si inversion layers were measured as a function of external field. In the small signal region, the channel conductance was found to vary logarithmically with the transverse field. The results are interpreted in terms of reduction of carrier mobility that is due to surface scattering. A model which consists of a uniformly distributed charge layer and self-consistent field is proposed to explain the observed results. It was found that in most samples measured a combination of specular and diffuse scattering is involved. Examples of completely diffuse scattering as well as the diffuse and specular combination are given. The temperature dependence of the surface mobility between 77K and 300K is presented.

Effect of Low Temperature Annealing on the Surface Conductivity of Si in the Si-SiO_2-Al System *by G. Cheroff, F. Fang, and F. Hochberg, p. 416.* Studies on insulated-gate field effect devices fabricated on both *n*- and *p*-type Si have shown the existence of inversion layers on *p*-type surfaces and of accumulation layers on *n*-type surfaces. The degree of inversion or accumulation was characterized by measuring the total series capacity of the SiO_2 gate and the underlying Si as a function of an applied dc potential. The initial surface conductivity, as measured by the source to drain conductance g_{sd} at zero gate bias, indicates that most of the surface charge is immobile. Prolonged heat treatments at 350°C on *p*-type substrates have resulted in a two order-of-magnitude increase in g_{sd} accompanied by little or no change in the total surface charge density N_t. On *n*-type substrates, however, the same treatment results in a factor of 5 decrease in N_t. The effects of these treatments on the surface uniformity as well as on appropriate device parameters are reported.

Chemical and Ambient Effects on Surface Conduction in Passivated Silicon Semiconductors *by H. S. Lehman, p. 422.* The effect of processing variables on the surface conduction properties of passivated silicon junction devices has been studied. Insulated gate field-effect transistors fabricated in *p*-type silicon were used as an experimental tool. Varying the metal used as the gate electrode is shown to strongly influence the surface conductivity of the field-effect device. The effects of heat treatments in various ambients and variations in the insulators used are also discussed. Surface conduction is shown to be a complex function of materials, thermal history and processing.

Hall Measurements on Silicon Field Effect Transistor Structures *by A. B. Fowler, F. Fang, and F. Hochberg, p. 427.*

Velocity of Sound in a Many-Valley Conductor *by E. Adler, p. 430.* The effect on the velocity of sound corresponding to the "Keyes effect," for nonzero frequency and finite wavelength, is calculated by means of the electron Boltzmann equation. The result may be expressed as an effective electronic contribution to the elastic constant; the deviation, ${}_{\chi}dK_0$ of δK from the Keyes electronic contribution to the elastic constant, δK_0, is examined as a function of frequency and other parameters. When the Fermi velocity v is much larger than the sound velocity s and the mean free path is of the same order or larger than the acoustic wavelength, we find that $\chi \approx (s/v)^2$. When the mean free path is small compared to wavelength, $\chi = \omega^2/[\omega^2 + (\nu + 1/\bar{\tau}_d)^2]$, where ν is the intervalley scattering rate and $\bar{\tau}_d$ is an average diffusion relaxation time.

Displacement Discontinuity over a Transversely Isotropic Elastic Half-Space *by W. T. Chen, p. 435.* The paper presents a solution to the elasticity problem where the discontinuity is in the displacement component parallel to the plane area

inside the transversely isotropic medium. The work previously performed on discontinuity problems is also discussed.

The Design of Transformer (Dimond Ring) Read-Only Stores *by D. M. Taub and B. W. Kington, p. 443.* The operation of transformer read-only stores is explained and the main methods of construction described. The optimum turns ratio of the transformers is calculated. It is shown how a transformer can produce an output current even though the energised word line is not threaded through it. The value of this ZERO current depends on the information pattern and is found to be greatest with one of two patterns, depending on the type of construction used. For both patterns, expressions for the maximum ZERO and minimum ONE output signals are derived.

The cause of resonances is explained and a method of damping described. The expressions for optimum turns ratio, maximum ZERO and minimum ONE output signals are modified to take account of the damping and a worked example is given. Computed and observed output waveforms are compared for a store containing a non-worst-case pattern and are found to agree well.

The Equilibrium Behavior of the Silicon-Hydrogen-Chlorine System *by R. F. Lever, p. 460.* The composition of the gas phase is calculated for various temperatures, pressures, and chlorine-to-hydrogen ratios for the two-phase system consisting of solid silicon in equilibrium with the gas phase. It is shown that in the range of variables most frequently used for vapor growth of silicon, the principal species under equilibrium conditions are H_2, HCl, $SiHCl_3$, and $SiCl_2$.

Stability Criteria for Large Networks *by R. K. Brayton, p. 466.* An arbitrarily large network of bistable tunnel diode switching circuits is analyzed for stability. One condition derived indicates that increasing the total "fan" of each circuit might tend to make the whole network unstable. This condition is independent of the tunnel-diode characteristic. Another condition is also derived which depends on this characteristic but does not involve the total "fan". Finally, two general theorems which were proved in another paper are stated and discussed in terms of their applicability to certain classes of large networks and the types of conditions for stability that can be obtained.

Mutually Quenched Injection Lasers as Bistable Devices *by G. J. Lasher and A. B. Fowler, p. 471.*

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A Statistical Approach to the Design of Diffused Junction Transistors *by D. P. Kennedy, P. C. Murley, and R. R. O'Brien, p. 482.* Monte Carlo methods of statistical analysis are applied to the problems of transistor design and optimization. The experimental tolerances associated with any diffusion process are shown to represent an important factor in the initial design of diffused junction transistors. Many transistor parameters exhibit a substantial degree of sensitivity to small variations in the diffusion process. This is confirmed by a comparison between the theoretical and experimental open-base breakdown voltage, and current gain, for a large number of devices. It is therefore proposed that the design of a transistor be based upon attaining a specified set of electrical characteristics when the device is assumed to be fabricated by a non-ideal diffusion process. An electronic computer has been used in an investigation of the foregoing problem. The investigation shows further that a margin-of-safety must be designed into each electrical parameter of a transistor to assure that the resulting device satisfies a given set of design specifications, even though this margin-of-safety may differ for each parameter. In this paper examples are presented to illustrate the theoretical trade-off between several opposing transistor parameters that exhibit a substantial degree of variability due to a non-ideal diffusion process.

Calculation of the Capacitance of a Semiconductor Surface, with Application to Silicon *by P. M. Marcus, p. 496.* The electrostatic problem of finding the surface capacitance of a plane semiconductor surface as a function of applied voltage is formulated and solved. The solution takes account of the space charge distribution in the semiconductor, of a surface dielectric layer, of the possible presence of surface states, and of the exact Fermi-Dirac statistics for the charge carriers. The macroscopic electrostatic problem and microscopic electronic description are kept separate, convenient reduced units are introduced, and the differential capacitance characteristic is expressed in a simple parametric form. For bands of normal form, and for a single-level acceptor or donor surface state, the reduced characteristic depends on eight reduced quantities for general statistics, and on six for the simpler Boltzmann limit; the latter include three quantities describing the surface state level, one for the dielectric layer, one bulk semiconductor parameter, and one contact potential constant which shifts the voltage scale. Explicit calculations are made for silicon at 293K for various doping levels, dielectric layers, and single-level surface states; the variation of the characteristic dip in the capacitance is exhibited as a function of these parameters.

Design of ACP Tunnel-Diode-Coupled Circuits *by D. W. Murphy and J. R. Turnbull, p. 506.* The performance of the Advanced Circuit Program (ACP) circuits described by D. H. Chung and J. A. Palmieri can be improved by replacing the coupling resistor with a pair of tunnel diodes. The low impedance and power gain properties of the tunnel diode increase the fan-power and provide better control of signal levels. In addition, the improved rise times increase circuit speeds to the extent that delays of less than 1 nsec per logic function have been demonstrated. Since the tunnel diode pair can be designed to perform AND, OR, or majority logic

functions, the logic flexibility of these circuits is greater than that of the resistor-coupled circuits. The design techniques which lead to a consistent set of logic circuits and to binary full adders are discussed.

