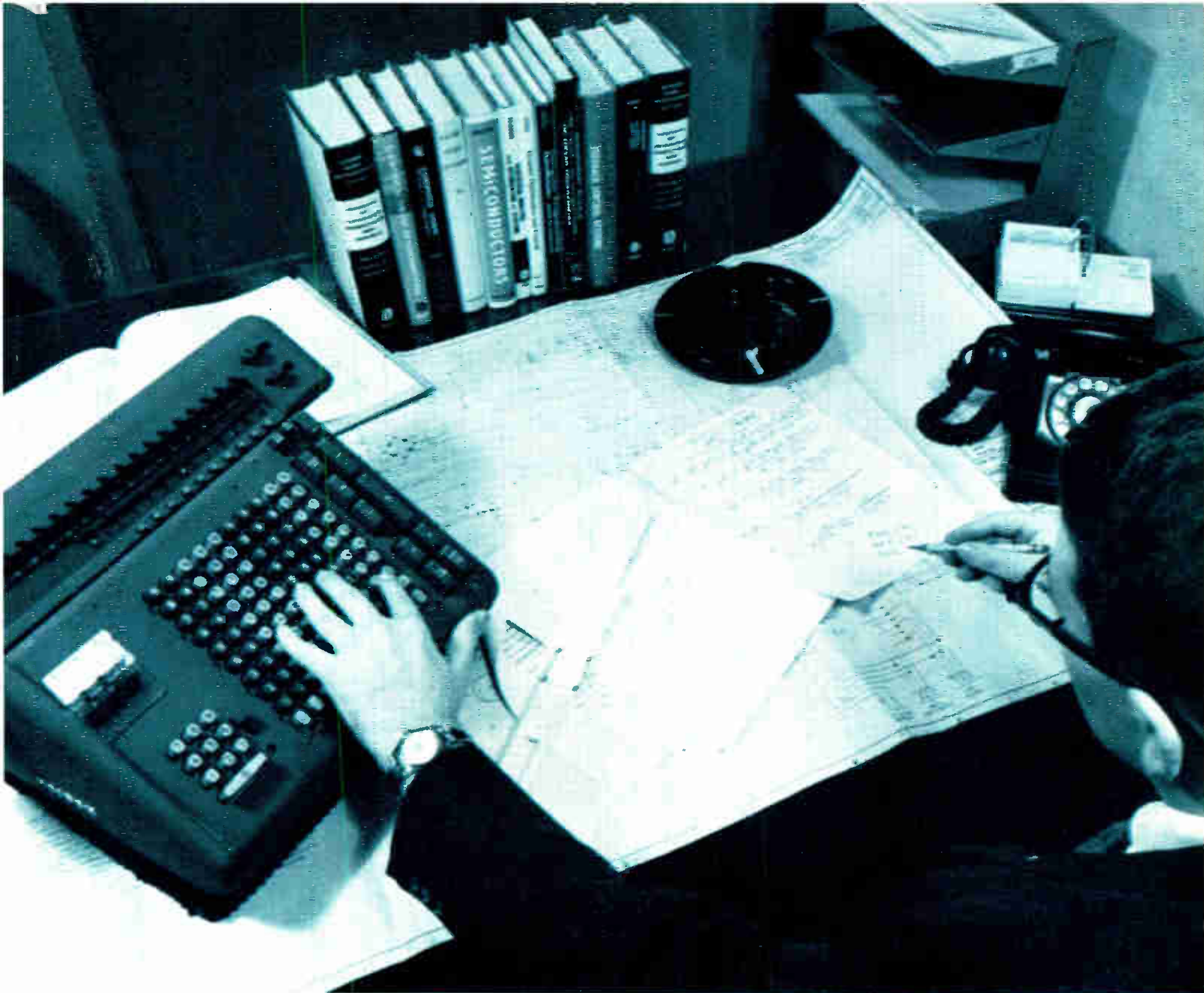


The circuit designer — *see cover story page 5.*

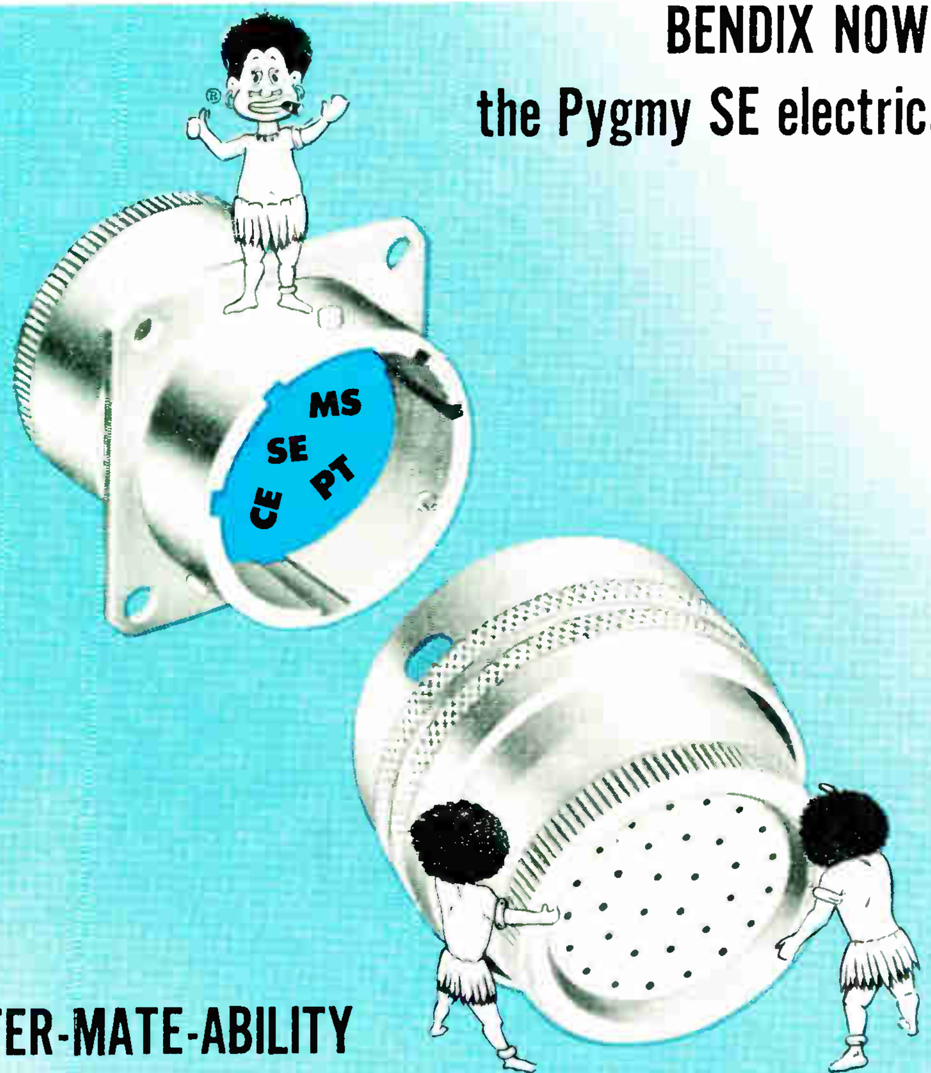
electronics and communications

Circuit Design — Special Issue

an age publication

JANUARY 1962

BENDIX NOW OFFERS...
the Pygmy SE electrical connector



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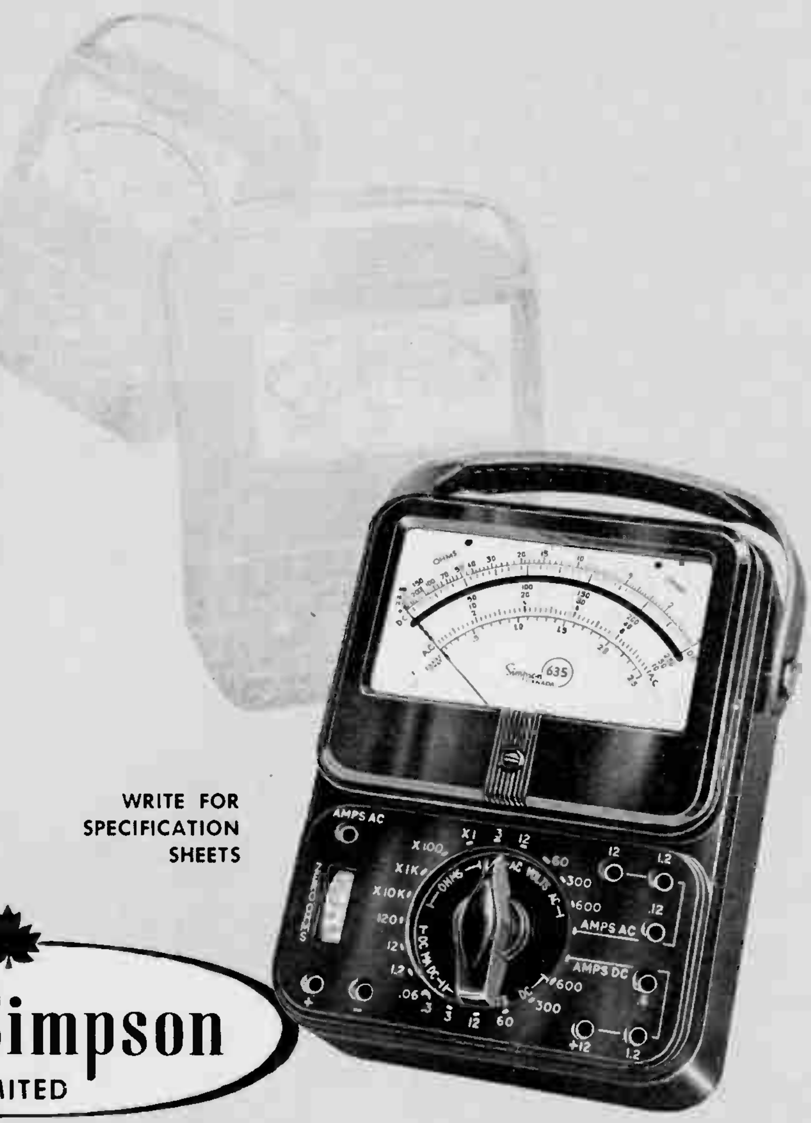

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60

electronics and communications

Canada's pioneer journal in the field of electronics and communications engineering

contents

JANUARY, 1962 Vol. 10, No.1

COVER STORY

The material tools of trade of the circuit engineer are shown in our picture . . . slide-rule, desk calculator, pencil and paper, reference books, and so on. Not shown, because it can not be shown, and by far the most important item is the logical and inventive mind of the circuit man himself.

departments

Electronic Industries Association of Canada news

by R. T. O'Brien

Symposium Program Shaping Up

The program is virtually completed for the 1962 Canadian Military Electronic Components Symposium to be held in Ottawa's National Gallery on April 11 and 12.

Government and industry speakers will present papers in four sessions; Session A for Research and Development papers; Session B for Engineering Aspects of Reliability; Session C the Management Aspects of Reliability; and Session D for papers on Trade and Production. Each session represents three papers.

While all the speakers have been determined the final papers are not yet complete. It is known, however, that the industry papers will explore areas of vital interest not only to those industry and government agencies already participating in the military electronics programs but to those manufacturers contemplating entry into the field.

