which $M > N$ components are subjected to burn-in initially and one in which intermediate replacements can be made at times before T.

A computerized algorithm for determining the reliability of redundant configurations. D. B. BROWN. *IEEE Trans. Reliab.* **R-20**, No. 3, August (1971), p. 121. A procedure is given for generating the reliability function directly from the Boolean algebra transmission function. This method is easily programmed on the computer so that it can be utilized both in the derivation of the reliability function and in the evaluation of the reliability. The easily obtained transmission function completely defines the relationship between elements in a configuration. Thus, by utilizing this technique, a large variety of complicated configurations can be easily evaluated and compared.

Ensuring carrier system reliability. W. G. ALBERT. *Bell Labs Rec.*, January (1972), p. 3. Bell System reliability programs study existing carrier systems to improve not only their performance, but that of future systems as well. As the carrier systems grow increasingly complex, so do the reliability programs, and data gathering and analysis become elaborate.

Analysis of maintenance man loading via simulation. K. WEIR and B. TIGER. *IEEE Trans Reliab.* **R-20**, No. 3, August (1971), p. 164. This paper provides the results of a computer simulation performed to test compliance with a system maintenance requirement. Special attention is given to the selection of the simulation run time (sample size) and fitting a curve to the output data. The actual simulation program was written in the RCA Flow Simulation language which is similar to the IBM GPSS (general-purpose simulation system) language. More specifically, the system requirement was as follows. The probability that the system maintenance-man loading exceeds 4-hr repair time in a day (24 hr) shall be less than 0·0025. Equipment failures and repairs were simulated via a computer. Equipment failure and repair probability distributions were used as input data. A year's operation was simulated in less than 2-min computer time. A simulation sample size of 360 days was selected on the basis of a statistical analysis using a non-parametric 0·60 confidence level. The results showed a maximum repair time in a day of 130 min, which indicates the system repair time distribution is considerably better than required. The output data were analyzed and the observed repair times were fit with an empirical distribution function.

The unserviceable probability of a class of telecommunications networks. L. LEE. *IEEE Trans Reliab.* **R-20**, No. 3, August (1971), p. 132. This paper discusses the use of computers in calculating the unserviceable probability of a class of telecommunication networks. The unserviceable probability for a pair of terminals in the network is derived and is so complicated that it is not feasible to calculate without the use of a computer. Under the condition that every junctor in the network has a small ratio of mean service time to mean time between failures, it is shown that the computer-aided methods available for calculating network unreliability and network blocking probability are also applicable to network unserviceable probability. For the general expression of the network unserviceable probability, no simple computer-aided method is yet known. However, no urgent need for a computer-aided method for the general expression of the network unserviceable probability is envisaged since practical networks usually have small ratios of mean service time to mean time between failures for each of its junctors.

4. MICROELECTRONICS—GENERAL

***Physical characterization of electronic materials devices and thin films** (1.12.69–1.12.70). S. A. KULIN and K. KREDER. Manlabs. Inc., Cambridge Mass, U.S.A. P-177101. AFCRL-71-0204. F-19628-70-C-0140 SC-R-1. January (1971), 46 pp. A summary is given of work done during the reporting period on the examination of the physical, chemical and structural properties of various materials. Experimental methods include chemical analysis, reflection electron microscopy and diffraction, X-ray diffraction and fluorescence analysis, light microscopy and electron microprobe analysis, in addition to the determination of specific properties, such as density, hardness and thermal conductivity. Special services, such as crystal orientation, cutting, grinding and polishing are also being performed. Specific materials submitted for characterization include spinel, lithium germanate, silicon, silicon carbide, quartz, ruby, magnesium oxide, copper chloride, gallium arsenide, boron, potassium tantalum niobate, yttrium-iron garnet, yttrium-aluminium garnet and lithium niobate. In addition, a variety of specimens have been submitted for specific studies such as phase identification, crystallinity and chemical analysis.

Integrated circuit industry. R. N. NOYCE. *EDN/EEE*, 15 September (1971), p. 28. You can probably remember back to the days when we thought resistors were cheap. The author reminds you of that to indicate just how much change really has occurred in our industry.

***Report on investigations of radiation resistance of the FBH 162 RTL integrated circuit. Bundesministerium fur Bildung und Wissenschaft.** A. SPENCKER and J. SIEGEL. P1178780. BMBW-FB-W-71-28, June (1971), 40 pp. (Report in German.) The FBH 162 integrated circuit represents two NOR gates

with two inputs each. Changes of the physical properties of individual devices and of signal transmission properties of the entire IC by means of 100 kV-X-ray radiation, Cobalt 60—X-ray radiation, 1·5 MeV electron radiation and reactor neutron radiation are investigated. Corresponding to the increasing base recombination currents of the IC transistors the different types of radiation damage are discussed. Decrease of transistor current gain below a certain limit marks the end of the IC function.

