

Technical Papers by IBM Authors Published Recently in Other Journals

Adsorption of Gases Activated by Electron Impact, H. F. Winters, D. E. Horne* and E. E. Donaldson, * *The Journal of Chemical Physics* **41**, No. 9, 2766-2772 (November 1, 1964).

Adsorption of nitrogen which has been activated by electron impact is shown to result from dissociation of the nitrogen molecule and from the interaction of energetic ions with a nickel surface. Excitation of N_2 to states at about 10.3, 12.2 and 14.0 eV causes dissociation. Dissociative ionization at 24.5 eV also leads to additional pumping. Energetic N_2^+ ions have an adsorption probability of approximately 0.85 when they collide with a nickel surface. It is shown that the ion adsorption probability is practically independent of energy between 30 and 100 eV. It is shown that thermal energy ions have a very low adsorption probability. These results lead to the postulate that the N_2^+ ions dissociate on impact and that the atomic nitrogen is subsequently adsorbed. Results have also been obtained which indicate that the adsorption probability of Ar^+ is strongly dependent on surface structure. Annealing of the surface greatly reduces the adsorption probability.

*Washington State University.

Amplifier and Driver Circuits for Thin Film Memories with 15 Nanoseconds Read Cycle Time, D. Seitzer, *IEEE Transactions on Electronic Computers* **EC-13**, No. 6, 722-729 (December, 1964).

Amplifier and driver circuit design principles for an experimental 4608-bit nondestructive thin film memory with 13.5-nsec read and 60-nsec write cycle times are given. The bit noise problems inherent in the common-bit sense line concept are solved by using tunnel diodes in a nonlinear balancing circuit. A further improvement of the signal-to-noise ratio is achieved by employing a noise resistant sense amplifier with non-linear negative feedback. The word driver described is capable of delivering 700 mA pulse amplitude at 50 Mc/sec repetition rate at a pulse width of 7 nsec.

Analysis of the Hydrogen Reduction of Silicon Tetrachloride Process on the Basis of a Quasi-Equilibrium Model, T. O. Sedgwick, *Journal of the Electrochemical Society* **111**, No. 12, 1381-1383 (December, 1964).

The process for the growth of silicon single crystals by the hydrogen reduction of silicon tetrachloride has been described using a model which assumes that chemical equilibrium obtains at the silicon deposition site. The thermodynamic calculations by Lever for the equilibrium gas phase composition in the Si-Cl-H system (primarily H_2 , HCl, $SiCl_2$, $SiHCl_3$) were used to calculate the growth rate of silicon as a function of mole fraction silicon tetrachloride input and temperature in an open tube system. Some of the features of the experimental results reported in the literature are predicted by the equilibrium model. The results are discussed in relation to similar calculations by Steinmaier who did not take the species $SiHCl_3$ into account.

Analysis of a One-Tunnel-Diode Bistable Circuit with a Counting Property, Thomas W. Collins, *Solid-State Design—Communications and Data Equipment* **5**, No. 12, 27-31 (December, 1964).

This paper is concerned with the analysis of a one-tunnel-diode bistable circuit, pulsed with unidirectional input pulses. The circuit contains one resistor, one inductor and one tunnel diode. The input pulses are current pulses of either polarity. The analysis investigates the mechanism by which the tunnel diode can be switched either way (high voltage state to low voltage state, or low voltage state to high voltage state) without changing the polarity of the input pulses. The addition of a relatively large external inductance gives the circuit this property (bistability with unidirectional input pulses). The property (bistability with unidirectional input pulses) is necessary for counters, and a circuit which has this ability is said to have the counting property. Therefore, this circuit can be used as one stage of a binary counter. The contributions of this paper are the use of piecewise linear analysis to explain the switching action of the circuit and the derivation of design equations which establish certain conditions—the correct value of external inductance, the correct bias arrangement, the correct amplitude and duration of the input pulse and the maximum repetition rate—for correct operation of the circuit. Finally, experimental results are given to verify the analysis.

Bidirectional Electrically Switched Laser, R. V. Pole, R. A. Myers and J. Nuñez, *Applied Optics* **4**, No. 1, 119-121 (January, 1965).

Operation of a double-rooftop ruby laser emitting along axes that are at an angle of 17.5° with respect to one another has been investigated. The ruby is a $1\frac{1}{4}$ in. cylinder with a 17.5° chisel at each end, one of which is silver-coated. The other end has an antireflection coating, so that external dielectric (or silver) reflectors complete two separate Fabry-Perot cavities, which have about one-half the active medium in common. A polarizer and nitro-benzene Kerr cell in each path allow fast switching from one axis of emission to the other; the switching has been accomplished within 1 μ sec in the present experiment. The experiment is a part of a larger program aimed at studying the methods of switching or scanning of laser light. Some of its implications with respect to the over-all program are discussed.

A Branching Poisson Process Model for the Analysis of Computer Failure Patterns, P. A. W. Lewis, *Journal of the Royal Statistical Society, Series B* **26**, No. 3, 398-441 (1964).

Current reliability models predict that the failure pattern of a computer should form a Poisson process. Experience has shown, however, that the times-between-failures of a computer are not exponentially distributed, and that successive times-between-failures are not independent. These deviations from a Poisson process are due to imperfect

repair of failed components; the resulting failure pattern is described by a branching Poisson process model. The probabilistic properties of this model are derived and used to analyze three series of computer failures.

Compatibility of Approximate Solution of Linear Equations with Given Error Bounds for Coefficients and Right-Hand Sides, K. L. Oettli and W. Prager, *Numerische Mathematik* 6, 405-409 (1964).

In the spirit of Wilkinson's backward error analysis, conditions are established under which a given approximate solution of a system of n linear equations with n unknowns is the exact solution of a modified system whose coefficients and right-hand sides are within a given neighborhood of those of the original system.

Contacting GaAs Planar Transistors, J. Wüstenhagen, *Zeitschrift für Naturforschung* 19A, No. 12, 1433-1434 (1964).

Contacts of a GaAs transistor were made by evaporation of silver and alloying with the GaAs. Silver was doped with 1% tellurium for the n -type contacts and with 2% magnesium for the p -type contacts. Contact stripes were made by evaporation of silver. In order to get good adhesion between contact stripes and the SiO_2 layer, chromium is sandwiched between silver and SiO_2 .