One industry paper will describe a production program for a military electronic equipment for severe environmental service with special reference to parts reliability and will attempt to show how new orders of reliability can be achieved.

Another paper will explore the organizational structure and the various procedures necessary to assess the reliability level of electronic equipments.

In a paper being generated in the EIA Prime Contractors Committee the general assemblage of documents required by an equipment manufacturers on contracts of varying origins will be outlined and their accessibility examined. Another will present a general industry view of the military components business.

In addition technical papers on developments in microminiaturization and in film devices and an appraisal of future military technical requirements for parts are included.

Government speakers will examine international standardization programs and the challenges of increasingly difficult military specifications.

Advance registration is being requested by the Organizing Committee and cards will soon be available but facilities will be arranged for registration at the entry to the National Gallery Auditorium at nine o'clock on the mornings of April 11 and 12.

Chairman of the Organizing Committee is Hans Reiche of the Army Equipment Engineering Establishment, Ottawa. Proceedings are in the hands of H. D. Adam of the Canadian Military Electronics Standards Agency, 72 Queen Street, Ottawa.

Committee Preparing Handbook on Sound

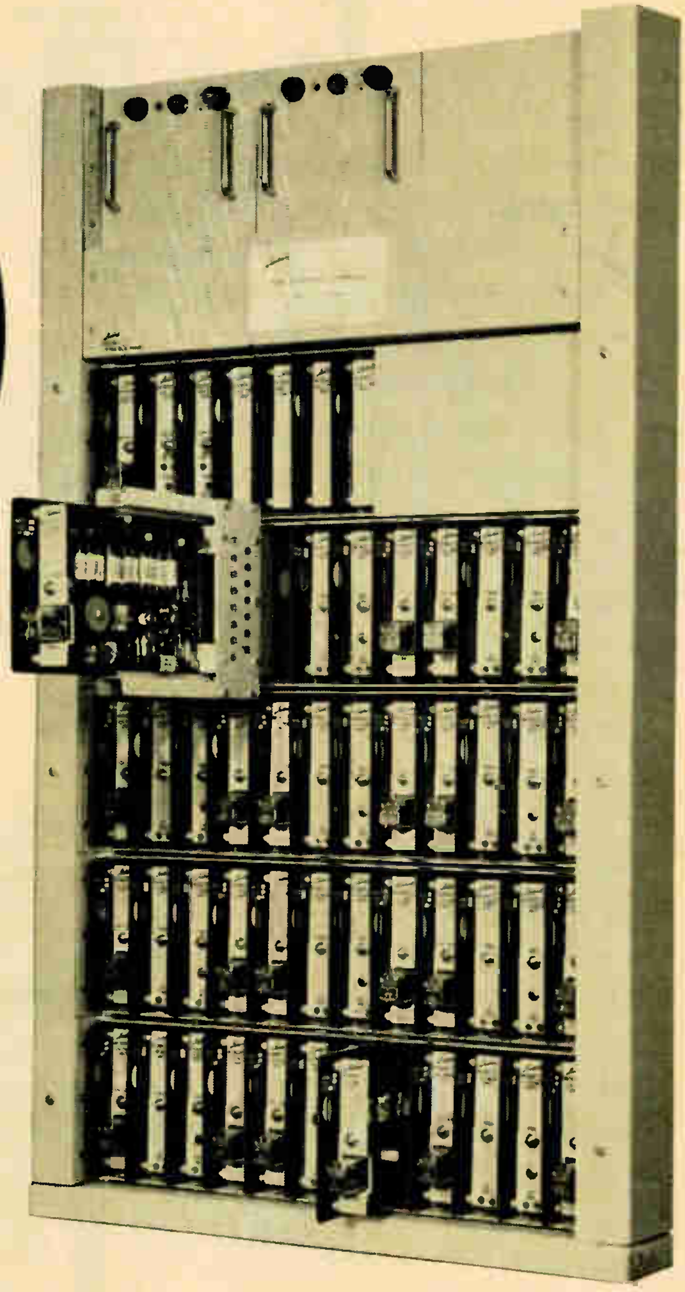
The Sound Equipment Engineering Committee of the Electronics Division is preparing an informative handbook for architects and engineers which will examine why. when, where and how sound systems should be used.

Chairman of the Committee is R. H. Tanner, Northern Electric Company Limited, Ottawa, one of the foremost sound engineers in the country.