The very fast rise times generated by the tunnel diode pair require the use of transmission lines as the interconnection medium. The techniques used to minimize the effects of noise and reflections on circuit performance are discussed.

Computer Analysis of Electron Paramagnetic Resonance Spectra *by J. D. Swalen and H. M. Gladney, p. 515.* Algebraic methods that are useful in the reduction of EPR spectra to the magnetic parameters in the phenomenological Hamiltonian are summarized and programs presently available to accomplish the necessary computations are described. Among the topics discussed are (i) the calculation of the spectrum of the complete spin Hamiltonian for single-crystal experiments, with the principal axis system; (ii) the transformation of the Hamiltonian to the magnetic quantization axes, which is convenient for perturbation theory; (iii) the use of iteration methods to determine the parameters by a least-squares technique; (iv) the detailed fitting of EPR spectra of polycrystalline or glassy-state magnetic sites; (v) the correlation methods in the analysis of solution spectra; (vi) a novel integral transformation to improve the resolution; and (vii) the calculation of the dipolar sum for line width studies.

Glass-Passivated GaAs Chip Tunnel Diode *by S. S. Im, J. H. Butler, and D. A. Chance, p. 527.* A novel approach to the fabrication of tunnel diodes described. The experimental tunnel diode is a gallium arsenide planar device, using a conventional alloyed junction in an epitaxially grown GaAs substrate, and hermetically sealed by a high-temperature glass coating. The tunnel diode is fused to a circuit module using a solder reflow method. This package provides a high degree of mechanical reliability, great reduction in size, and an easy means of interconnection. Another unique feature is that the peak current is tailored electrically to within 1% by altering the impurity distribution near the junction, rather than by the conventional electrochemical etching technique. The resulting gallium arsenide tunnel diodes, having peak currents of 8 mA and capacitances of 5 pF, are suitable for use in a one-nanosecond switching circuit.

Thermal Limitations on the Energy of a Single Injection Laser Light Pulse *by G. J. Lasher and W. V. Smith, p. 532.* The upper limits on the output pulse power of an injection laser arising from heating effects are estimated. The heat is assumed to be dissipated by conduction through a large homogeneous body. A simple method for computing over-all diode efficiency is given.

Derivation of Maximal Compatibles Using Boolean Algebra *by M. P. Marcus, p. 537.*

Negative Resistance Tunnel Diodes in Silicon Carbide *by R. F. Rutz, p. 539.*

High Power CW Operation of GaAs Injection Lasers at 77° K *by J. C. Marinace, p. 543.*

Continuous Microwave Oscillations of Current in GaAs *by N. Braslau, J. B. Gunn, and J. L. Staples, p. 545.*

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Ab Initio Computations in Atoms and Molecules *by E. Clementi, p. 2.* The present status of *ab initio* computations for atomic and molecular wave functions is analyzed in this paper, with special emphasis on the work done at the IBM Research Laboratory, San Jose. The Roothaan-Hartree-Fock method has been described in detail for atomic systems. A systematic tabulation of atomic Hartree-Fock functions has been made available in an extended supplement to this paper. Techniques for computing many-center, two-electron matrix elements have been discussed for Slater or Gaussian basis sets. It is concluded that the two possibilities are comparable in efficiency. We have advanced a few suggestions for the extension of the self-consistent field technique to macromolecules. The validity of the suggestions have not been tested.

Following the Bethe and Salpeter formalism, the relativistic correction has been discussed and illustrated with numerical results for closed-shell atoms. A brief analysis of the relativistic correction for molecular systems shows that the relativistic effects cannot be neglected in ionic systems containing third-row atoms.

The correlation energy is discussed from an experimental starting point. The relativistic and Hartree-Fock energies are used for determining the correlation energy for the elements of the first three periods of the atomic system. A preliminary analysis of the data brings about a "simple pairing" model. Data from the third period force us to consider the "simple pairing"model as a first-order approximation to the "complex pairing" model. The latter model is compared with the geminals method and limitations of the latter are pointed out.

A semiempirical model, where use is made of a pseudopotential that represents a coulomb hole, is advanced and preliminary results are presented. This model gives reason to some hope for the practical formulation of a Coulomb-Hartree-Fock technique where the correlation effects are accounted for and the one-particle approximation is retained.

Automatic Distortion Correction for Efficient Pulse Transmission *by K. E. Schreiner, H. L. Funk, and E. Hopner, p. 20.* Automatic correction of pulse distortion provides the prospect for materially extending the efficiency of data communications over telephone networks. Systems that will compensate automatically for deficiencies in the phase and amplitude characteristics of a transmission channel are shown to be technically feasible. Two specific systems are demonstrated: The first, a "time-reversal" system, compensates for distortion in the phase characteristic only, and the second, a "time-domain" system, compensates for distortion in amplitude as well as phase. The theoretical basis of this work is presented and verified by experimental results obtained on simulated lines and on common-carrier channels.

Active Image Formation in Lasers *by W. A. Hardy, p. 31.* An optical cavity is described in which the modes are determined as stationary states of the diffraction-limited object/image transformation of classical optics; these modes are selected by the insertion of controls into the optical cavity and lead to field distributions which image these controls. When the cavity is driven by an active medium, laser oscillation can occur, and this is discussed in terms of the coupled mode equations used by Wagner and Birnbaum in their theory of quantum oscillation in a multimode cavity. Some properties of these modes in the limits of small and large optical aperture are described and illustrated with experiments using the helium-neon gas laser.

On Relations Defined by Generalized Finite Automata *by C. C. Elgot and J. E. Mezei, p. 47.* A transduction, in the sense of this paper, is a n-ary word relation (which may be a function) describable by a finite directed labeled graph. The notion of n-ary transduction is co-extensive with the Kleenean closure of finite n-ary relations. The 1-ary transductions are exactly the sets recognizable by finite automata. However, for $n > 1$ the relations recognizable by automata constitute a proper subclass of the n-ary transductions. The 2-ary length-preserving transductions constitute the equilibrium (potential) behavior of 1-dimensional, bilateral iterative networks. The immediate consequence relation of various primitive deductive (respectively computational) systems, such as Post normal systems (respectively Turing machines) are examples of transductions. Other riches deductive systems have immediate consequence relations which are not transductions. The closure properties of the class of transductions are studied. The decomposition of transductions into simpler ones is also studied.

Amplification of Sound by Hot Electrons *by P. J. Price, p. 69.*

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Hazard Detection in Combinational and Sequential Switching Circuits *by E. B. Eichelberger, p. 90.* This paper is concerned with a unified approach to the detection of hazards in both combinational and sequential circuits through the use of ternary algebra. First, hazards in a combinational network resulting from the simultaneous changing of two or more inputs are discussed. A technique is described that will detect hazards resulting from both single- and multiple-input changes. The various types of hazards connected with gate-type sequential circuits are also discussed, and a general technique is described that will detect any type of hazard or race condition that could result in an incorrect terminal state. This technique could be easily implemented in a computer program which would be capable of detecting hazards in circuits containing hundreds of logic blocks.

Coincidence Counter Models with Applications to Photographic Detection Theory *by H. J. Zweig and D. P. Gaver, p. 100.* Various types of counter models have been treated in the literature over the past twenty years. In all these models the counter mechanism involves a fixed or random dead time following a registered event. In this paper a different type of counter mechanism is introduced in which the occurrence of two or more input events within a relatively short time is required to produce a registered (output) event. This model of an "*R*-fold coincidence counter" is applied to the development of grains in a photographic emulsion for both low-intensity and high-intensity reciprocity failure.