The Contact Problem of a Plate Pressed Between Two Spheres, Y. O. Tu and D. C. Gazis, *Journal of Applied Mechanics—Transactions of the ASME, Series E* 31, No. 4, 659-666 (December, 1964).

The elastic contact of a plate with two axisymmetric bodies, generally of dissimilar elastic properties and curvatures, is considered. The solution of the resulting two integral equations is given as a truncated series of Legendre polynomials of even order whose coefficients may be determined from a system of linear algebraic equations. The relationships between the total load, radii of curvature of the bodies, contact radii, approach, radial displacements, maximum contact stress, and the plate thickness can then be computed in terms of these coefficients. Numerical computations have been carried out for the contact of a plate with two identical spheres.

Controlling Part Dimensions During Fabrication and Heat Treatment, J. A. Ferrante, *Metal Progress* 87, No. 1, 87-90 (January, 1965).

This article discusses production experience and practices of heat treating IBM component parts. Various problem parts are disclosed that typify methods of maintaining close tolerances and good parts after heat treatment. Heat treat cycles, equipment, straightening practices and metallurgical theories are examined to evaluate their respective roles. Experimental test data on the dimensional stability of maraging steels are also discussed.

Determination of Stress in Films on Single Crystalline Silicon Substrates, R. Glang, R. W. Holmwood and R. L. Rosenfeld, *Review of Scientific Instruments* 36, No. 1, 7-10 (January, 1965).

A convenient method to determine stress in thin films deposited on single crystalline silicon wafers is described. The film is treated as an elastic membrane attached to the edges of a thin circular disk. Due to the stress forces of the film, the substrate deforms elastically and assumes a parabolic curvature. This parabolic deflection is determined by measuring the substrate profile on the surface with a light section microscope. Knowing the curvature and the elastic constants of the substrate wafer, one can calculate the stress forces exerted by the film. The experimental accuracy of the method is about $\pm 10\%$.

The Effect of Temperature on the Properties of GaAs Injection Lasers, G. Burns and M. I. Nathan, *Electronic Magnetic Resonance and Solid Dielectrics, Proceedings of the XIIth Colloque Ampère*, pp. 549-553 (1964).

The temperature dependencies of a number of properties associated with the GaAs injection laser are discussed. These properties include the temperature dependence of the spontaneous emission, the stimulated emission, the mode spacing, the threshold current, and the loss factor. In addition to the laser data, one can also obtain information about GaAs that is difficult to obtain by any other means.

Effect of Temperature on the Stimulated Emission From GaAs p-n Junctions, M. Pilkuhn, H. Rupprecht* and S. Blum,* *Solid State Electronics* 7, 905-909 (December, 1964).

The temperature dependence of the threshold current density was examined for a series of GaAs injection lasers with different lengths but otherwise identical structure. From a plot of threshold current density as a function of reciprocal length at constant temperature, the gain and loss factor can be calculated. The laser losses exhibit only a small temperature dependence in the range from 4.2 to 300°K. The reciprocal gain factor, however, has the same temperature dependence as the threshold current density j_t . The detailed nature of the temperature dependence of j_t does depend on the length of the laser and on the doping level in the active region. The influence of these two parameters is discussed and compared with theoretical predictions.

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Epitaxial Growth of Homogeneous Solid Solutions of GaAs-GaP, E. M. Hull, *Journal of the Electrochemical Society* 111, No. 11, 1295-1296 (November, 1964).

A technique is described for producing epitaxial deposits of gallium-arsenide/gallium-phosphide mixed crystals of predetermined alloy composition and impurity concentration. The gallium-iodide disproportionation reaction is utilized in a sealed tube apparatus to transport the alloy from a presynthesized doped source to a gallium-arsenide substrate. The method used to synthesize the doped alloy source material, dopants used for various purposes, and electrical and optical properties of some of the deposits are discussed.

Fast Rise Current Switch, T. W. Collins, *EEE Circuit Design Engineering* **13**, No. 1, 65-66 (January, 1965).

The circuit demonstrates the use of the law of conservation of electrokinetic momentum (i.e., constant flux linkages) in driving highly inductive loads which require fast rise currents. Using this principle, the current is not limited to the slow L/R rise-time constant. Instead, the current will rise as fast as it can be switched into the load.

Gallium Arsenide Planar Transistor, W. V. Münch, *Zeitschrift für Angewandte Physik* **18**, No. 3, 129-132 (November, 1964).

A method for the fabrication of planar *npn*-transistors is described. The process steps include pyrolytic deposition of silicon dioxide, photoresist technique, zinc and tin diffusion, and contact evaporation. Silver doped with magnesium and tellurium is used for the base and emitter contacts. A method for simultaneous base and emitter diffusion is suggested.

Generation of Openings in Vacuum Deposited SiO Diffusion Masking Films, A. J. Rideout and T. K. Worthington, *Solid-State Electronics* **8**, No. 1, 13-15 (January, 1965).

A simple method for obtaining moderately small planar arsenic emitter diffusions in germaniums is described. Positive masks of 0.15-mil thick NaCl evaporated through a metal mask prior to the vacuum deposition of SiO are easily dissolved after the deposition. The resulting SiO film is suitable for diffusion masking of 2.5×3.5 -mil structures.

Graphic Data Processing, Irving Abzug, *Datamation* **11**, No. 1, 35-37 (January, 1965).

The Graphic Data Processing System allows the user to communicate with a computer in almost the same way he talks to his colleagues. This computer-controlled system is intended to help engineers, designers, and businessmen work directly with graphics—charts, sketches, and drawings. The major elements in the Graphic Data Processing configuration include an IBM System/360 processor, visual display consoles, a 35-mm film recorder, and a 35-mm film scanner.

Graphical Solution of Three-Mode Two-Mode Control Equations, J. O. Jacques, *ISA Journal* **12**, No. 1, 61-63 (January, 1965).

A graphical method is used to determine the coefficients of the 3-mode control equation when closed loop system performance is specified in terms of the steady state error and the dominant roots. The method is derived directly from the characteristic equation of the system. Thus, the solution is exact and no trial and error is performed. The range of problems that may be brought into system specifications is easily determined. A quick check of the plant will show if it can be adjusted by a 3-mode controller to meet a particular set of specifications. Solution of the 2-mode control equation is also shown.