The handbook will outline the reasons for using sound systems, the times and places where they should be used and some of the basic design factors which will assist architects, consulting engineers and others in assuring that the best and least obtrusive results will be obtained.

LENKURT . . . *recognized leader in telecommunication systems • carrier • microwave • data and telegraph • supervision and control • military electronics*

34A CARRIER SYSTEM



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LENKURT ELECTRIC

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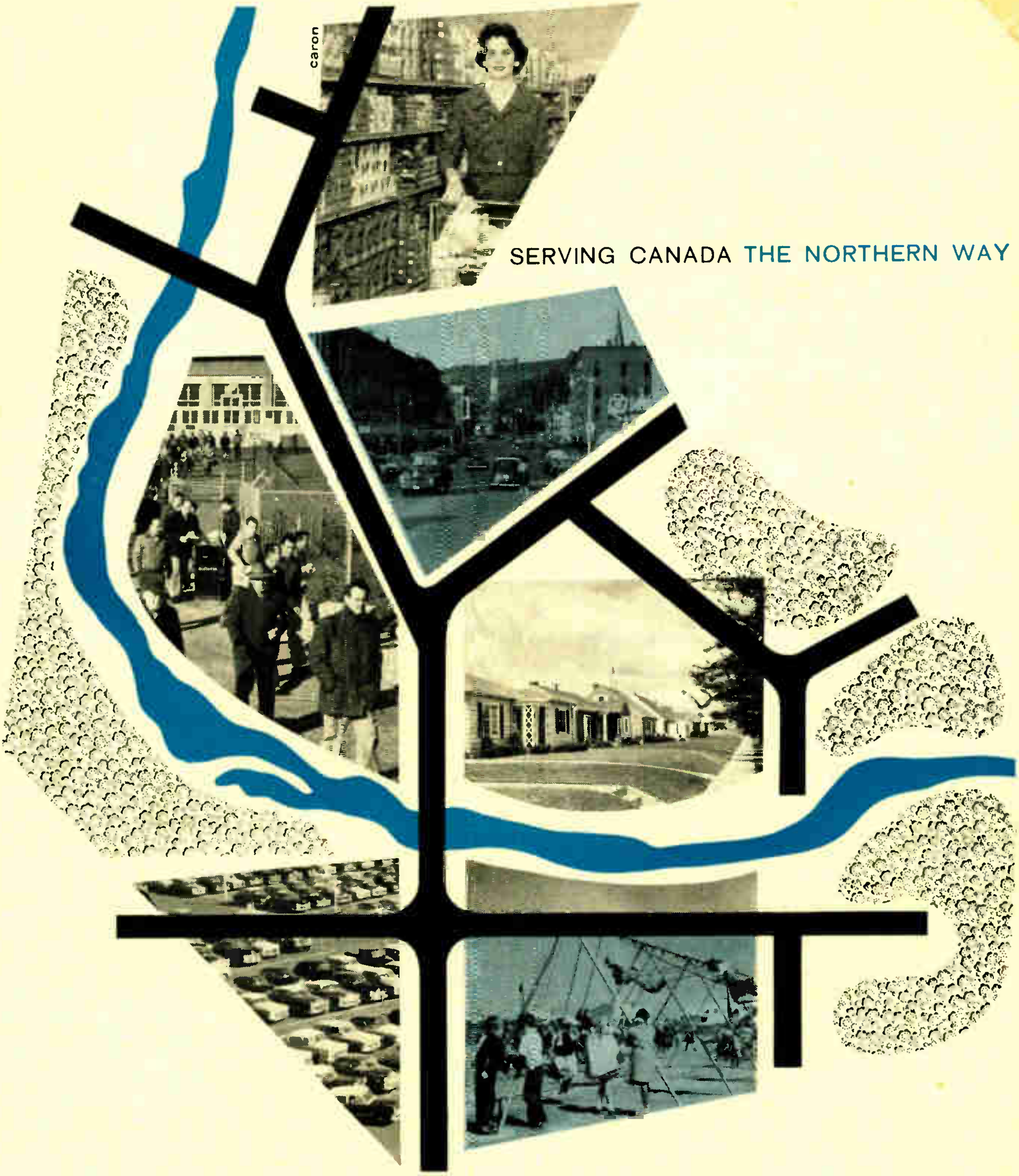
For complete details check No. 23 on handy card, page 69



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15,000 Northern People . . . individuals all with different personalities . . . different lives . . . holding various positions . . . making numerous products . . . but all linked together by a common bond as a member of the Northern Electric family, in the design, manufacture, and installation of a large proportion of Canada's telephone communication systems and equipment. ▒ They produce all types of electrical wire and cable for communication and power transmission, and distribute a complete line of electrical apparatus and supplies. ▒ At Northern Electric, product research and development never stops, and continuing progress is made in the communication, electrical wire and cable fields.

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COMPANY LIMITED

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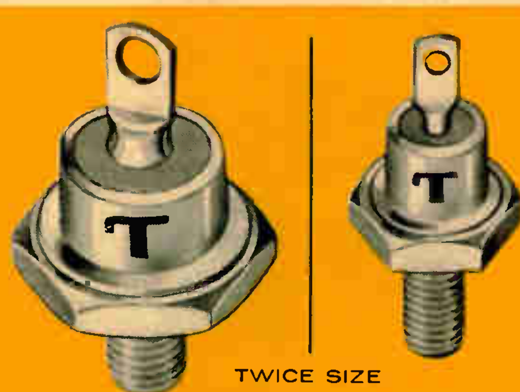
Transitron's EXCLUSIVE

HEATLESS SEAL RECTIFIERS



This new line of heatless seal silicon rectifiers by Transitron, the originator of the silicon rectifier, brings to the electronic industry a notable new advance in the state of the art.

The reliability of internal rectifier junctions is now further enhanced because no heat is used to seal the packages. Cap and base are joined by the "cold flow" of copper into steel as the parts are forced together under high pressure. Rectifier junctions are no longer exposed to contamination by the sputtering or splashing of molten metals or by flux fumes and gases, weld flashes, or hot sparks. Therefore the new process creates the most reliable hermetic seal yet attained in silicon rectifiers. Consequently heatless seal rectifiers meet or exceed all required military and industrial tests for moisture resistance and hermeticity. Four series now in quantity production are available for immediate delivery.

For further information, write for bulletins indicated in the chart at right.

SERIES TYPE	PEAK INVERSE VOLTAGE (VOLTS)										BULLETIN NUMBER
	50	100	150	200	250	300	350	400	500	600	
3 AMP TYPES	1N1581 (TM7)	1N1582 (TM17)		1N1583 (TM27)		1N1584 (TM37)		1N1585 (TM47)	1N1586 (TM57)	1N1587 (TM67)	TE-1351F
20 AMP TYPES	1N248A	1N249A	TR152	1N250A	TR252	TR302	TR352	TR402	TR502	TR602	TE-1351K
35 AMP TYPES	TR53	TR103	TR153	TR203	TR253	TR303	TR353	TR403	TR503	TR603	TE-1351K-1
MILITARY TYPES		1N253		1N254				1N255		1N256	TE-1336

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Canadian **R**adio **T**echnical **P**lanning **B**oard newsletter

by R. C. Poulter

17th Annual Meeting Again Elects Officers Frank Pounsett Returned as President

F. H. R. Pounsett, Philips Electronics Industries Limited, Toronto, was re-elected President of the Planning Board at the 17th Annual Meeting held recently in Ottawa's Chateau Laurier Hotel.

Many of the country's top scientists and engineers, representing every facet of communications services and equipment manufacture, attended the one-day forum. They heard F. G. Nixon, Director of Telecommunications and Electronics in the Department of Transport, discuss Canada's role in the future of space radiocommunication by passive and active satellites and of the country's interest in the work of the CCIR, the ITU's Consultative Committee on International Radio.