On Plane Blazed Gratings *by E. S. Barrekette and R. L. Christensen, p. 108.* The Fraunhofer patterns of blazed gratings are derived on the basis of a scalar theory which includes the non-linear dependence of the obliquity factor and the phase modulation on the spatial frequencies defining the positions of the source and of the observer. The solution based on the usual 'linear communications' theory is compared with one based on the more general non-linear theory; it is shown that the former is meaningful only in the neighborhood of the blaze wavelength. The behavior of blazed gratings is examined in the light of non-linear theory in the region away from the blaze wavelength. It is shown that the envelope function describing the amplitude distribution due to a single groove depends on the single parameter defining half the phase difference between the two edges of a single diffracting facet. It is also shown that certain wavelengths are missing from the zero order and that 'dark' lines exist into which no light of any order is transmitted. A useful maximum for the aspect ratio is derived. The Littrow and spectrograph configurations are examined in some detail.

Demagnetization of Flat Uniaxial Thin Films Under Hard Direction Drive *by H. J. Kump, p. 118.* The demagnetizing fields are derived for all points of flat uniaxial thin films under various drive fields. The derivation is accomplished by breaking up the flat film into a number of sheets in superposition and integrating their individual contributions to the demagnetizing fields. The scheme is self-consistent in that the magnetization results as a consequence of the derivation, and need not be assumed. Further, the accuracy does not depend on the position with respect to the edges, but rather on the number of sheets.

The general approach to the problem is discussed briefly and the final equation for a rectangular geometry given. The discussion is concerned with one-dimensional examples, demonstrating the somewhat unexpected form of the demagnetizing fields under various hard axis drive conditions. Single bits as well as continuous films of Permalloy driven by uniform fields and multiple strip lines are treated. The effect of registration on the demagnetization is also discussed.

Average Motion Times of Positioners in Random Access Devices *by F. R. Hertrich, p. 124.* An analysis is made of the average motion times of mechanical positioners based on trapezoidal velocity vs time curves. The results are plotted in terms of dimensionless motion parameters. It is shown that average motion time may be optimized by balancing acceleration and velocity in a proper way. The selection of optimum transmission ratios between motor and load is discussed and demonstrated in an example.

Sheet Thermoforming of a Superplastic Alloy *by D. S. Fields, Jr., p. 134.*

A New Method for Frequency-Division Multiplexing, and Its Integration with Time-Division Switching *by P. M. Thrasher, p. 137.*

Electrodeposition of Stress-Insensitive Ni-Fe and Ni-Fe-Cu Magnetic Alloys *by C. LeMéhauté and E. Rocher, p. 141.*

Peculiar Domain Behavior in Thin, Magnetic Ni-Fe Double Films *by S. Middelhoek, p. 147.*

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Fresnel Holograms: Their Imaging Properties and Aberrations *by J. A. Armstrong, p. 171.* A simple and unified treatment is given of the properties of the magnified or demagnified images reconstructed from Fresnel holograms. The resolution attainable in wavefront reconstruction is discussed with particular attention to the aberrations of reconstructed images. Explicit expressions are given for the five primary wave aberrations, viz., spherical aberration, coma, astigmatism, curvature of field, and distortion.

Analysis of the Impurity Atom Distribution Near the Diffusion Mask for a Planar *p-n* Junction *by D. P. Kennedy and R. R. O'Brien, p. 179.* Presented here are the results from a mathematical investigation of the impurity atom distribution within a planar *p-n* junction. Two fundamentally different diffusion processes are considered: In the first, a constant impurity atom concentration is maintained at the semiconductor surface; in the second, a fixed quantity of impurity atoms is involved in the entire diffusion process. The results of this investigation show than a one-dimensional approximation inadequately characterizes the impurity atom distribution within a planar junction, and that in theory, the planar junction is not at a constant distance from its impurity atom source. Instead, the junction is closer to its source at the semiconductor surface than deep within the bulk material. Further, it is shown that when diffusion takes place from a source of constant concentration density, the junction impurity atom gradient is maximum at the semiconductor surface. In contrast, this junction impurity atom gradient is shown to exhibit a minimum at the semiconductor surface when the total number of impurity atoms is time invariant throughout the entire semiconductor material.

Some Numerical Experiments in the Theory of Polynomial Interpolation *by F. W. Luttmann and T. J. Rivlin, p. 187.* An important unsolved problem in the theory of polynomial interpolation is that of finding a set of nodes which is optimal in the sense that it leads to minimal Lebesgue constants. In this paper results connected to this problem are obtained, and some conjectures are presented based upon numerical evidence garnered from extensive computations.

On a Circular Crack in a Transversely Isotropic Elastic Material Under Prescribed Shear Stress *by W. T. Chen and R. P. Soni, p. 192.*

Chain Matrices and the Crank-Nicolson Equation *by H. P. Flatt, p. 196.*

A Drive Scheme for the GaAs-Si Light-Activated Switch *by P. Polgar, M. M. Roy, and T.-H. Yeh, p. 200.*

Mapping an Arbitrary Range into (−1, 1) with a Side Condition: Application to Numerical Quadratures *by A. D. McLean and M. Yoshimine, p. 203.*

A New Technique for Dynamic Analysis of Acoustical Noise *by R. H. Peterson and R. L. Hoffman, p. 205.*

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On Communications and Data Processing: A Foreword *by M. C. Andrews, p. 226.*

A New Approach to Time-Domain Equalization *by E. Gorog, p. 228.* A theoretical study is made of the time-domain equalization procedures for the correction of delay distortion in high-speed data transmission lines. In the first part of the paper the conditions that insure valid and effective use of a class of conventional time-domain equalizers are reviewed. In the second part of the paper, a new type of nonlinear time-domain equalizer is proposed, in which iterative methods are not required. The theoretical basis is given for the new equalization method.

Decoding of Cyclic Codes Using Position Invariant Functions *by J. D. Ullman, p. 233.* Ratios that are sufficient to detect classes of error patterns in cyclic codes are discussed. Systematic procedures for the correction of Bose-Chaudhuri codes are given; it is shown that these are quite fast but practical only for small numbers of random errors. It is seen that there is the capability of simultaneous independent and burst error correction.

A Comparison of Pseudo-Noise and Conventional Modulation for Multiple-Access Satellite Communications *by H. Blasbalg, p. 241.* This paper compares pseudo-noise (PN) with conventional modulation techniques for multiple-access satellite communications of voice messages. The reference for all comparisons is the conventional frequency-division multiplex telephone system. The comparison study is concerned with theoretical channel parameters as well as practical considerations which are unique to satellite communications. For PN modulation, curves are presented which show the relationship between the intrinsic signal-to-noise ratio and the number of channels per megacycle for a given test-tone-to-noise ratio.

It is concluded that high quality voice transmission can be achieved efficiently with PN-multiplexing. In particular, pulsed pseudo-noise transmission with some form of wide-deviation pulse-time message modulation and matched filter reception uses the down-link intrinsic signal-to-noise ratio and bandwidth as efficiently as the conventional single-sideband up and composite frequency-modulation with feedback down, provided that up-link power control is used. For lower quality communications, conventional modulation is more efficient in rf bandwidth utilization. Where rf bandwidth is not a significant factor, but the down-link intrinsic signal-to-noise ratio is important, then in the case of PN modulation, communications can be made thermal noise limited in the down-link. Here PN is, for all practical purposes, as efficient as orthogonal multiplexing.

A Pulsed Pseudo-Noise VHF Radio Set *by F. Corr, R. Crutchfield, and J. Marchese, p. 256.* The design of a radio set using pulsed pseudo-noise signals is described. The unit uses pulse position modulation and matched-filter detection. The use of pulse compression techniques permits the radio to achieve good signal detectability; it also permits privacy for each of several sets operating in a common channel. Characteristics of the 280 Mc/sec rf system are given and the call-up logic for achieving telephone-like operation is described. Some aspects of the digital matched filter design are discussed. Analysis of theoretical operation shows only a small performance difference between digital and linear matched filters.