Graphics Sampling Plans for Consumer Acceptance of Electronic Components, L. Danziger, *Industrial Quality Control* **21**, No. 6, 312-317 (December, 1964).

Sampling plans have previously been derived for testing a minimum mean life with a guaranteed consumer protection. These non-replacement plans are examined in a different light, expanded, graphed, and compared to replacement plans. A table is derived for quickly approximating the operating characteristic curve for any choice of consumer-oriented plan, thus enabling one to evaluate the protection that the plan affords the producer. All of the plans are based on the assumption that the distribution of times-to-failure is exponential.

Grundlagen der Miniaturisierung in der Digitaltechnik (Fundamentals of Integrated Circuits), G. Kohn, *Bulletin des Schweizerischen Elektrotechnischen Vereins* **53**, No. 26, 1277-1284 (1964).

Some fundamental engineering problems of integrated circuits are discussed. Relations between element size, packing density, signal level, power dissipation and speed are investigated and some limits for monolithic circuits are defined. The improvement of reliability and yield by employing redundant elements is estimated.

Heat Transfer Characteristics of Fluids Moving in a Taylor System of Vortices, C. Y. Ho, J. L. Nardacci,* and A. H. Nissan,** *American Institute of Chemical Engineers Journal* **10**, No. 2, 194-202 (March, 1964).

Heat transfer coefficients, in the form of Nusselt numbers, increase when fluids rotating in the gap between concentric cylinders exceed a critical parameter known as the critical Taylor number. A theoretical approach, for Prandtl number equal to one, successfully gives this increase for a short range of Taylor numbers above the critical value; as Taylor numbers increase, the deviation between theory and experimental increase. Reasons are given for this discrepancy. Experimental results of this work are combined with those of previous research to demonstrate these points.

* West Virginia Pulp and Paper Co., New York.

** Douglas Aircraft Co., Santa Monica, California.

Infra-Red Spectroscopy of Brominated Epoxy Resins, H. W. Mackinney and J. T. Spalik, *SPE Transactions* **5**, No. 1, 39-43 (January, 1965).

The method of determining the epoxy equivalent weight of resins derived from Bis Phenol A and epichlorohydrin described by Kagarise and Weinberger has been extended to resins derived from epichlorohydrin and Tetra Brom Bis Phenol A and/or Bis Phenol A. In the infra-red spectra of the latter, the characteristic aromatic band at 1610 cm^{-1} is replaced by a strong band at 738 cm^{-1} , the intensity of which increases linearly with the content of Tetra Brom Bis Phenol A. The logarithm of the epoxy equivalent weight is linearly related to the ratio of the absorbance at 915 cm^{-1} to a linear combination of those at 1610 and 738 cm^{-1} , respectively.

Intensity Fluctuations in a GaAs Laser, J. A. Armstrong and A. W. Smith, *Physical Review Letters* **14**, No. 3, 68-70 (January 18, 1965).

We have observed the intensity fluctuations in the light emitted by a single mode of a cw GaAs laser. The injection current was varied from a value below the threshold for coherent oscillation to a value well above threshold. We have thus been able to observe the change in noise properties of the single mode output as the laser begins to oscillate. Below threshold the mode emits random noise like a narrow band blackbody source; above threshold its noise is characteristic of a quieted, amplitude-stabilized oscillator. Our measurements of the intensity fluctuations were made with the two-detector coincidence counting technique of intensity interferometry first used successfully by Twiss, Little, and Hanbury Brown and by Hanbury Brown and Twiss.

Interactions Between Closely Coupled GaAs Injection Lasers, C. E. Kelly, *IEEE Transactions on Electron Devices* **ED-12**, No. 1, 1-4 (January, 1965).

Interaction effects between injection lasers have been experimentally studied at 2°K and 77°K under pulse conditions in a single block configuration which permits close optical coupling between the lasers. This close coupling made previously reported effects an order of magnitude more prominent and revealed a new effect. The reduction of the threshold current of one laser by the influence of the coherent beam of a second laser by as much as a factor five has been observed. With respect to the quenching of one laser by a second laser, a quenching ratio (defined as the ratio of the quenched power to the quenching power) of 0.7 was obtained. A new effect observed was the reduction of the threshold current of one laser by the influence of the spontaneous emission from a second laser. A reduction of 10 per cent is typical for this effect. A qualitative discussion treating the two lasers as one optical cavity is given to incorporate these effects into one coherent picture. Logical device applications are also discussed.

The Junction Depth of Concentration-Dependent Diffusion: Zinc in IV-V Compounds, L. L. Chang, *Solid-State Electronics* **7**, 853-859 (December, 1964).

The dependence of the junction depth on various parameters in a concentration-dependent diffusion is considered. The result is applicable to any diffusion in which the diffusion coefficient is expressible in terms of the ratio of the concentration to the surface concentration, and decreases at low concentrations. In particular, the process of interstitial-substitutional diffusion is investigated. The derived expression of the junction depth is compared and found in agreement with the experimental results of zinc diffusion in some IV-V compound semiconductors. This result enables one to predict the junction depth under various experimental conditions. It also supports an interstitial-substitutional mechanism for zinc diffusion in all the semiconductors under consideration.

Leaky Space-Charge Waves. I: Čerenkov Radiation, I. Palócz and A. A. Oliner,* *Proceedings of the IEEE* **53**, No. 1, 24-36 (January, 1965).

In this paper a new theoretical approach is presented for the analysis of the Čerenkov effect. The radiation is associated with the presence of leaky space-charge waves on a modu-

lated electron beam. The new theory, which is rigorous within the customary linearized regime, takes into account the effect of finite beam thickness and the actual space charge waves on the beam. Of greater significance is the fact that it permits a self-consistent type of description, i.e., it includes the influence of the radiation back on the beam. A linear perturbation calculation is also employed to obtain useful expressions in simple but accurate form. This leaky wave approach not only reproduces rapidly the known results relating to Čerenkov radiation, but offers some new information as well. Among other results, it is found that there exists an optimum beam thickness and velocity, and that a discrete infinite set of leaky space waves occurs so that the radiation does not emerge ideally at a single angle, although the angular spread is found to be very small. Interesting differences arise between the fast and slow space charge waves; the fast waves decay along the beam while the slow waves are growing waves. The transverse field dependences of these two wave types are also different. Numerical results are presented for certain typical parameter values.