Besides reporting on a heavy list of projects completed throughout the year the delegates laid out an impressive program of work for 1962. Planning for Canada's part in the future use of the radio spectrum, the space radiocommunication question and a serious appraisal of frequency tolerances and methods of measurement are just some of the many projects to be undertaken by the various committees of the Board in the coming year.

Technical Coordinator Sees Expanding Need For Frequencies

In his annual report to the Board, the Technical Coordinator, Ralph A. Hackbusch says there is a continuing need for more allocations for new and expanded communication services. Some of the additional requirements must come from designs of equipment and systems which require less spectrum space such as was the case in split channelling for the Land Mobile Service. "Other approaches appear to reside in the use of Single Sideband equipment for some services," Mr. Hackbusch said.

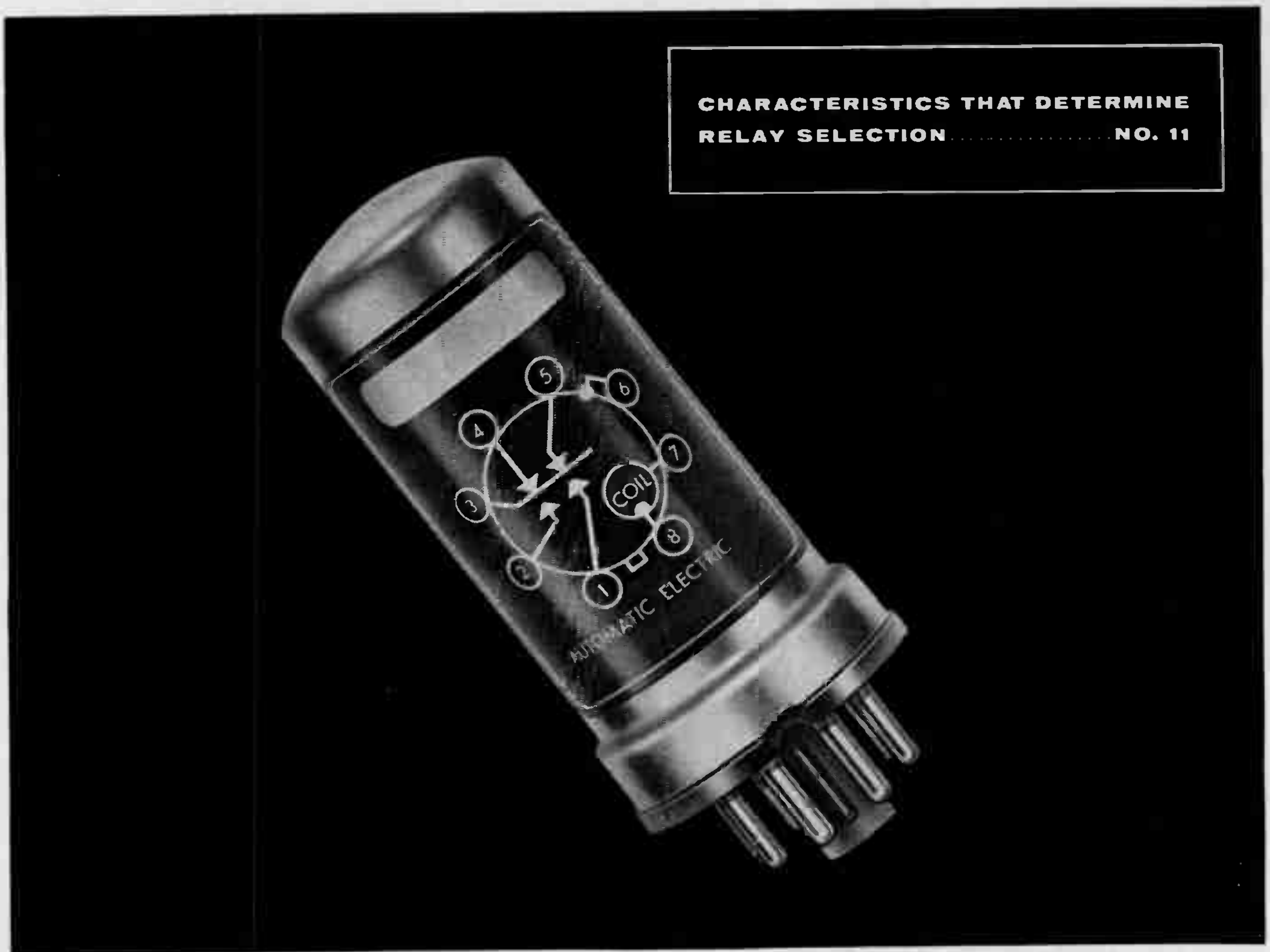
In order to provide communication systems occupying less channel space, and to provide reliable systems performance, there is a need to have a systems concept or a systems specification which will provide a basis for preparing the specifications for the transmission and reception equipment which will be type-approved, or which will have type-acceptance to operate under license granted by the Department of Transport to the user. A report on the activities of a special committee set up to study the problems in this area was made by the Vice-President, C. J. Bridgeland.

President Reports on Spectrum Utilization

In his report to the Board President Pounsett said that it was clearly indicated at the last Annual Meeting that the Board should direct its attention more towards matters of efficient spectrum utilization and place less emphasis on detailed specifications. He outlined the steps which the Executive Committee has taken to accomplish this.

He pointed out that at a meeting of the Standards and Allocations Committee held early in the year a general review was made of the status of frequency requirements in the various fields and since then several committees and sponsors have prepared reports or briefs which will be coordinated and rationalized where necessary at forthcoming meetings. It has become evident in connection with this activity that the presently active committees do not represent completely the interests in radio frequency requirements of all of the Sponsors of the Board, nor of the public at large and it is therefore advisable to reactivate the General Utilities and Public Service Committee. The membership in this committee is now being finalized and the first meeting should be called shortly, Mr. Pounsett reported.

Continued on page 77



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Because of its unique construction, the new Class V requires no maintenance whatsoever. Contact and armature assemblies are hermetically sealed in a glass capsule with a high pressure hydrogen atmosphere, and mercury wetting renews the contacts continuously, eliminating both wear and welding problems. The relay is wax-potted and enclosed in a rugged steel cover. With its standard octal plug it can be installed in seconds.

If you would like further details, call or write Automatic Electric Sales (Canada) Limited, 185 Bartley Drive, Toronto, Ontario. Branches across Canada.

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For complete details check No. 36 on handy card, page 69

the industry's business

Improved economic conditions stimulate TV sale rise

Television sales in 1961 continued ahead of same period in 1960, said F. W. Radcliffe, general manager, Electronic Industries Association of Canada.

At October 31, 1961, the increase for the 10 months compared to same period in 1960 was 1.7 per cent — 232,765 units vs. 228,734. This as reported by Receiver Division members. Improved economic conditions have stimulated trading-in old models. The replacement market has definitely opened up. October saw increased demand for portable TV's and radio-TV phonograph distributor sales to dealers were at an all time high.

Inventories at factory and distributor levels continue to show decreases — down 23.4 per cent for the EIA member group compared to October 31, 1960. Inventory shortages of many models were reported.

Many manufacturers of commercial and industrial electronic equipment report substantial contracts secured and sales increases over last year. There is a real shortage of engineers and trained technicians in this section of the industry.

The Federal Government's plans to assist in Industrial Research are most encouraging and will provide the Electronics Industry with the stimulus to develop the products required to sustain increased future employment and production.

Hewlett-Packard establishes new Canadian subsidiary

Due to the rapid growth of the Hewlett-Packard product line and the increasing demand for their products in Canada, the company is establishing a new subsidiary to be known as Hewlett-Packard (Canada) Ltd. Beginning January 1, 1962, this subsidiary will handle the sale of all test instruments in Canada.

The new Canadian subsidiary will be fully staffed by Hewlett-Packard sales engineering and service personnel recruited in Canada. The company's principal office, warehouse and service facility will be in Montreal. For added convenience, there will also be branch offices in Toronto and Ottawa.