Analysis and Simulation of a Digital Matched Filter Receiver of Pseudo-Noise Signals *by R. Van Blerkom, R. E. Sears, and D. G. Freeman, p. 264.* This paper discusses the performance of a digital matched filter receiver matched to a biphase-modulated signal in a clutter environment consisting of other biphase-modulated signals. Analytic results for a white-Gaussian model and for a non-linear capture model are compared with simulation results obtained from an IBM 7094 computer. The white-Gaussian model is in general agreement with the simulation results for equal power clutter signals; the capture model and the simulator yield similar results when a dominant clutter source is present.

Design of an Automatic Telephone Intercept Switch *by G. F. Abbott, R. L. Bence, J. A. Ceonzo, and J. M. Regan, p. 274.* A system has been designed to automatically perform the functions of intercepting misdirected telephone calls and providing correct dialing information. This paper concentrates on the design of the switching unit of the system. The switch

is a space-division, wired-logic controlled device using dry-reed relays as crosspoints. It is organized so that separate networks perform the functions of concentrating incoming lines and selecting operator positions for identification of the number the customer thinks he called. While the presently installed system is not completely automatic, provision is made for incorporation of automatic identification of the "called number" when the necessary telephone central office features become available. Although the system was built for a particular telephone installation, modular construction makes it readily adaptable to installations with a variety of requirements. The switching networks can handle a maximum of 200 incoming intercept trunks, 64 automatic audio response trunks, 22 called-number identifying operators, and 14 special intercept operators.

Filter Performance in Integrated Switching and Multiplexing *by K. M. Roehr, P. M. Thrasher, and D. J. McAuliffe, Jr., p. 282.* To achieve the advantages of a new technique (ISAM) for integrating the functions of time-division switching and frequency-division multiplexing, it is necessary to design filters that are somewhat different from those used in conventional switching and multiplexing systems. This paper analyzes the performance of ISAM filters. Since in the new technique signals are resonantly transferred between band-pass filters, the theory of resonant transfer for this general case is developed. The conditions for obtaining resonant transfer between ideal filters are determined and then the effects of using nonideal filters are investigated. An example is given showing the synthesis of a set of filters designed to meet ISAM requirements.

On Definitions of a Burst *by R. T. Chien and D. T. Tang, p. 292.*

A Technique for Determining and Coding Subclasses in Pattern Recognition Problems *by R. L. Mattson and J. E. Dammann, p. 294.* The problem of organizing and partitioning large amounts of data into classes such that all data in one class will have similar properties is well known in pattern recognition research. The first step in the process, a cluster finding technique, involves grouping a large amount of data into clusters which must be detected and encoded so that automatic pattern recognition can take place. This paper describes a method for detecting and coding clusters. The principal advantages of this technique are that clusters need not be known *a priori* and no matrix inversion is required.

Thermal Problems of the Injection Laser *by R. W. Keyes, p. 303.* Heat is produced during the operation of an injection laser. The thermal conduction problems associated with the flow of the heat away from the junction region have been solved and the temperature increase of the junction has been calculated for several simple model cases. The results have been applied to the calculation of thermal limitations on the performance of gallium arsenide lasers.

Properties of GaAs Diodes with P-P^0-N Structures *by K. Weiser, p. 315.* The electrical and electroluminescent properties of GaAs diodes with P-P^0-N structure are discussed with special emphasis on their negative resistance characteristics. A description is given of the fabrication of diodes, consisting of a central, manganese-doped, high-resistivity layer (the P^0 region) between low-resistivity P- and N-layers. The theory of Dumke for the origin of the negative resistance characteristics is shown to give a good account of their static characteristics. Extension of the theory to transient characteristics (i.e., response to voltage pulses in excess of the breakdown voltage) predicts faster switching speeds than have been observed experimentally; nevertheless, diodes fabricated by one technique switch within a few nanoseconds at room temperature with overvoltages of only a few volts.

Vapor-Phase Polishing of Silicon with H_2-HBr Gas Mixtures *by L. V. Gregor, P. Balk, and F. J. Campagna, p. 327.*

Two-Dimensional Laser Deflection Using Fourier Optics *by H. J. Zweig, p. 333.*

Fatigue Strength of Case Hardened Steel Specimens Containing Through-The-Case Cracks *by W. D. Kehr, p. 336.*

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A Hard-Sphere Model to Simulate Alloy Thin Films *by A. S. Nowick and S. R. Mader, p. 358.* A model is developed for the simulation of alloy thin films by forming a layer consisting of spheres of two different sizes mixed randomly in any desired proportion. Included in the model is the possibility for vibration to simulate low-temperature annealing, as well as the use of a "substrate" containing periodic grooves to simulate epitaxial growth. Optical (Fraunhofer) diffraction patterns are taken from photographs of the model for comparison with the structural features observed directly. The model serves to show strikingly the role of the size factor in determining film structures. In particular, it shows that for size differences near 25% amorphous structures are obtained over a wide range of compositions. It also shows that such amorphous structures are essentially unchanged by vibration "annealing." On the periodically grooved substrate, the existence of an "epitaxial" deposition rate is demonstrated. These and other features of the model are compared with experience concerning evaporated thin films and found to be in excellent qualitative agreement.

Observations of "Clean" Surfaces of Si, Ge, and GaAs by Low-Energy Electron Diffraction *by F. Jona, p. 375.* The {100}, {110} and {111} surfaces of silicon, germanium and gallium arsenide, cleaned in ultra-high vacuum by heat-treatments alone or by ion-bombardments followed by anneals, were studied with the display-type low-energy

electron diffraction technique. Most surface structures reported in the literature by others could be reproduced, namely, Si(111)7, Ge(111)8, GaAs(111)2, and GaAs(100)1. Some, however, could not, namely, Si(111)5 and Ge(111)12. Two unreported structures were found to exist, even simultaneously, on the GaAs{100} surface and six different structures were detected on Si{110} surfaces after annealing treatments at different temperatures. The significance of a "clean" state of semiconductor surfaces, as identified by the observation of low-energy electron diffraction patterns, is discussed.

Simulation of the Catalytic Cracking Process for Styrene Production *by B. Davidson and M. J. Shah, p. 388.* A mathematical model is presented for simulating the steady-state catalytic dehydrogenation of ethylbenzene to styrene and other associated side reactions. The various differential equations describing the material and energy balances were integrated using a fourth-order Runge-Kutta method on an IBM 7090. Several runs on the computer were made to study the effect of change in feed rates, feed-to-steam ratio, and inlet temperature and pressure, on styrene yield. It is shown how, with the computer results, a profit equation for a particular plant may be derived for possible use in on-line optimization and control.

Junction Heating of GaAs Injection Lasers During Continuous Operation *by M. H. Pilkuhn and H. S. Rupprecht, p. 400.* The rise of the junction temperature during continuous operation of an injection laser has been measured as a function of current and is discussed for different cases. The dependence of the emitted light power on current is computed from the thermal data and compared with the experiment. The threshold current and the differential quantum efficiency for continuous operation are discussed.

Solution of the Equation for Wave Propagation in Layered Slabs with Complex Dielectric Constants *by J. W. Cooley and F. Stern, p. 405.* A numerical procedure for solving the eigenvalue equation $u'' = [V(x) - E\,]u$, where $V(x)$ is complex, is described. The number of eigenvalues, and their approximate location, can be determined by contour integration in the complex trial eigenvalue plane. Some general features of the solutions, and an example, are given.