* Polytechnic Institute of Brooklyn.

Light Emission from Reverse-Biased GaAs and InP p-n Junctions, A. E. Michel, M. I. Nathan and J. C. Marinace, *Journal of Applied Physics* **35**, No. 12, 3543-3547 (December, 1964).

The light emission from reverse biased diffused p-n junctions made in the direct band-gap semiconductors GaAs and InP has been measured. In addition to the broad emission spectrum observed from junctions in other materials which have indirect band gaps, a sharp line ($\Delta\lambda \cong 150 \text{ \AA}$) is observed at photon energies slightly less than the energy gap. In most diodes this line dominates the spectrum. It is almost identical in shape to the line observed at this photon energy when the junction is forward biased. The measured external quantum efficiency of the reverse biased light is higher ($\sim 10^{-5}$ to 10^{-4}) than has been reported for most other materials. The spatial distribution of the light emission and the I-V characteristics have also been measured and found to be similar to other materials.

Light Modulation Experiments at 16 Gc/Sec, R. A. Myers,* P. S. Pershan,** *Journal of Applied Physics* **36**, No. 1, 22-28 (January, 1965).

An experimental study of light modulation at 16 Gc/sec, using the linear electro-optic (Pockels) effect, has been performed. The principal result has been the demonstration of a new type of traveling-wave-like light modulator, which takes advantage of the fact that in crystals which have a $\bar{4}$ -axis (such as KDP—potassium dihydrogen phosphate), an electric field parallel to this axis is equivalent to a field in the opposite direction if the crystal is rotated 90° about the axis. The modulator is made of a stack of crystals alternately rotated 90° with respect to one another and of a height such that the electric field changes phase by 180° in the time light takes to pass through one crystal. In this way, the electrically-induced birefringence increases with optical path even though the microwave modulating field is a standing wave with no spatial variation in the direction of light propagation. For the experiments to be described, the microwave field is obtained with a multimode solid dielectric cavity efficiently driven in its TE_{101} mode. Results on simple devices containing two and three crystals are reported, and a discussion of the

general properties of this type of device is presented. In addition, the magnitude of the electro-optic effect in KDP and ADP (ammonium dihydrogen phosphate) has been found, at 16 Gc/sec, to be the same as the low-frequency clamped effect in these materials (within experimental errors of 25% in ADP and 12% in KDP). This agrees with previous observations at 9 Gc/sec. Results concerning the variation with optical wavelength of the electro-optic in these materials at 16 Gc/sec are also reported.

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 ** Harvard University.

Light Sources for Double-Resonance and Level-Crossing Spectroscopy, B. Budick, R. Novick and A. Lurio, *Applied Optics* 4, No. 2, 229-235 (February, 1965).

The requirements on light sources for double-resonance and level-crossing spectroscopy are reviewed. A modern version of the Cario-Lochte-Holtgreven flow lamp is described and its performance for a number of elements is compared with that of sealed-off electrodeless discharge lamps and Schultze-type hollow cathode sources. None of these sources is useful under all circumstances. The electrodeless lamp is particularly effective in the case of the group IIB intercombination lines. The high atomic density available in the flow lamp makes it useful for partially forbidden resonance lines for a number of chemical species including highly reactive metals, such as Ca. The hollow cathode lamp is well suited to the fully allowed resonance lines of a wide range of elements including highly refractive metals.

Mantissa Distribution, A. G. Konheim, *Mathematics of Computation* 19, No. 89, 143-144 (January, 1965).

Let b be a positive integer, at least 2, and write each positive real number in the form $x = mb^c$ where m (the mantissa) satisfies $1/b \leq m < 1$ and c (the characteristic) is an integer. The product of mantissas $m_1 \cdot m_2$ is defined so as to correspond to the product operation $x_1 \cdot x_2$. In this paper we find all distribution functions $F_M = Pr(M \leq x)$ which satisfy $Pr(M_1 \cdot M_2 \leq x) = Pr(M_1 \leq x)$ when M_1 and M_2 are independent, identically distributed random variables taking values in $[1/b, 1)$.

Maser und Zeitmessung (Masers and Time Measurement), Peter Kartaschoff* and Paul Edrös, *Der Mensch und die Technik* (Technisch-Wissenschaftliche Blätter der Süddeutschen Zeitung) 6, No. 81, 297 (December 11, 1964).

This review article describes the different masers which have been built in Switzerland and elsewhere for use as high precision primary time standards. The operation characteristics of the hydrogen maser are discussed and compared with quartz clocks, ammonia masers, caesium resonators and gas cells. Some applications of high stability time standards are explained.

* Director of the Section for Atomic Frequency and Time Standards, Swiss Laboratory for Watch Research, Neuchâtel, Switzerland.

Matching Communication Facilities to Data Processors, M. A. Berk and C. F. Haugh, *Computers and Automation* 13, No. 10, 14-19 (October, 1964).

A number of problems arise when data processing equipment is to be connected to communications lines in real-

time systems. Four different solutions, utilizing essentially three basic approaches consisting of (a) a system modification, (b) an addition, and (c) an independent stored-program device, are discussed. Each has certain advantages and disadvantages; the desirable choice depends on the system complexity and size, information flow rates, and the central processor requirements.

A Mathematical Model for Mechanical Part Description, J. Y. S. Luh* and R. J. Krolak, *Communications of the Association for Computing Machinery* 8, No. 2, 125-129 (February, 1965).

The flexibility of a mathematical model takes advantage of the common information requirements of computer-aided engineering drawing, numerical control tape generation, and physical characteristic computation. By judicious control of man-machine communication requirements, improved results over conventional engineering design processes are possible. An English-like input language, tailored for use by draftsmen and designers, will describe the part and specify the output desired. One approach to the mathematical model consists of a group of surface-defining quadric equations, which are created by a system of modular subprograms. Other subprograms will convert the mathematical model into instructions for driving automatic drafting machines and numerical controlled machine tools. Physical part characteristics, such as center of gravity, can be computed by subprograms and used in dynamic analysis work. The proposed over-all system is presented and experiments and demonstrations are discussed.

* Present address: Honeywell, Inc., Minneapolis.