Canadian industry to benefit from joint development program

A joint development program by Westinghouse Electric Corporation and the Remington-Rand Division of Sperry-Rand Corporation will give Canadian industry the benefits of new and improved control systems.

For the past several years, Canadian Westinghouse has been actively engaged in local development work which has produced controls specifically for the Canadian market based on original Westinghouse Electric Corporation design.

"The new joint development program brings to bear on manufacturing process problems the combined experience and abilities of three organizations and will result in an advanced line of modern control systems. Our liaison with the American study teams has already begun," said H. N. Muller, vice-president of Canadian Westinghouse.

Under the joint agreement, Remington-Rand through its Univac division and Westinghouse will develop an entirely new and advanced line of computers for the process control field, which will combine industrial and business data processing systems. Both companies will continue independent research in their specific fields.

200 classroom TV receivers installed in Metro schools

A television receiver specially designed for the schoolroom has been developed by Canadian Admiral Corporation and nearly 200 are now in use in Metropolitan Toronto schools.

The Boards of Education of the City of Toronto and neighboring North York have installed the new sets in local schools.

Special features not found in home TV include two half-doors which serve as light shields when open and permit locking the set when closed. The closing of the doors automatically shuts off the receiver. The classroom set features the latest wide-angle 23-inch bonded picture tube with safety glass bonded directly to the tube faceplate, thus reducing glare and reflection and increasing contrast. A polished chrome tubular steel stand raises the receiver to proper viewing height for the class.

RCAF receives first emergency transceiver from Collins Radio

First of the Collins UHF Emergency Transceivers for the CF-104 Super Starfighter was delivered recently to Air Vice-Marshal C. L. Annis, Air Officer Commanding Air Materiel Command. He accepted the AN/ARC-504 at the Toronto plant of Collins Radio Company of Canada Ltd., where the unit was designed and manufactured.

D. B. Mundy, director of the Electronics Branch of the Department of Defense Production and J. L. Plant, Collins Canada Vice-President and General Manager, were present as A.I.O. Davies, Collins Canada Director of Sales, delivered the unit, 11 days ahead of schedule The production contract for 250 AN/ARC-504 transceivers will be completed by July 1962.

Shown accepting the first of Collins Canada emergency UHF transceivers for the CF-104 Super Starfighter is Air Vice Marshal C. L. Annis, Air Officer Commanding Air Materiel Command. A. I. O. Davies, director of sales for Collins Canada, presents the unit. At left, D. B. Mundy, director of the Electronics Branch of the Department of Defense Production, and at right, J. L. Plant, Collins Canada vice-president and general manager, look on.

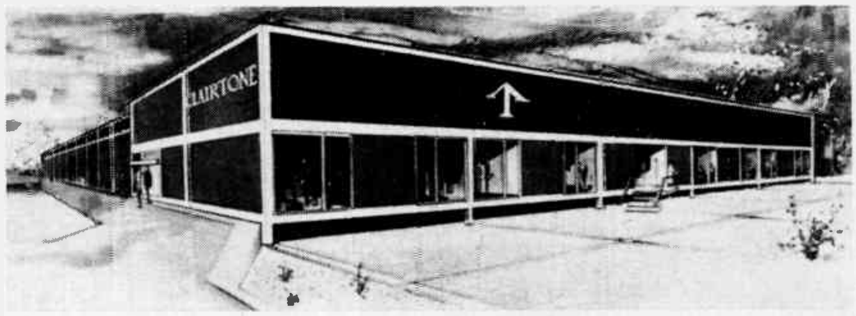
Clairtone triples sales and expands to larger plant facilities

Clairtone Sound Corp. Ltd., Toronto, reports that total sales from January to August, 1961, were more than triple those of the similar eight-month period in 1960.

Sales rose from $422,746 to $1,396,-772 and are expected to be between $3½ to $4 million by the end of 1961, Peter M. Munk, President, announced.

"Clairtone is now the largest selling name in stereo hi-fi on the Canadian market, and by far the best-selling Canadian line in the United States," Mr. Munk said. U.S. sales, which currently make up approximately ⅓ of the total volume, will probably equal or exceed Canadian sales within the next year or two, he predicted

A result of the company's success is the fact that it has considerably outgrown its present facilities and is now having a new plant built on Ronson Drive (just above Highway 401 in Etobicoke Township, Toronto).

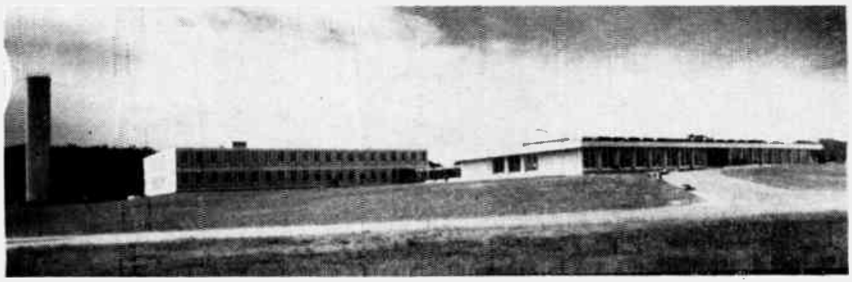


Styled and planned for Clairtone by designer Hugh Spencer, this $500,000 building will have 80,000 square feet of floor area when completed.

Northern Electric opens R & D laboratory

On November 13, 1961, the new home of Northern Electric's Research and Development Laboratories was officially opened by Dr. C. J. Mackenzie, CMG, MC, DSc., FRS.

This new research laboratory, in which "snow white" environmental conditions are maintained, is situated in a garden in Ottawa's green belt, two miles west of the city, on Highway No. 17.



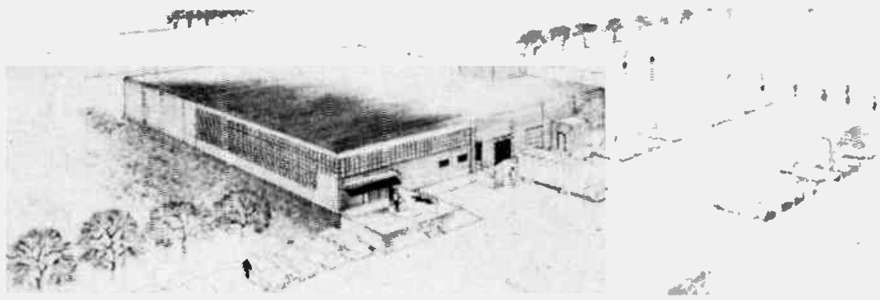
Northern Electric's new Research and Development Laboratories are located on Highway 17 near Ottawa.

Andrew Antenna expands manufacturing facilities

Andrew Antenna Corp. Ltd. announced the expansion of manufacturing facilities in Whitby, Ontario, to provide a complete line of antennas and transmission lines for the Canadian antenna system market from one integrated Canadian manufacturer.

The new factory and office area, more than four times larger than the previous area, will allow shipment from stock for standard products as well as fast, economical production of special, non-standard components. New products, such as large aluminum waveguide and parabolic antennas larger than 10 feet in diameter, will be fabricated in Canada for the first time.

Additions to test facilities now allow pre-production and production testing of components in all commercial bands including the 7 KMC microwave band. Inspection procedures instituted to meet military quality requirements insure continuing quality improvement for commercial components.

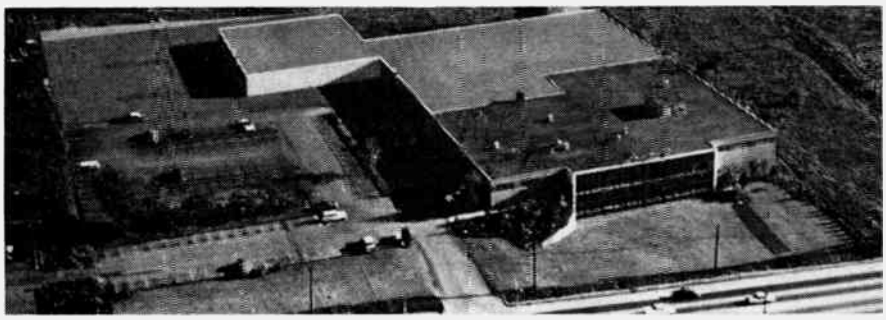


Andrew Antenna Corporation Ltd. expanded their facilities with this new factory in Whitby, Ontario.