The Chain Magnetic Memory Element *by J. C. Sagnis, Jr., P. E. Stuckert, and R. L. Ward, p. 412.*

Digital Pneumatic Logic Using Coded Tapes *by W. F. Voit, Jr., p. 418.*

The Effective Carrier Ionization Rate in a *p-n* Junction at Avalanche Breakdown *by D. P. Kennedy and R. R. O'Brien, p. 422.*

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Solution of the Partial Differential Equations Describing Photodecomposition in a Light-absorbing Matrix having Light-absorbing Photoproducts *by C. E. Herrick, Jr., p. 2.* A solution has been obtained for the system of partial differential equations describing the photolysis of an arbitrary number of light-sensitive materials contained in a semirigid, nonscattering, actinic light-absorbing matrix. Each photoreactant may produce stable, actinic light-absorbing products. The solutions reduce to known closed form expressions for the simplest cases.

Calculations of Impurity Atom Diffusion Through a Narrow Diffusion Mask Opening *by D. P. Kennedy and P. C. Murley, p. 6.* Relaxation methods have been used to solve a mixed boundary value problem arising in the fabrication of junction transistors: impurity atom diffusion through a narrow diffusion mask opening. This particular problem is encountered in the fabrication of very narrow diffused *p-n* junctions. It is shown that the depth of a very narrow junction cannot always be determined from an elementary one-dimensional analysis of this diffusion process. If the width of a diffusion mask opening is less than two impurity atom diffusion lengths, the junction depth becomes geometry dependent. Normalized graphs are presented to illustrate the impurity atom distribution resulting from this particular geometric configuration.

Design Technique for High-Efficiency Frequency Doublers Based on the Manley and Rowe Energy Relations *by E. M. Philipp-Rutz, p. 13.* This paper describes a design technique for high-efficiency microwave frequency doublers using a varactor diode. In this technique design parameters that can be measured in microwave circuits are derived from the Manley and Rowe energy relations in nonlinear reactances. These design parameters are: the characteristic impedances of the transmission lines of the microwave structure, the input and output powers of the frequency doubler, and the distances between the varactor diode and the filters that reject the fundamental frequency and the second harmonic.

The design technique for the microwave frequency doubler enables us to "match" the microwave structure to the varactor diode. Furthermore, the technique makes it possible to convert the maximum real fundamental power in the varactor diode to the second harmonic. The design procedure determines the operating region on the diode characteristic that, for a given diode, yields highest conversion efficiency. Our objective was to evaluate the design parameters of the frequency doubler for the region that gives this efficiency.

Two experimental models of a series type *L*-band frequency doubler were built to verify the design technique. The measured conversion efficiencies of the diodes operated in the doubler were in close agreement with the computed conversion efficiencies. We obtained 5 W output power from the varactor diode at 2.1 Gc/sec with 0.79 efficiency. (These values do not include circuit losses.)

Computation of Ion Trajectories in the Monopole Mass Spectrometer by Numerical Integration of Mathieu's Equation *by R. F. Lever, p. 26.* A high speed digital computer used with an off-line curve plotter enabled ion trajectories to be readily obtained in terms of the initial conditions and the parameters appearing in the differential equation of motion (Mathieu's equation). A study of these trajectories has led to the conclusion that ions should not be injected parallel to the axis of the instrument, as is done at present, but through the axis and at an angle to it. A simple empirical expression enables the variation of position of ion focus with mass and operating parameters to be predicted.

On the Design and Performance of a Small 60-nsec Destructive Readout Magnetic Film Memory *by W. Anacker, G. F. Bland, P. Pleshko, and P. E. Stuckert, p. 41.* The design of a small very-high-speed magnetic film memory using existing components is summarized. The memory has a capacity of 32 words and 36 bits per word, operates in a destructive-readout mode, and has a cycle time of 60 nsec and an access time of 32 nsec. The storage medium is a continuous sheet of NiFe film. The operational characteristics of the film and the properties of the strip line array are given, with worst case pulse conditions applying to both. The design and operation of the electronic circuitry are also described. A model of the memory, populated with three word-driver circuits and three regeneration-loop circuits for reading, rewriting, and writing, has been built and operated successfully. The paper concludes with oscillograms of waveforms which were obtained in closed regeneration-loop operation with that model.

On Measures of Logic Performance: Logic Quantum, Factor, and Figure of Merit *by L. J. Giacoletto, p. 51.* A basic logic operation is considered of transferring a logic decision from one point to another point. A certain energy level, W_L, corresponding to decision threshold and a time delay, T_L, are encountered in the transfer process. The product, $W_L T_L$, is a logic quantum, H_L. If the logic transfer takes place through an intermediate device, a logic factor, F_L, can be introduced to describe the reduction in logic quanta that the device can produce under optimum conditions. Optimization is carried out, as for instance with ideal transformers, to "match" the logic source to the device and the device to the logic detector. The condition $F_L = 1$ marks a boundary between a useful and a useless device, and a logic figure of merit, T_{FM}, in units of time corresponds to the fastest source-detector combination such that $F_L = 1$. Logic performance is considered in some detail for a particular linear model of a device. Nonlinear devices and relay devices are considered in less detail, although some numerical calculations are given for a current-switch, two-transistor computer device. The logic figure of merit represents a unique measure of high-speed logic performance and is

therefore valuable in comparing devices including associated circuitry on a common basis.

Some Experiments in Spoken Word Recognition *by J. H. King, Jr. and C. J. Tunis, p. 65.* This paper describes some experimental work in the recognition of limited-size, but arbitrary, vocabularies of spoken words. The equipment consists of a filter-bank voice-spectrum analyzer providing real-time input of measurement data to an IBM 1620-II digital computer system. The computer implements various transformations on the input data and also implements various linear decision functions which are designed by means of adaptive algorithms. Recognition experiments have investigated the recognition capability of this system on arbitrary vocabularies of up to 30 words. Several normalizing transformations on the primary measurements were investigated.

An Experiment in Cluster Detection *by J. E. Dammann, p. 80.*

The Dispersion Locked Memory Mode for Magnetic Films *by H. J. Kump, H. G. Hottenrott, B. I. Bertelsen, and P. T. Chang, p. 89.* In the usual thin film magnetic memory, that which utilizes the two stable easy direction magnetization states for storage, inverted films ($H_c > H_k$) are often used to reduce disturb sensitivity. In general, inverted films exhibit a high angular dispersion and an open hard direction hysteresis loop with considerable remanence. Middelhoek has attributed this high remanence to the large number of Néel walls formed after the application of a hard direction field exceeding the anisotropy field. The stable state resulting from this "dispersion locking" finds utility as a storage state and is the subject treated here. This paper describes an orthogonal storage mode which could form the basis for a word-organized high-speed memory using unipolar drivers. Test programs and the results obtained therefrom are illustrated to show the useful operating range in a typical film. The total absence of "creep" and the unipolar digit current input to the device are seen to be features of this dispersion locked mode.

Dynamic Thermal Response and Voltage Feedback in Junction Transistors *by F. A. Reid, p. 95.*

Conditions for Termination of the Method of Steepest Descent after a Finite Number of Iterations *by W. E. Langlois, p. 98.*

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Formation of Built-in Light-emitting Junctions in Solution-grown GaP Containing Shallow Donors and Acceptors *by L. M. Foster, T. S. Plaskett, and J. E. Scardefield, p. 114.* The growth of GaP from a gallium-rich solution is described and the morphology and dendritic growth habit of the crystals are discussed. By control of growth conditions it was possible to produce built-in junctions in crystals doped with the shallow donors, S, Se, or Te, and the shallow acceptor, Zn. Green junction electroluminescence of higher efficiency than has been reported heretofore was observed from these structures. The effective segregation coefficients for the above impurities in GaP were determined by radiochemical techniques. On the basis of differences existing between these coefficients for the donor and acceptor dopants, and with the assumption of a two-step growth process, a mechanism for the formation of the junctions during precipitation of the crystals from solution is set forth.