A Method of Optimal Plastic Design, P. V. Marçal* and W. Prager, *Journal de Mécanique* 3, No. 4, 509-530 (December, 1964).

Plastic design of a structure to minimize its cost is discussed under the assumption that the unit cost is a convex function of the plastic resistance. A general method of treating problems of this kind is presented, which uses an associated nonlinearly elastic structure. This is supported and loaded in the same manner as the plastic structure that is to be designed, and the minimum of its complementary energy is made to correspond to the minimum of the cost of the plastic structure. Examples concerning the optimal design of beams and plates are given.

* Lecturer, Imperial College of Sciences and Technology, London.

The Microimage Characteristics of a Kalvar Film, M. E. Rabedeau, *Photographic Science and Engineering* 9, No. 1, 58-62 (January/February, 1965).

The microimage characteristics of Kalvar film, which differ from those of silver halide materials, are given. A "viewing adjacency" effect has been observed, and granularity has been found to be a nonmonotonic function of density. The modulation transfer function (MTF) of the film has been found to be very nearly independent of exposure and viewing adjacency effects; consequently, image quality can be specified by a unique MTF. MTF data are presented for the particular Kalvar film investigated.

A Multivariate Analysis of an Experimental Design Involving a Complete Set of Latin Squares, Man-Wai Chan, *Psychometrika* **29**, No. 3, 233-240 (September, 1964).

A model for an experimental design involving a complete set of Latin squares for testing the homogeneity of treatment effects was constructed and analyzed by Gourlay. In his analysis, however, if one or both of the preliminary *F*-tests are significant, the analysis cannot differentiate. He then suggests the use of a less desirable test which is biased and has fewer degrees of freedom, regardless of the number of replications (the d.f. cannot be increased by increasing the replications). Further, when heterogeneity of variance occurs, Gourlay's test procedures are in general invalid. The present paper reviews Gourlay's analysis and proposes a modified test procedure.

NPL: Highlights of a New Programming Language, G. Radin and H. P. Rogoway, *Communications of the Association for Computing Machinery* **8**, No. 1, 9-17 (January, 1965).

NPL is a new, high-level program language designed to allow both the novice and the experienced programmer to program in a straightforward manner a broad range of applications for contemporary and perhaps future computers. This paper discusses the design criteria for the language and is an examination and justification of those features which are not generally present in higher-level languages and of other features for which the NPL approach is somewhat different from that in previous languages. Topics discussed include program structure, types of data, input/output, non-sequential facilities, and compile time facilities.

Nuclear Quadrupole Coupling in Polyatomic Molecules, C. W. Kern* and M. Karplus, *Journal of Chemical Physics* **42**, No. 3, 1062-1071 (February 1, 1965).

The Gaussian-transform method has been applied to the evaluation of the deuteron and nitrogen-14 quadrupole coupling constant (eqQ/h) with the various minimal and extended basis-set SCF-LCAO-MO functions that are available for the linear polyatomic molecules DCN, C_2D_2 , DF_2^- , and N_3^- . Comparisons are made between calculations neglecting and including the three-center integral contributions. The coupling constant is found to be quite sensitive to the choice of basis orbitals, particularly those responsible for the form of the valence-shell charge density. This suggests that the quadrupole coupling constant in polyatomic molecules is a useful criterion for testing the wave function obtained in approximate calculations. Of particular interest is the variation in the $(eqQ/h)_D$ result for DF_2^- , which points out the importance of an experimental coupling constant measurement for this hydrogen-bonded species.

* Present Address: Department of Chemistry, State University of New York at Stony Brook.

On the Electrophoretic Term of the Limiting Law for Electrical Conductance in Solutions, H. L. Friedman, *Journal of Chemical Physics* **42**, No. 2, 450-458 (January 15, 1965).

The model to which the cluster theory of conductance was applied in an earlier paper is extended to allow for nonpairwise contributions to the interactions among the ions. When

the nonpairwise parts of the long-range hydrodynamic interactions are included in the cluster theory calculation, the electrophoretic term of the limiting law found by Debye, Hückel, and Onsager is recovered.

On the Use of Oseen's Velocity Field in the Calculation of Electrical Conductance in Solutions, H. L. Friedman, *Journal of Chemical Physics* **42**, No. 2, 459-462 (January 15, 1965).

The electrophoretic term of the limiting law for conductance is evaluated using Oseen's expression for the velocity field generated in a fluid medium by the motion of an immersed ball. This expression accounts for the nonzero inertia and kinetic energy of the fluid, unlike Stokes' velocity field which is usually used in conductance theory. The electrophoretic term calculated in the framework of the Debye-Hückel conductance theory reduces to the classical result in the usual range of experimental conditions and also makes a very small contribution to the Wien effect for electric fields in the accessible range.

Optimum Control of a System of Oversaturated Intersections, D. C. Gazis, *Operations Research* **12**, No. 6, 815-831 (November/December, 1964).

The problem of optimizing the control of two oversaturated traffic intersections is solved by using the semi-graphical methods employed in a previous paper for an isolated intersection. As in the case of a single intersection the optimum control involves values of the control variables that lie along edges of the control region, which in this case is defined by the permissible ranges of the green phase splits. An analytical formulation of the method using Pontryagin's control theory is also given.

Opto-Electric Effects in Ge-GaAs p-n Heterojunctions, B. Agusta and R. L. Anderson,* *Journal of Applied Physics* **36**, No. 1, 206-210 (January, 1965).

In an abrupt Ge-GaAs p-n heterojunction, a plot of conduction band edge vs position shows a discontinuity at the material interface. As a result, a "notch" occurs in the band-edge profile which strongly affects the opto-electric characteristics of such a junction. The conversion efficiency is much less than that of a homojunction of similar doping levels. At room temperature the photocurrent is limited by the rate at which electrons can be thermally excited from the notch into the GaAs. At 78°K this contribution to current is negligible. For reverse bias, the photocurrent results from electron tunneling from the notch into the GaAs. In forward bias, the space charge resulting from the presence of the optically excited electrons in the notch changes the potential profile in such a way so as to reduce the forward current, and to cut it off entirely for sufficiently high light intensity. Because of the low conversion efficiency, it is concluded that such a heterojunction collector in an optical transistor is not practical.

* Department of Electrical Engineering, Syracuse University.