Lenkurt expands production facilities to meet growing market

For the second time since their move to Burnaby in 1956, Lenkurt Electric Co. of Canada, Ltd., a subsidiary of General Telephone and Electronics International Inc., is expanding its factory and offices to accommodate increased production requirements.

Land has been levelled, foundations poured, and actual construction is forging ahead on the 40,000 sq. ft., addition that will bring the total building area to 74,000 sq. ft. With completion scheduled for early in the new year Lenkurt will have increased facilities to meet the growing competition in both the Canadian and International markets.



Lenkurt Electric's new accommodations provide an area of 74,000 square feet for company expansion.

Continued on page 61

NEW LOW-NULL MOTOR GENERATORS

NOW MADE IN CANADA BY DAYSTROM!

Daystrom has whittled the null output voltages of its Size 9 and 11 Motor Generators down to a slim 0.003 and 0.006 respectively. Signal to noise ratio gets a big boost up to 120:1 for Size 9 and 100:1 for Size 11. Linearity is within .25%. A wide range of gear ratios can be furnished.

Complete specifications with drawings and charts are yours for the asking. Other types and sizes of motor and motor generators are also available. And be sure to get complete details on our new synchro line.

For more information, call or write Daystrom Limited, 1480 Dundas Highway E., Cooksville, Ontario; 5430 Ferrier Street, Montreal 9, Quebec. A subsidiary of Daystrom, Incorporated.

CANADIAN PLANT—COOKSVILLE, ONT.

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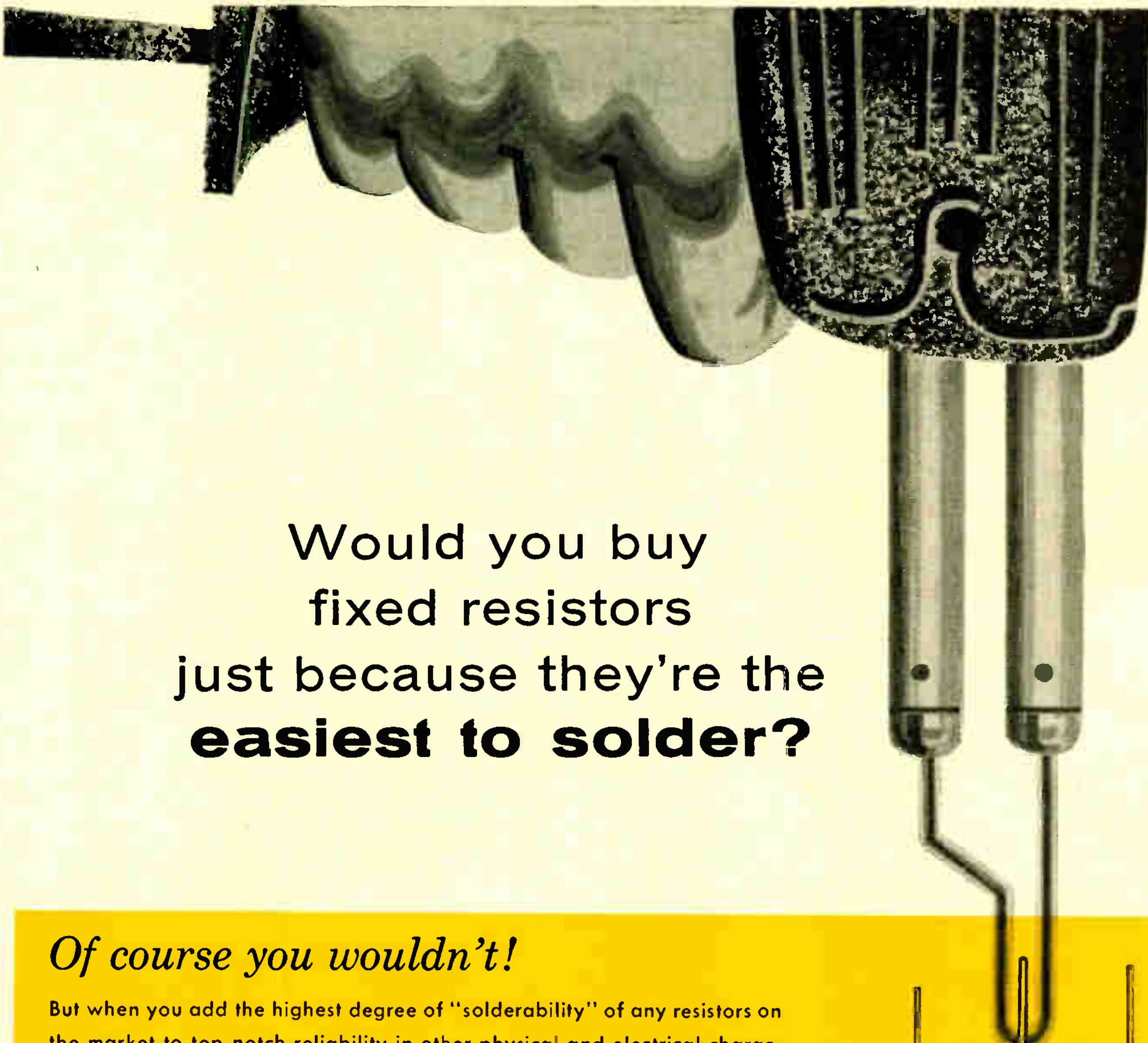
WORLD LEADERS IN MEASUREMENT AND CONTROL

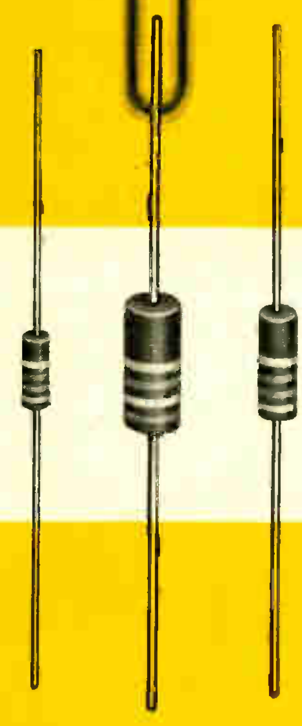
For complete details check No. 14 on handy card, page 69



Would you buy fixed resistors just because they're the **easiest to solder?**

Of course you wouldn't!

But when you add the highest degree of "solderability" of any resistors on the market to top-notch reliability in other physical and electrical characteristics — well, that's something else. Like a lot of other cost-conscious producers, you'll then be using Stackpole Coldite 70+ Resistors!



Stackpole Coldite 70+ "solderability" saves time and money in your production. It assures perfect connections that eliminate a lot of possibilities for costly field service later on.

Coldite 70+ performance fully matches the "solderability" of the leads. They're designed to meet or excel MIL-R-11 in every respect. And they're tops in load life, humidity and moisture tests!

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Coldite 70+®

fixed composition resistors

CERAMAG® FERRITE CORES • VARIABLE COMPOSITION RESISTORS • SLIDE & SNAP SWITCHES • CERAMAGNET® CERAMIC MAGNETS • FIXED COMPOSITION CAPACITORS BRUSHES FOR ALL ROTATING ELECTRICAL EQUIPMENT • ELECTRICAL CONTACTS GRAPHITE BEARINGS, SEAL RINGS, ANODES • HUNDREDS OF RELATED CARBON & GRAPHITE PRODUCTS.

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COLLINS MICROWAVE AND CARRIER . . .