Green Luminescence from Solution-grown Junctions in GaP Containing Shallow Donors and Acceptors *by M. H. Pilkuhn and L. M. Foster, p. 122.* Gallium phosphide diodes doped with shallow donors and acceptors that partially compensate one another in both the *n*- and *p*-regions give rise to bright green emission. This green emission is more efficient at room temperature than the so-called "*A*-line" emission commonly observed in lightly doped diodes. The peak energy of the green emission varies with the donor binding energy, and the emission is interpreted as a radiative donor-acceptor or a donor-valence band transition. Its intensity-voltage dependence and its current-voltage dependence are discussed for room temperature conditions. At 77K, large shifts in peak energy were observed to accompany changes in applied voltage. Data concerning this peak shift, the intensity-voltage dependence, and the linewidth-voltage dependence are presented and discussed. Time effects and the temperature dependence of the quantum efficiency are also examined.

Effects of a Keeper on Thin Film Magnetic Bits *by C. G. Ravi and G. G. Koerber, p. 130.* When Permalloy films are used for computer storage, a magnetic keeper can improve performance by reducing the following undesirable conditions: stray fields from adjacent lines and from adjacent bits; the effect of current spreading in the ground plane; and trapped flux in the ground plane which opposes switching in the absence of a low reluctance path outside the bit. Theoretical analysis and experimental verification of these important keeper functions are presented in this paper. Through the use of high-frequency pulse techniques, effects of both metallic and non-metallic keepers, at distances from the ground plane ranging from 5 to 30 mils, have been determined. By defining efficiency as the percentage reduction in the average of four worst-case effects, the efficiency factor of a metallic keeper is shown to be 56 and that of a non-metallic keeper, 73. It is suggested that better efficiency is due more to lower electrical conductivity than to any intrinsic magnetic properties.

PERT as an Aid to Logic Design *by T. I. Kirkpatrick and N. R. Clark, p. 135.* A new application is presented for PERT, the well-known statistical project-scheduling method. Using PERT, the logic designer could circumvent usually unrealistic worst-case criteria. He substitutes a formalized statistical method which determines (1) expected or most probable delays, (2) critical timing paths, (3) timing slack allowable

between various inputs, and (4) probability of achieving an output by a certain time. From these data the designer can make a meaningful judgment regarding the reliability of his system. Significantly, he may achieve high reliability without being forced to resort to worst-case design.

Design of a Printed Card Capacitor Read-Only Store *by J. W. Haskell, p. 142.* The Printed Card Capacitor Read-Only Store system is introduced as one of three Read-Only Store (ROS) technologies presently employed in the IBM System/360 computers. A detailed description is given of the elementary storage structure—a capacitor matrix with a novel arrangement for rapidly and economically changing the matrix configuration. The changeable element is an etched or printed Mylar card, prepared with standard IBM card-punch equipment. The assembly of storage structures into a compact 4032-word, 60-bit module is described. Considerations involved in the selection of matrix parameters are reviewed and a theoretical analysis of matrix performance is presented. It is shown that some of the limitations associated with a linear matrix are minimized by an incomplete integration of the matrix output. The impact on over-all ROS performance of factors external to the capacitor matrix is considered. These factors include the effects of a noisy drive system and the asymmetrical character of the matrix relative to the access circuitry. Computed and observed results are compared for typical System/360, Model 30 ROS operation. The actual matrix response amplitude is observed to be greater than the computed value due to the level of system background noise; however, computed and observed waveforms are otherwise in good agreement.

A Practical Class of Polynomial Codes *by W. F. Rogers, p. 158.* Error detecting polynomial codes are usually formed by defining a correspondence between data bits and coefficients of the representative polynomial. These codes are easily implemented in hardware using shift registers; however, implementation in character-oriented processors may be too time consuming. A new class of polynomial codes is described for which a correspondence between n-bit data characters and polynomial coefficients is defined. Two particular types of these "character polynomial codes" are discussed; these may be easily implemented with hardware or with processor character manipulations. The burst error detecting ability of these two types of codes is shown to be the same as for the common "bit polynomial codes."

Stimulated Emission Observed from an Organic Dye, Chloro-aluminum Phthalocyanine *by P. P. Sorokin and J. R. Lankard, p. 162.*

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Analysis and Synthesis Procedures for Geneva Mechanism Design *by C. E. Hasty and J. F. Potts, p. 186.* This paper contains general analytical results which can be applied to high-speed Geneva design. The results are derived from classical mechanics theory and provide explicit relationships between the performance parameters (those parameters such as contact stress, maximum load, etc., which can have a significant effect on the mechanism performance) and the design variables which specify a Geneva mechanism (number of slots, wheel diameter, pin diameter, etc.). In the past, the complexity of the mathematical formulation of this problem has precluded synthesis of the Geneva wheel proportions. Using these results, however, it is now possible to synthesize the wheel configuration directly, instead of by a repeated trial and error analysis. Two examples are given demonstrating the analysis and synthesis techniques.

Separation of the Linear and Parabolic Terms in the Steam Oxidation of Silicon *by W. A. Pliskin, p. 198.* Using accurate film thickness measurements, it was found possible to separate linear and parabolic terms in the steam oxidation of silicon, and thus obtain much more precise expressions for the thermal oxidation under different conditions. The combined linear-parabolic relation was found to be applicable to various crystallographic orientations. The pure parabolic "constant" obtained from this relation was the same for different crystal orientations, but the linear term in the relation was found to be very surface sensitive. By these techniques, more accurate parabolic rate "constants" can be obtained and the linearity of the $\log k$ vs $1/T$ plot can be extended to much lower temperatures. The activation energy of the parabolic term for steam oxidation was found to be only 16 kcal/mole. The effect of neglecting the linear term in various methods of computing the parabolic rate is discussed.

Tensor Analysis of Spatial Mechanisms *by C. Y. Ho, p. 207.* The position analysis of a general four-bar spatial mechanism is developed using tensor notation and operations. To exemplify the convenience of tensors in kinematic analysis the solution is obtained for a mechanism containing two revolute pairs of links and two spherical pairs.

Avalanche Breakdown Calculations for a Planar *p-n* Junction *by D. P. Kennedy and R. R. O'Brien, p. 213.* A mathematical analysis is presented on the avalanche breakdown voltage of a planar *p-n* junction. This analysis takes into consideration junction curvature, as encountered near a diffusion mask edge. Three different impurity atom profiles are considered: abrupt, linearly graded, and diffused. For an asymmetrical abrupt structure, it is shown that regions of junction curvature exhibit either an increase or a decrease in avalanche breakdown voltage. It is also shown that similar regions in a linearly graded junction exhibit a combination of these abrupt junction mechanisms; thereby, their breakdown voltage is little influenced by junction curvature. In addition, the diffused planar junction can be designed to exhibit nearly the same breakdown voltage as a corresponding mesa structure, or, instead, it can be designed to exhibit a substantially lower avalanche breakdown voltage.

Stability of Flexible Tapes in Parallel Flow *by G. T. Czaykowski, I. G. Tadjbakhsh, and Y.-O. Tu, p. 220.* A stability analysis by the method of normal modes is carried out for a plane Poiseuille flow in a channel with a free-flying elastic tape in midstream. The effects of transverse and rotary inertia and flexural rigidity of the tape on the stability criteria are investigated. An increase of transverse inertia due to heavier tapes tends to decrease the critical Reynold's number while the addition of flexural rigidity improves the stability criteria by increasing the critical Reynold's number.

Intensity Noise in Multimode GaAs Laser Emission *by A. W. Smith and J. A. Armstrong, p. 225.* As presently manufactured most GaAs lasers have several lasing modes when the injection current is more than 25% above threshold. This paper describes the noise properties of three groups of multimode lasers operating cw at 10K, classified on the basis of their sub-threshold spectra. Two main types of intensity noise have been found: (1) low frequency nonstationary noise which occurs when a weak mode is lasing in competition with a strong mode, and (2) broadband stationary noise which occurs when two modes are about equal in intensity. The first type of noise is believed to arise from heat transfer processes in the diodes and dewar, while the second is probably the partition noise which must occur when a photon can be stimulated into one of a number of lasing modes. An important result of these experiments is that the total noise for all modes is very small, being comparable to that for a single mode with the same total power.