Performance Criteria for Photodetectors—Concepts in Evolution, H. J. Zweig, *Photographic Science and Engineering* **8**, No. 6, 305-311 (November/December, 1964).

Over the past 25 years there has been an evolution in the concepts for evaluating the performance of photodetectors.

Among the important new concepts are those of modulation transfer, information capacity, informational sensitivity, and detective quantum efficiency. This concept of quantum efficiency is explained and differentiated from the notion of quantum yield. It is shown how the concept applies to diverse detector mechanisms.

Photochemical Transformations of 1, 5-Cyclooctadiene, R. Srinivasan, *Journal of the American Chemical Society* **86**, No. 16, 3318-3321 (August 20, 1964).

Photolyses are reported of 1,5-cyclooctadiene: (i) by sensitization with mercury (3P_1) atoms in the vapor phase, (ii) by direct irradiation in solution in the presence of cuprous chloride, and (iii) by irradiation in solution in a complexed state with rhodium chloride. The products from (i) are a polymer, bicyclo [5.1.0] octene-3 and tricyclo [3.3.0.0.^{2,6}] octane. The polymer is believed to arise from a primary process which gives rise to free radicals. The other two products which are isomeric to 1,5-cyclooctadiene seem to be formed by intramolecular processes, analogs of which may be found in the photochemistry of 1, 5-hexadiene.

Piezo-Resistance of Metallic and Semiconducting Bismuth, R. Jaggi, *Physics of Semiconductors, Proceedings of the 7th International Conference, Paris*, pp. 413-415 (1964).

In single crystals of pure bismuth, the resistance parallel and perpendicular to the trigonal axis has been measured as a function of hydrostatic pressure and temperature. Under pressures $p > 6 \times 10^8$ kg/cm², and temperatures $45^\circ \leq T \leq 120^\circ$ K, the resistivity varies as $r = A \exp [\epsilon(p)/2kT]$. The activation energy ϵ increases with pressure and is $\epsilon = 15.3 \times 10^{-3}$ eV for $p = 24.7 \times 10^8$ kg/cm².

Potentiometer Setting Nomograph Eliminates Loading Error, K. Kraut, *Electronic Design* **12**, No. 23, 70 (November 9, 1964).

When a constant voltage E_{in} is impressed across the total potentiometer resistance, the original voltage E_o from the slider will not vary linearly with respect to its position along the coil if current is drawn through the slider. This is commonly referred to as "loading error." The effects of this "loading error" are eliminated when this nomograph is used.

Propagation of Microwave Phonons in Germanium, M. Pomerantz, *IEEE Transactions on Sonics and Ultrasonics* **SU-11** No. 2, 68-73 (November, 1964).

The effects of various kinds of interactions on the propagation of 9 Gc/sec microwave phonons in germanium have been studied experimentally. We will discuss phonon interactions (1) with conduction electrons in degenerate n -Ge, which produces attenuation of waves of specific polarization in particular directions of propagation, (2) with thermal phonons, which gives temperature-dependent ultrasonic attenuation, and (3) with microwave phonons, which gives nonlinear effects.

A Property of the Ratio of Trigonometric Polynomials, T. J. Rivlin, *Journal of SIAM, Series B, Numerical Analysis* **1**, 131-132 (1964).

A simple and brief proof that it is possible to "factor out" zeros common to the numerator and denominator of a ratio of trigonometric polynomials is given.

Reactions of Gallium Arsenide with Water Vapor and Hydrogen Chloride Gas, M. Michelitsch, W. Kappallo and G. Hellbardt, *Journal of the Electrochemical Society* **111**, No. 11, 1248-1253 (November, 1964).

Vapor etching as well as vapor growth experiments in an open-tube GaAs/H₂O/H₂ system and vapor etching experiments in an open-tube GaAs/HCl/H₂ system revealed straight-line relationships between the logarithm of the etching deposition rates g_w and $1/T_w$, respectively, at temperatures between 600° and 1000°C. For the GaAs/H₂O/H₂ system the reaction enthalpy is $\Delta H_{r_{calc}} = 57 \pm 3$ kcal/mole and $\Delta H_{r_{exp}} = 54 \pm 3$ kcal/mole. For the GaAs/HCl/H₂ system the reaction enthalpy is $\Delta H_{r_{calc}} = 31$ kcal/mole and $\Delta H_{r_{exp}} = 32 \pm 2$ kcal/mole. Deposition experiments revealed a relationship between the growth rate at a constant wafer temperature and the square of the gallium-to-oxygen ratio.

Relaxation Term of the Limiting Law of the Conductance of Electrolyte Mixtures, H. L. Friedman, *Journal of Chemical Physics* **42**, No. 2, 462-469 (January 15, 1965).

The calculation of the limiting-law terms from the cluster theory of conductance, as presented in recent papers, is extended to solutions of mixtures of electrolytes. The more general evaluation of one of the cluster integrals required for this purpose is achieved by using some results from the theory of symmetric polynomials. The resulting relaxation term is very different in form from that of Onsager and Kim but, at least for solutions of three solute species, the two theories give the same numerical results for the ionic conductances in a variety of systems.

Room Temperature Chemical Polishing of Ge and GaAs, A. Reisman and R. L. Rohr, *Journal of the Electrochemical Society* **111**, No. 12, 1425-1428 (December, 1964).

Results of experiments using NaOCl solutions as a polishing etchant for Ge and GaAs at boiling and room temperatures are described. Techniques are outlined for the room temperature chemical polishing of common Ge and GaAs crystallographic orientations including both the Ga and As faces of wafers oriented perpendicular to the (111) in GaAs. Effects of dilution variation, polishing cloths, equipment and removal rate are discussed.

Saturable Optical Absorption in Phthalocyanine Dyes, J. A. Armstrong, *Journal of Applied Physics* **36**, No. 2, 471-473 (February, 1965).

Strong optical absorption lines have been almost totally saturated in two phthalocyanine molecules. A giant pulse ruby laser served as the source of intense resonance radiation. The qualitative behavior of the nonlinear absorption is in good agreement with theory.

The Scanistor—A Solid-State Image Scanner, J. W. Horton, R. V. Mazza, and H. Dym, *Proceedings of the IEEE* 52, No. 12, 1513-1528 (December, 1964).