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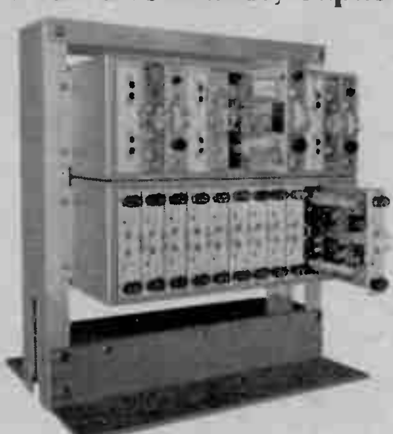


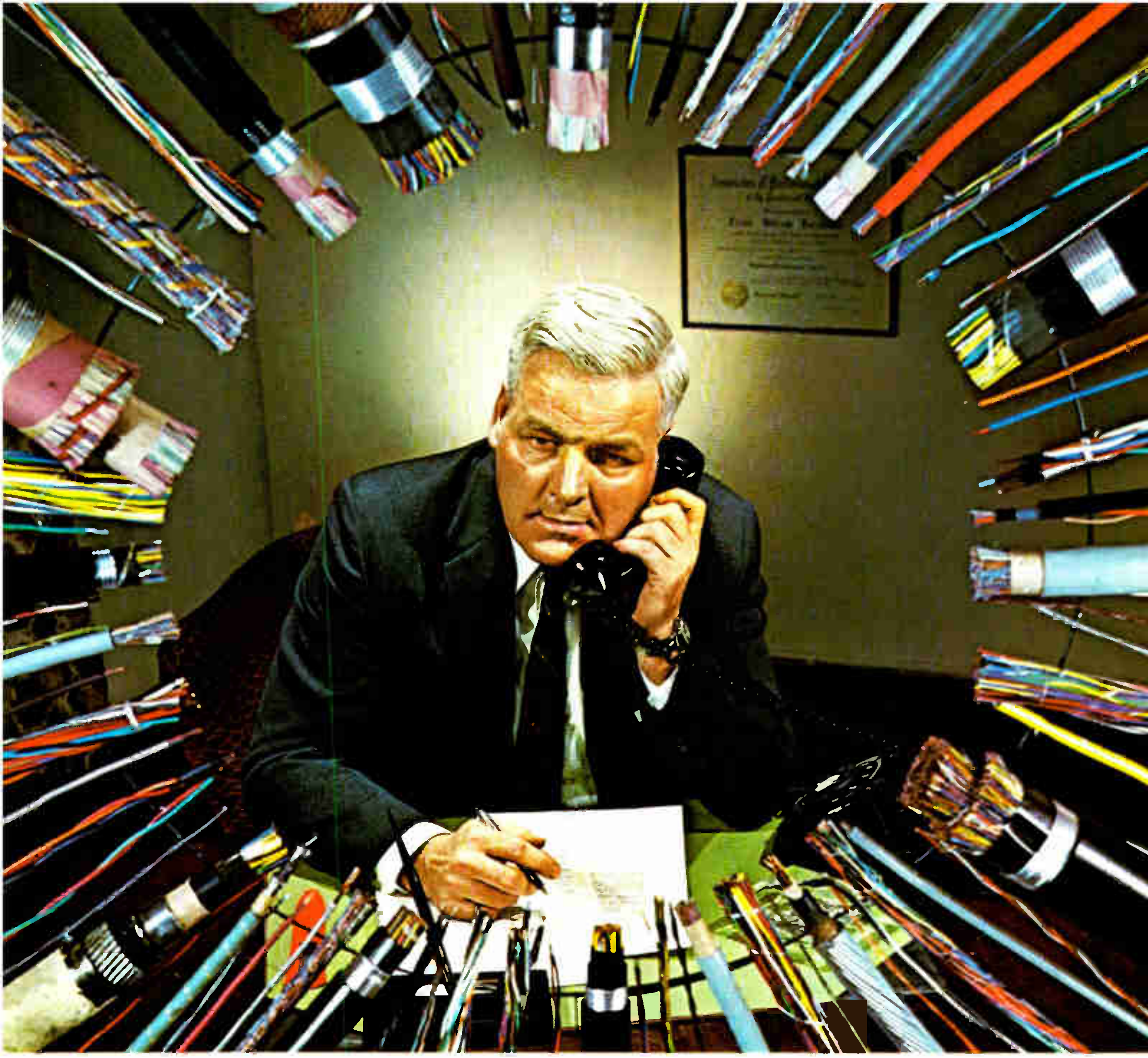
Collins MX-106 Transistorized Carrier, combined with Collins microwave RF equipment, offers the flexibility, channel capacity and long-hop capability needed to meet the most exacting microwave/carrier requirements. The MX-106, incorporating the high reliability inherent in transistorized equipment with a saving of up to 90% in power consumption, provides up to 600 toll-quality voice channels. With up to five watts output from Collins RF equipment, it delivers all the capability you need for long-haul systems across miles of rugged terrain.

Take advantage of as much — or as little — of this capacity as you need in custom tailoring a microwave/carrier system to your particular needs. With Collins microwave, you can start with a few channels, then easily and economically expand your system to meet any changing requirements — including those for high-speed data and TV transmission. Options include both space and frequency diversity.

For further information and technical literature, contact Collins Radio Company of Canada, Ltd., 11 Bermondsey Road, Toronto, Ontario.

COLLINS

For complete details check No. 11 on handy card, page 69



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stands the existing network of specialized wires and cables that feeds the modern telephone system. The functioning of the entire complex depends upon the reliability of this wide range of conductors.

Almost as old as the communications industry it serves, Phillips has the experience, the manufacturing facilities and the advanced technical knowledge necessary to produce telephone wires and cables that are second to none!

Phillips Electrical Company Limited, Head Office—Brockville, Ontario. Branches—Halifax, Montreal, Ottawa, Toronto, Hamilton, Winnipeg, Edmonton, Vancouver. The Canadian affiliate of the BICC Group. Phillips Telephone Wires & Cables are also distributed in Canada by Automatic Electric Sales (Canada) Limited.