A Theoretical Analysis of Saturation Magnetic Recording *by D. E. Speliotis and J. R. Morrison, p. 233.* A theoretical analysis of the saturation magnetic recording process is presented. The approach is based on the complete characterization of an isolated magnetization transition on the recording surface. The effects of the writing process, demagnetization, recording surface thickness, transducer-to-medium spacing, and readback transducer resolution are considered in calculating the exact pulse shape read back from such an isolated magnetization transition. The theory predicts the significance of each individual parameter that affects the pulse amplitude and resolution of digital recording systems. The theoretical predictions are compared with experimental results measured over a wide range of recording surface properties, and the agreement is excellent. The theory is also in excellent agreement with correlations between magnetic and recording properties that heretofore have been established by experiment alone.

Some New Methods for Digital Encoding of Voice Signals and for Voice Code Translation *by G. Knauft, H. Lamparter, and W. G. Spruth, p. 244.* Recently developed techniques are described for improving the speech quality of voice signals that are first digitally encoded, placed in random access storage, and on demand are then translated into normal speech in an audio response unit under the control of a host processor. The development is an extension and modification of the channel vocoder principle. Speech quality is enhanced by hardware and software features for treatment of unvoiced components of the coded speech signal in particular by separating harmonics from the excitation function digital signal before smoothing. A new program of bit selection is used to assure that the aggregation function digital signal carries maximum information. In addition, an efficient method of storage assignment is shown for the excitation function and the aggregate function registers in the voice code translator.

Thermostrictive Recording on Permalloy Films *by H. J. Kump and P. T. Chang, p. 255.* Where the magnetostrictive coefficient is of the order of 10^{-6} or greater, recording may be accomplished on uniaxial Permalloy films by the application of a local stress in coincidence with a biasing field. Here, the stress is introduced into the film as a result of a temperature gradient produced by an incident laser or electron beam.

The mechanism of recording is studied and a model developed in agreement with the mechanism. Several modes of recording are discussed, with the advantages and disadvantages of each. Extrapolating the model to a large capacity memory of 10^7 bits per square inch with 8 micron diameter spots on a Permalloy film having a magnetostrictive coefficient of 10^{-5}, a 20°C temperature rise will be experienced with 2×10^{-10} joules of energy in the beam. The beam power required is 10^{-3} watts at 10% efficiency and a one megacycle information rate.

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Diagnosis of Automata Failures: A Calculus and a Method *by J. P. Roth, p. 278.* The problem considered is the diagnosis of failures of automata, specifically, failures that manifest themselves as logical malfunctions. A review of previous methods and results is first given. A method termed the "calculus of D-cubes" is then introduced, which allows one to describe and compute the behavior of failing acyclic automata, both internally and externally. An algorithm, called the D-algorithm, is then developed which utilizes this calculus to compute tests to detect failures. First a manual method is presented, by means of an example. Thence, the D-algorithm is precisely described by means of a program written in Iverson notation. Finally, it is shown for the acyclic case in which the automation is constructed from AND'S, NAND'S, OR'S and NOR'S that if a test exists, the D-algorithm will compute such a test.

A Numerical Analysis of the Transient Behavior of a Transistor Circuit *by R. K. Brayton, F. G. Gustavson, and W. Liniger, p. 292.* This paper describes some difficulties encountered in the numerical solution of nonlinear circuit equations. A particular transistor circuit is analyzed to illustrate the nature of the difficulties and how they may be resolved. In this circuit it is possible, without sacrificing

accuracy of the physical model, to eliminate unimportant stray parameters whose presence destroys the efficiency of most integration routines. A method based on a potential function is used for deriving the circuit equations and it is shown how these equations can be systematically reduced upon removing the stray parameters. Application of such techniques to the circuit considered reduced the calculation time (on an IBM 7094) from 30 minutes to 7 seconds.

Properties of a Free, Steadily Travelling Electrical Domain in GaAs *by J. B. Gunn, p. 300.* Experiments are described on the travelling domains of high electric field which can exist in *n*-type GaAs. A brief discussion of the appearance of stationary domains near the cathode and of the nucleation and transient behaviour of travelling domains is given, but the main topic is the steady-state behaviour of travelling domains. Measurements are reported on the dependence of domain velocity, and of the voltage drop across the domain, on the field E_∞ existing outside the domain. It is found that the velocity increases with E_∞, but the voltage decreases. The resulting negative resistance is seen to have important consequences for the stability of the domain in real specimens.

Effect of Domain and Circuit Properties on Oscillations in GaAs *by J. B. Gunn, p. 310.* A discussion is given of the complications obtaining when a bar of GaAs, generating microwave oscillations, is allowed to interact with an external circuit. Three very different modes of operation can be expected, each corresponding to a mechanism of extinction of the travelling domains of electric field that cause the current modulation. It is seen that the domains may be extinguished (1) when they reach the end of the bar, (2) when the voltage drops too low for the stability of a domain, or (3) when it rises too high. In the last two circumstances, the external circuit plays an important role. Conditions for the existence of the various modes are deduced, and their properties are studied experimentally.

Resonant Excitation of Magnetostrictive Driven Print Wires for High-Speed Printing *by M. Preisinger, p. 321.* A developmental resonant wire printing device utilizing ultrasonic vibration is described and results given on some preliminary work on the resonant excitation of magnetostrictive print wires. This paper discusses the characteristics of the magnetostrictive material, the transducer design and some special methods of measuring small, rapid mechanical motion. In the present test setup of the printing device, impact rates up to 1400/sec were obtained.

A High-Speed Read Only Store Using Thick Magnetic Films *by R. E. Matick, P. Pleshko, C. Sie, and L. M. Terman, p. 333.* This paper describes a high-speed, magnetic film, read only store of about 300K bits. The device and its implementation into a system have many unique advantages, including loose magnetic tolerances, minimal delay in the cell, linear drive-sense coupling, and ease of information change. The basic device consists of a thick, anisotropic magnetic film sandwiched between the conductors of a strip transmission line. The cell utilizes the coupling between parallel word and sense line sections obtainable through the hard axis characteristics of an anisotropic permalloy film to store a binary ONE state. For a ZERO the coupling is inhibited by saturating the film with a small permanent magnet. Switching of the film can be described qualitatively, and to a large extent quantitatively, by a quasistatic analysis. A dynamic analysis describes the behavior of the film more completely and aids in optimization of some film parameters.

The ROS system is designed in four planes of 256 words by 288 bits each. A single array plane was built and tested with a cross-section of drive and sense circuits. Because of the linear drive-sense relationship, the array can preferably be driven with a low current directly from a logic stage. The worst-case access time, including one level of decode, was measured to be 19 ns; the corresponding cycle time was 45 ns.

Localized-Field Permanent Magnet Array for the Thick-Film Read Only Store *by C. Johnson, Jr. and R. C. Turnbull, p. 343.*

Dynamic Laser Wavelength Selection *by M. A. Habegger, T. J. Harris, and E. Max, p. 346.* This paper describes the dynamic selection of the emission wavelengths of a laser by insertion of a dispersive tunable electro-optic *Q*-spoiler within the laser cavity. Five different oscillation wavelengths of an argon ion laser have been individually selected by varying the voltage on the KD*P electro-optic crystals in the *Q*-spoiler.