Scanistors form a new class of semiconducting devices which perform image scanning or dissection by reason of a novel electronic method of commutating a single output terminal to any preselected illuminated portion of the device. The selection is uniquely determined by a voltage applied across two terminals of the device. The present investigation is concerned with a strip-shaped unit called the multijunction scanistor which is comprised of a linear, integrated-circuit array of photodiodes. This device provides an output either as a sequence of pulses which represent spatial sampling of a line image at a discrete number of points, or as an analog waveform which is a linear transformation of the line image. A theory appropriate to scanners of this type is developed and applied to the multijunction scanistor for purposes of design and analysis. A time-dependent circuit analysis of a model of the scanistor is carried out and tested experimentally. It provides an understanding of the upper limits to the scanning rate set by junction capacitance. Experimental units designed according to theory are tested for their sine-wave response, uniformity of output, sensitivity, and scanning linearity. These units are shown to give good results when used to scan a typewritten document for facsimile display on an oscilloscope.

Sensory Feedback Analysis in Medical Research. II. Spatial Organization of Neurobehavioral Systems, K. U. Smith, J. D. Gould, and L. Wargo,* *American Journal of Physical Medicine* 43, No. 2, 49-84 (April, 1964).

This paper reviews much original research, based upon time- and space-displaced, delayed, and distorted sensory feedback, which led to a neurogeometric-sensory feedback interpretation of behavior. The experimental techniques and findings, as well as the theoretical implications, are related to medical research and human factors.

* University of Wisconsin.

Serial-to-Parallel Transformation of Linear-Feedback Shift-Register Circuits, H. H. Hsiao and K. Y. Sih, *IEEE Transactions on Electronic Computers* EC-13, No. 6, 738-740 (December, 1964).

Linear-feedback shift-register circuits have been studied extensively for the serial case, i.e., with one input channel and one output channel. In practical cases, circuits with parallel multiple-channel inputs and outputs are also considered important. In this paper, an application of cyclic error-correcting codes in multiple parallel channels is studied. A design started in a conventional way for a serial circuit and then transferred to a required parallel circuit. Three methods—engineering approach, companion matrix, and polynomial roots—are given to perform this serial-to-parallel transformation. Furthermore, a theory of encoding and error detection is developed which shows that a set of transformed check bits can be used to replace the true remainder so that the code will have the same error detection ability with economic hardware implementation.

The Stability of Glazed Silicon Surfaces to Water Attack, W. A. Pliskin, *Proceedings of the IEEE* 52, No. 12, 1468-1471 (December, 1964).

IBM has developed a glassing technology for the passivation of transistors and diodes. For effective surface protection,

the glass should have long-term stability to ambient attack, particularly moisture attack. Since it is difficult to evaluate all glasses under moderate moisture conditions for extended periods, several accelerated tests for determining the stability of glasses to water and humidity were compared. Although the results obtained from exposure of a glassed silicon wafer to boiling water for times ranging from a few minutes to an hour were more severe than those obtained by conventional long-term humidity tests, the results could be correlated. The films were evaluated by infrared spectroscopy and by changes in weight, thickness, and microscopic appearance. It was found that glazed silicon surfaces can best be evaluated for water stability by comparison of the infrared spectra of the films before and after boiling in water. Changes in film thickness or weight was found to be insufficient for a complete evaluation.

A Stability Theory for Nonlinear Mixed Initial Boundary Value Problems,† R. K. Brayton and W. L. Miranker, *Archive for Rational Mechanics and Analysis* 17, No. 5, 358-376 (December, 1964).

In this paper a method for constructing Liapounov functionals is devised. The method is based on a canonical form in which many nonlinear mixed initial boundary value problems may be written. Problems of this type are interpreted as generating dynamic systems in function space. This interpretation is combined with the Liapounov functional to give a stability theorem. Several examples of the method are included.

† The results reported in this paper were obtained in the course of research jointly sponsored by the Air Force Office of Scientific Research (Contract AF 49(638)-1139) and IBM.

Stereoscopic Television Pursuit Tracking,† J. D. Gould, *Journal of Applied Psychology* 48, No. 6, 369-377 (December, 1964).

This research was concerned with tracking a remote target moving in depth. A 3-D television system provided visual feedback, and direct and aided pursuit tracking systems were evaluated as a function of target speed. The stereoscopic display was shown to be generally satisfactory for remote-control operations, although some fatigue or "eye-strain" was reported, probably due to the optics of the system. Contrary to previous tracking studies on nondepth courses, it was shown that on a depth course direct tracking is consistently superior to aided tracking at the 3 target speeds used. Amplitude of error analysis provided answers concerning what S's do when not on target. Tracking behavior was interpreted in terms of the sensory-feedback mechanisms governing the control of motor patterns.

† This research, submitted as a doctoral dissertation at the University of Wisconsin, was supported in part with the National Institute of Mental Health and National Science Foundation grants of K. U. Smith, and it was conducted while the author was a National Institutes of Health research fellow.

A Survey of Digital Simulation—Part 1: Digital-Analog Simulator Programs, R. N. Linebarger and R. D. Brennan, *Simulation* 3, No. 6, 22-36 (December, 1964).

This is the first of an intended series of articles on digital simulation. The first article restricts attention to digital-analog simulator programs—those programs which simulate the elements and organization of analog computers. It is

intended to be both tutorial and documentary in its presentation. This topic was selected for the first article because this segment of digital simulation is of most general interest to analog users.

Thermal Decomposition Processes in the System Tricyclo [3.3.0.0^{2,6}] octane-1,5-Cyclotadiene, R. Srinivasan and A. A. Levi, *Journal of the American Chemical Society* **86**, No. 18, 3756-3759 (September 20, 1964).

The thermal isomerization of tricyclo [3.3.0.0^{2,6}] octane in the gas phase at 1.5 mm pressure in the temperature range from 327 to 366°K is a homogenous, first-order reaction. The rate of the reaction fitted the equation $K = 3.22 \times 10^{15} \exp(-55,900 \pm 1400/RT)$. The addition of propylene had no effect on the kinetics. The products that were observed (in the order of decreasing yield) were 4-vinylcyclohexene, 1, 3-butadiene, and 1, 5-cyclooctadiene.

Thin Films Deposited by Bias Sputtering, L. I. Maissel, P. M. Schaible, *Journal of Applied Physics* **36**, No. 1, 237-242 (January, 1965).