5. MICROELECTRONICS DESIGN AND CONSTRUCTION

Multiplying made easy for digital assemblies. C. GHEST. *Electronics*, 22 November (1971), p. 56. New IC multiplies 2-bit by 4-bit number and adds constant; iterative arrays of the device can multiply larger numbers, yet bypass complex designs and long sequential operations of previous multipliers.

The development of polyimide multiplayer boards containing flexible circuitry. J. R. CANNIZZARO. *Solid State Technol.*, November (1971), p. 27. The semiconductor industry is seeking increased circuit density, reliability, miniaturization, and at the same time faces stringent, economic demands, as illustrated in the transition of integrated circuits from "flatpacks" to MSI and LSI packages. To keep pace, and to provide the necessary interdependent relationship with these semiconductor devices, the printed circuits industry has expanded tremendously in the past 5 yr, and along with this growth has come the necessary advanced technology. Starting with the commonplace two-sided plated-through-hole printed circuit board, dimensional tolerances and material specifications were tightened, thus providing the groundwork for the development of Multilayer Interconnection Boards (MIBs) and flexible circuitry. This article describes the development of a combination of multilayer and flexible circuits into a circuit board called a Flex/MIB. This packaging concept provides three-dimensional interconnections rather than the conventional planar approach.

Planox process smoothes path to greater MOS density. F. MORANDI. *Electronics*, 20 December (1971), p. 44. By levelling the oxide surface of MOS chips, an Italian process improves their mechanical reliability; automatic partial self-alignment boosts performance also, and full self-alignment is possible with polysilicon.

Focus on linear ICs. G. ROSTKY. *Electron. Des.* **21**, 14 October (1971), p. 52. As suppliers develop newer and better linear ICs (many of them not really linear) to make life easier for engineers, they also refine and polish the ancient art of specsmanship, which tends to make life more difficult. Because linear-IC competition is fierce, specsmanship—the art of concealing deficiencies and highlighting strengths—has become a way of life that's not likely to go away. Engineers must learn to cope with it.

ICs simplify v.-f. and v.-t. conversions. A. CIVIT and S. BRACHO. *Electron. Engng*, December (1971), p. 36. The problems of voltage-to-time and voltage-to-frequency conversion are discussed, and it is shown how they can be simplified by the use of IC operational amplifiers, with the benefits of higher accuracy and lower production costs. A simplified method of achieving division of analogue functions is also suggested.

Pyrohydrolytic Al_2O_3 for MOS applications. F. B. MICHELETTI, P. E. NORRIS, K. M. SCHLESIER and J. M. SHAW. *Solid State Technol.*, December (1971), p. 37. Complementary MOS integrated circuits with vapor deposited Al_2O_3 have been fabricated for the first time using the pyrohydrolysis of $AlCl_3$. Modifications in the deposition conditions have led to a significant reduction in the normal negative oxide charge in previous Al_2O_3 vapor-deposited films. This allows the fabrication of enhancement *p*-channel devices and low threshold *n*-channel devices as required for CMOS operation. Individual transistor characteristics were found to be well saturated with high gain. The nearly symmetrical NMOS and PMOS device parameters lead to excellent switching characteristics of the CMOS inverters and circuits. In addition, the excellent radiation hardness found with other forms of Al_2O_3 have been achieved in preliminary tests on Al_2O_3 MOS capacitors.

Models for contacts to planar devices. H. H. BERGER. *Solid-State Electron.* **15** (1972), p. 145. Two basic models for rectangular contacts to planar devices, the Kennedy–Murley model (KMM)[1] and the transmission line model (TLM)[2, 3] are discussed and compared. The KMM does not take into account the interface resistance between metal and semiconductor, whereas the TLM disregards the vertical structure of the semiconductor layer. An extension of the TLM is derived (ETLM), which approximately considers this vertical structure. KMM and TLM thus appear as special cases of the ETLM. The calibration of the latter on the KMM then yields a simple quantitative criterion for the applicability of the KMM or the pure TLM. Measurement results on typical aluminum–silicon contacts are described satisfactorily by the (E)TLM. Concurrently with the applicability criterion, the KMM proves inadequate for these contacts due to the disregard of interface resistance. Conclusions are derived from the TLM pertaining to current distribution over the contact area and to contact resistance. In particular, the contacts are classified according to their operation mode. Finally, the TLM approach is applied also to circular contacts.

***Beam lead technology.** T. W. FITZGERALD and K. ANDERSON. GTE Labs Inc. Waltham, Mass. U.S.A.