Domain Wall Velocities in Thin Magnetic Films *by S. Middelhoek, p. 351.*

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Design of Monolithic Circuit Chips *by O. Bilous, I. Feinberg, and J. L. Langdon, p. 370.* The influence of semiconductor chip design on the logic partitioning of a computer is discussed and some design rules are given. A chip size of 60 × 60 mils with 24 terminals and 168 components was shown to be optimum. RF-sputtered quartz insulation was used for multilevel wiring and a hermetic seal. Using a master chip technique, a 9-part-number logic set was successfully fabricated. Propagation delays for the circuits were 2.5 to 3 nsec.

Theory of Domain-Wall Structure in Multiple Magnetic Films *by J. C. Slonczewski, p. 377.* This paper derives analytically a two-dimensional wall-structure applying to the case of two identical magnetic films separated by a non-magnetic film. It applies also to a variety of other multilayer problems. The calculation is based on the usual micro-magnetic principle of energy minimization and all approximations are justified. The wall-structure is found to

consist of two "flank" regions, whose shape is governed by anisotropy and stray-field coupling between films, arranged symmetrically about a central "kernel" region whose shape is governed by anisotropy and exchange. In the widely applicable limit of negligible exchange the theory reduces to one given earlier [*J. Appl. Phys.* **37**, 1268 (1966)]. Also included in the discussion are effects of quasi-walls and film-to-film exchange interactions. Existing experimental data on wall-shape confirm the shape of the kernel but are not of sufficient precision to test the shape of the flanks. Existing data for permalloy suggest that perpendicular anisotropy may play a significant role in reducing multiple-film wall energy and thickness.

On Multi-Head Finite Automata *by A. L. Rosenberg, p. 388.* Let M_n be the class of languages defined by n-head finite automata. The Boolean and Kleene closure properties of M_n are investigated, and a relationship between M_n and the class of sets of n-tuples of tapes defined by n-tape finite automata is established. It is shown that the classes M_i form a hierarchy; and that, moreover, for all n, there is a context-free language (CFL) in $M_{n+1} - M_n$. It is further shown that there is a CFL which is in no M_n for any integer n. Finally, several decision properties of the multi-head languages are established.

The Quantum Mechanical Extension of the Boltzmann Equation *by P. J. Price, p. 395.* It is shown that the method of Kohn and Luttinger may be applied to obtain a generalized Boltzmann equation, for electrons in a solid, when the driving field has nonzero wavevector as well as frequency. By means of this equation, the behavior of the electrons in response to the field may be followed from the quasi-classical limit at small rates of change to the quantal limit at large rates of change.

End-Pumped Stimulated Emission from a Thiacarbocyanine Dye *by P. P. Sorokin, W. H. Culver, E. C. Hammond, and J. R. Lankard, p. 401.*

The Kantorovich Theorem and Two-Point Boundary Value Problems *by S. M. Roberts and J. S. Shipman, p. 402.*

Digital Simulation of Image-Forming Systems *by D. P. Paris, p. 407.*

Design of a Moiré Fringe Torque Transducer *by T. D. Abbott, p. 412.*

Influence of Non-ideal Filters on the Transmission Characteristics of Resonant Transfer Switching Systems *by K. M. Roehr, p. 416.*

Surface Attack in Chromium-Iron Alloys *by W. D. Kehr and H. E. Seese, p. 420.*

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Gallium Arsenide Planar Technology *by W. von Münch, p. 438.* Some of the main problems of the gallium arsenide planar technology are discussed. The most suitable starting material used has been obtained by vapor growth. Methods of zinc and tin diffusion have been studied in connection with masking by pyrolytic SiO_2/P_2O_5 layers. An alternative technique using doped silicon dioxide for the production of planar devices has been developed. The latter method features complete surface protection and easy control of the impurity concentration. The application of both methods to the production of *npn, pnp,* and four-layer devices is described. Using an epitaxial etch-refill technique it is possible to obtain electrically isolated devices on a common semi-insulating GaAs substrate.

Dislocation-Induced Deviation of Phosphorus-Diffusion Profiles in Silicon *by M. L. Joshi and S. Dash, p. 446.* Deviation of phosphorus-impurity profiles in silicon from ideal ones under the diffusion condition of high surface concentrations is well known. Diffusion of high concentrations of phosphorus is also known to cause generation of dislocations with edge character in silicon wafer surfaces. A major cause of the deviation of the phosphorus profile is shown to be solute accumulation at these dislocations. The dislocation-precipitated profile is calculated for the ideal complementary error-function diffusion profile of phosphorus with 10^{21} atoms/cm^3 of surface concentration, using Ham's model of stress-assisted precipitation on dislocations. The results are shown to account for most of the major features of the experimental diffusion profiles.

The Integrated Vocoder and its Application in Computer Systems *by E. H. Rothauser, p. 455.* This paper reviews the conceptual features and the applications of the integrated vocoder. In a comparison with the structural properties of the channel vocoder and other experimental types, the integrated vocoder is shown to be a technically simple solution to the well-known problems of pitch description and vocoder signal transmission. The design reduces the complexity of the over-all speech processing equipment and features a saving in device hardware. The potential of this vocoder design for time division multiplex transmission systems is discussed and an application of the new vocoder concept is shown for computer input-output equipment.

New Methods for De Haas-Shubnikov Measurements *by R. D. Brown III, p. 462.* Improved techniques and instrumentation for observing the de Haas-Shubnikov (dHS) effect are described and preliminary results of their application to measurements on bismuth are presented. The two main features of the method are: first, the monotonic H^2 term in the magnetoresistance is subtracted out, allowing increased amplification of the oscillatory part, and therefore increased sensitivity in detecting the periods; second, the magnetic field is swept such that $1/H$ varies linearly in time, producing dHS

oscillations sinusoidal in time, making it possible to use real-time differentiation and filtering to separate interfering periods. The method thus provides a large amount of data reduction prior to recording, permits direct measurement and averaging of the periods from the recorded data, and allows a more accurate and unambiguous interpretation of the data. Much of the instrumentation described ($1/H$ sweep, filter, differentiator) has been built around commercially available operational amplifiers.

A Partial Error Analysis for the Solution of Differential Equations in Simulation: A Look at Fowler's z-Transform Root-Locus Method *by J. W. Daniel, p. 472.* A partial analysis is made of the types of error of Fowler's method, which uses the z-transform procedure for digital simulation of complex systems.

In-situ Measurements of Magnetic Properties in Vacuum-Deposited Permalloy Films *by K. Y. Ahn, p. 477.* The quasi-static magnetic properties of vacuum-deposited Permalloy films of zero-magnetostrictive composition are examined *in situ* in an evaporator equipped with a laser-operated Kerr magneto-optic hysteresigraph. The coercive force, which depends strongly upon the film thickness, is large ($H_c > 20$ Oe) when the hysteresis loop is first observable with a thickness of ~ 50 Å for low substrate temperatures ($T < 50$°C) and ~ 100 Å for high substrate temperatures ($T > 100$°C). There are two peaks of coercivity, at ~ 400 Å and ~ 1000 Å; the two are thought to be related, respectively, to the transitions from the Néel to the cross-tie walls, and from the cross-tie to the Bloch walls. Two distinct components of the uniaxial anisotropy field are identified, both of which are characteristic of fabrication parameters: K_1, which is difficult to re-orient once the anisotropy is induced; and K_2, which is readily re-oriented (with time constant less than 10 sec) along any angle between the easy and the hard axis. The net anisotropy field and the easy-axis orientation, both of which are affected by the K_2 components, can be calculated for a given set of fabrication parameters. Experimental results agree well with the calculated values. The angular dispersion does not appear to be affected by the amplitude of the orienting field H or the nature of the field (a.c. or d.c.) when $H > H_c$. There is a slight increase in angular dispersion as the K_2 component of the anisotropy rotates from the easy to the hard axis.

Electron Barriers in Al-Al_2O_3-SnTe and Al-Al_2O_3-GeTe Tunnel Junctions *by L. L. Chang, P. J. Stiles, and L. Esaki, p. 484.*