It has been found that the application of a suitable negative bias to a film that is being deposited by dc sputtering produces a film of substantially lower resistivity (than without bias). The action of the bias is shown to result from positive ion bombardment of the film during deposition, leading to the selective removal of adsorbed impurities. An analytical expression describing the process is developed which gives good agreement with experiment. Various other aspects of bias sputtering are explored and discussed, and a brief comparison to asymmetric ac sputtering is made.

Van der Waals Forces in Atoms and Molecules, M. Karplus and H. J. Kolker,* *Journal of Chemical Physics* **41**, No. 12, 3955-3961 (December 15, 1964).

The time-dependent variation-perturbation method is applied to the estimation of van der Waals forces ($-C/R^6$ term) in atoms and molecules. Use is made of an expression for the coefficient C involving an integral over imaginary frequencies of the dynamic polarizabilities of the interacting species. With an analytic approximation to the dynamic polarizabilities that can be extended into the imaginary frequency range, a simple formula for the van der Waals force is obtained. Applications of the method to the interactions between S -state atoms (H, He, Ne, Ar) are given and the results are compared with available theoretical and experimental values. Also, atom-molecule interactions involving (H, H₂) and (He, H₂) are examined, and the anisotropies in the van der Waals forces are calculated.

*National Science Foundation Postdoctoral Fellow. Present address: United Aircraft Research Laboratory, East Hartford, Connecticut.

Vibrational Interactions in Pariser-Parr-Pople Theory. II. Ground and Excited State Force Fields, W. E. Donath, *Journal of Chemical Physics* **42**, No. 1, 118-126 (January 1, 1965).

Expressions are derived for the interaction between ground and excited states to give resonance contributions to the

vibrational force field. Two contributions are found; the dominating term reflects largely the change in the bond resonance integral due to bond length variation with some contribution of the electrostatic terms; the other, relatively small term, is generated by the polarization due to the field generated by a vibrational distortion. Calculations are made for the ground states of a number of aromatics; adequate agreement with experiment is found for benzene and naphthalene.

The possible distortion of molecules and the Born-Oppenheimer approximation are investigated when the resonance interactions become strong. Application is made to the ¹B_{1u} and ³B_{1u} states of benzene and the ground state of the polycyanines. Distortion and violation of the Born-Oppenheimer approximation is predicted to occur for the two B_{1u} states of benzene.

Vibrational Spectra and Molecular Structure of Bicyclo [1.1.0] butane, Ivan Haller and R. Srinivasan, *Journal of Chemical Physics* **41**, No. 9, 2745-2752 (November 1, 1964).

The infrared and Raman spectra of bicyclo [1.1.0] butane and the infrared spectrum of its deuterated analogue were observed. The rotational structure of some infrared bands were partially resolved. If the numerical values occurring in cyclopropane and its derivatives are adopted for the related structural parameters of bicyclobutane, the spectrum is found consistent with a C_{2v} structure with an angle between the planes of the rings of 126° ± 3° and a bridgehead C-C distance of 1.54 ± 0.02 Å. A complete assignment of the fundamental vibrational frequencies of the light isotope is given.

Letters to the Editor

Autoconvolution of an Ellipse, J. V. Cornacchio and R. P. Soni, *Journal of the Optical Society of America* **55**, No. 1, 107 (January, 1965).

A Complicating Factor in the Photochemical Reaction of Aliphatic Ketones with Oxygen-18, R. Srinivasan, *Journal of Physical Chemistry* **68**, No. 7, 1997-1999 (July, 1964).

Cr³⁺-Cr³⁺ Ion Exchange Interactions in LaAlO₃, K. W. Blazey and G. Burns, *Helvetica Physica Acta* **37**, No. 7/8, 638 (1964).

Field Dependence of Surface Mobility at n-n Heterojunction Interface, L. L. Chang, *Solid State Electronics* **8**, 86-87 (January, 1965).

Innere Verformung in elastisch verformten Kristallen (Internal Strain in Elastically Strained Crystals), Armin Segmüller, *Helvetica Physica Acta* **37**, No. 7/8, 617 (1964).

Laser Deflection With The Conjugated Plano-Concentric Resonator, R. A. Myers, R. V. Pole and J. Nuñez, *Applied Optics* **4**, No. 1, 140 (January, 1965).

Low Temperature Effects in Si FET's, W. E. Howard and F. F. Fang, *Solid-State Electronics* **8**, 82 (January, 1965).

A Molybdenum-Oxide Negative-Resistance Device, C. Pettus, *Proceedings of the IEEE* **53**, No. 1, 98 (January, 1965).

Paramagnetic Resonance Study of Fermi Level Motion and Defect Formation in High Resistivity Cadmium Sulfide Crystals, G. A. Somorjai and R. S. Title, *Journal of Physical Chemistry* **68**, No. 12, 3907-3910 (December, 1964).

The Potential Averaging Property of Thin Film Resistors, I. G. Akmenkalns and M. H. Partovi,* *Proceedings of the IEEE* **52**, No. 12, 1755-1756 (December, 1964).

* Physics Department, MIT.

Properties of NiFe Double Films, S. Middelhoek, *Physikalische Verhandlungen* **15**, No. 10, 213 (1964).

Resonance Relaxation of Ni^{3+} in MgO and CaO, P. Wysling*, U. Höchli and K. A. Müller, *Helvetica Physica Acta* **37**, No. 7/8, 629-630 (1964).

* Physikalisches Institut der Universität Zürich.

Solvent Effects on the Spin-Orbit Coupling in Semi-quinone Ions, P. J. Zandstra, *Journal of Chemical Physics* **41**, No. 11, 3655-3656 (December 1, 1964).

Spinstrukturen (Spin Structures), H. Thomas, *Physikalische Verhandlungen* **15**, No. 10, 212 (1964).

Strong Field g-Value Calculation for d^7 Ions in Octahedral Surroundings, R. Lacroix*, U. Höchli and K. A. Müller, *Helvetica Physica Acta* **37**, No. 7/8, 627-628 (1964).

* Institut de Physique de l'Université de Genève.

Struktur und Eigenschaften der Hochdruck-Modifikation Bi II (Structure and Properties of the High Pressure Modification Bi II), R. Jaggi, *Helvetica Physica Acta* **37**, No. 7/8, 618 (1964).