Phillips Electrical Company LIMITED

WIRES CABLES

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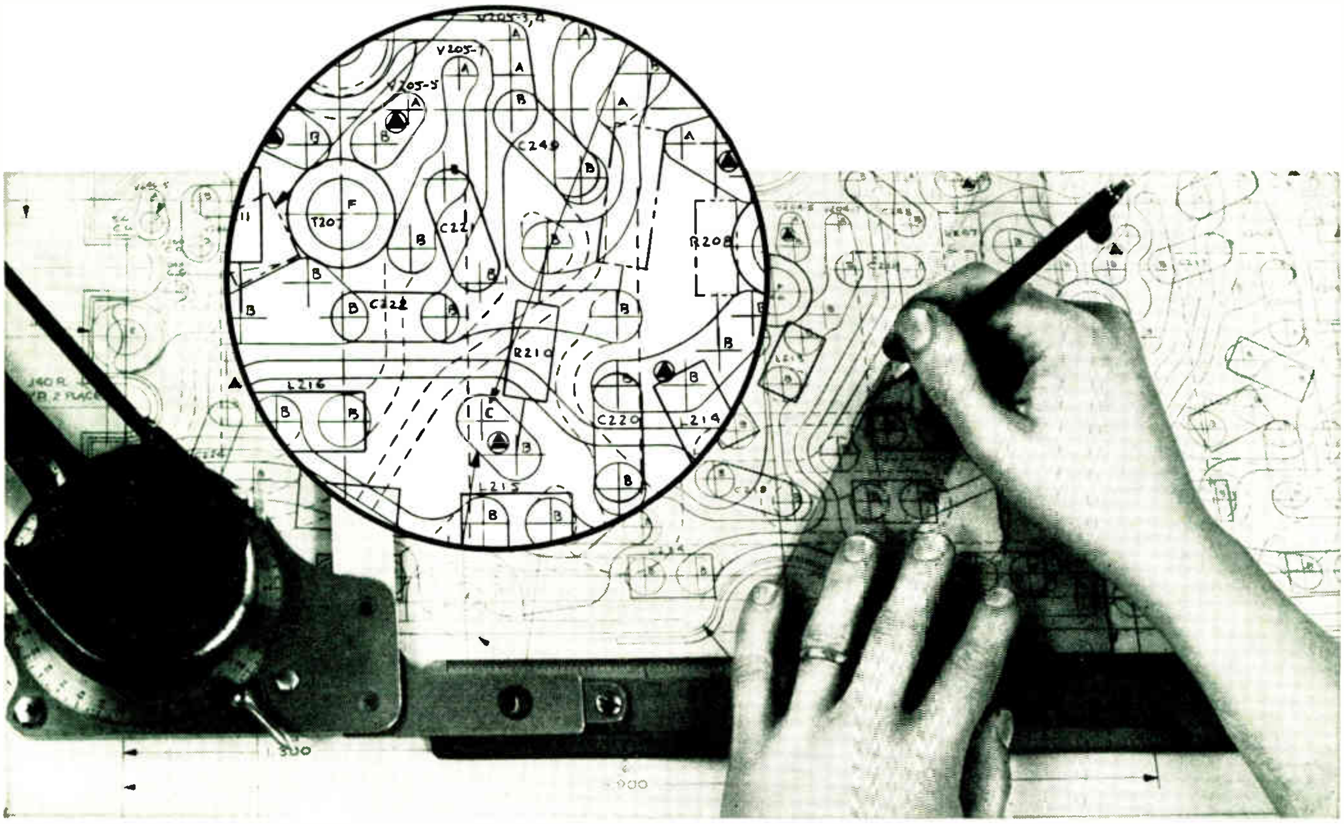

Designer drafts master layout of printed circuit design on dimensionally stable CRONAFLEX. Inset shows detail: solid lines indicate circuitry on component side of board; broken lines, circuitry on reverse side.

At Bendix-Pacific...

CRONAFLEX* *CUTS COSTS,* *SPEEDS PREPARATION OF PRINTED CIRCUITS*

Versatile CRONAFLEX Engineering Reproduction and Drafting Films have made possible a new, simplified method of preparing printed circuits at Bendix Corporation's Bendix-Pacific Division. Not only has it proven much more efficient and economical, it also assures uniform quality of finished boards and steps up the entire production cycle.

Commenting on the procedure, Edward E. Benjamin, Methods and Design Standards Engineer, says: "CRONAFLEX lets us do a better, faster job, at lower cost, all along the line. For master layouts, where basic design begins, CRONAFLEX Drafting Film is ideal. It holds its size under varying temperature and humidity conditions, takes erasures and handling without damage, and has a far superior matte surface.

"From the master layout we make our master transparency, machine board drawing and assembly board drawing, using CRONAFLEX Direct Positive. Here again results are phenomenal. In the assembly drawing alone, for example. we've cut drafting time from 3-5 days to 4-8 *hours!* Add to this elimination of the negative step, fast printback and excellent halftone quality, and you'll see why we're sold on CRONAFLEX!"

For a FREE booklet that describes this new method in detail, plus information on the many ways CRONAFLEX can help *your* firm cut costs and increase efficiency, clip and mail this handy coupon *now.*

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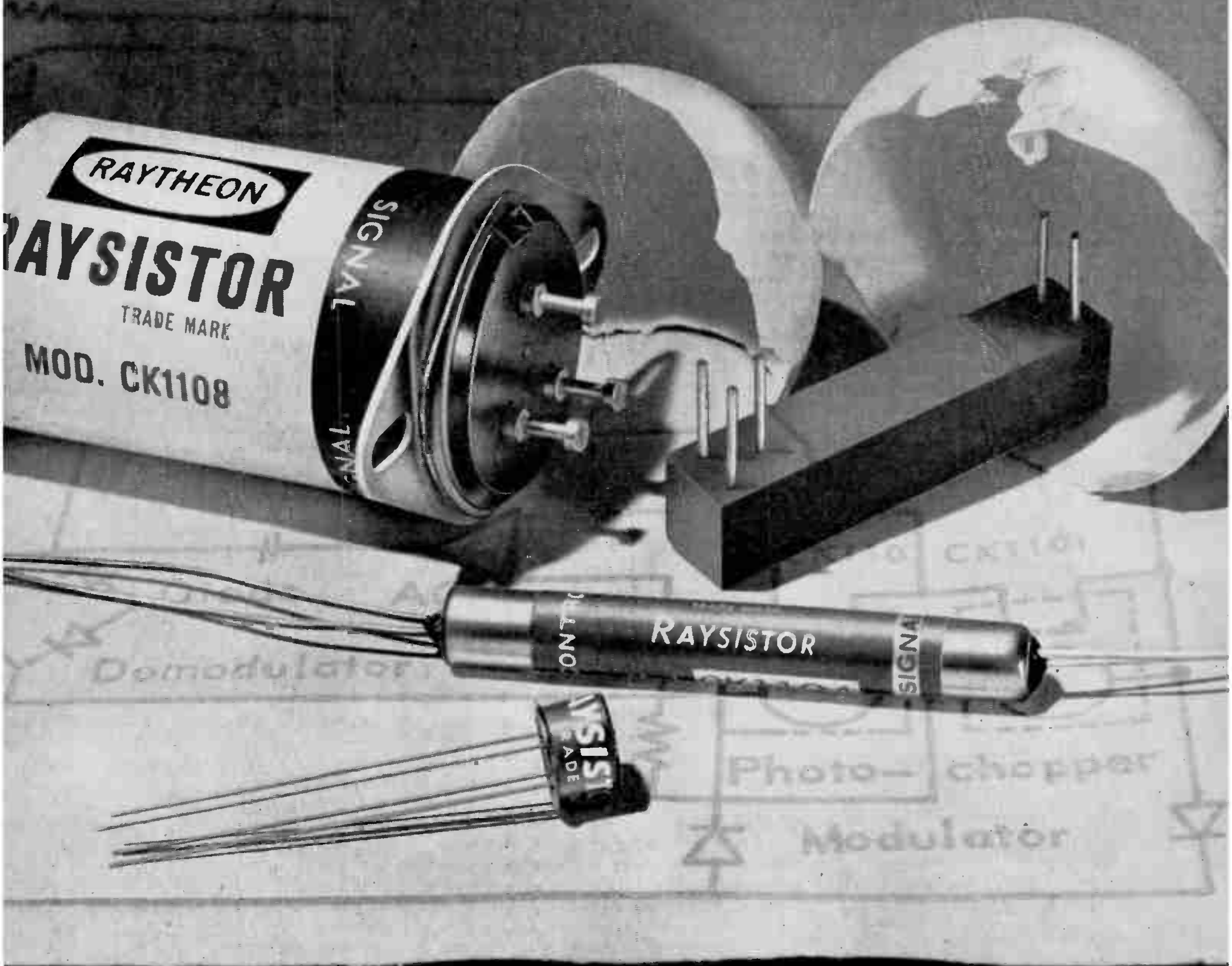
BETTER THINGS FOR BETTER LIVING ... *THROUGH CHEMISTRY*

For complete details check No. 16 on handy card, page 69

NEW products from RAYTHEON



...hatch a new design

Looking for new ideas? New Raytheon Raysistors® may be the components you need to spark a new design or solve a circuit problem.

Raysistors are four terminal circuit components. They consist of a light source and photocell assembled in a light-tight casing. When the input to the light source is varied, the photocell resistance changes — without electrical connection between the light source and photocell, *and* without moving parts. The result: low noise pedestal-free switching of AC or DC signals over a wide dynamic range without transients, contact or wiper chatter.

Raysistors come in a wide range of types: standard, printed circuit, miniature, high voltage. They are ideal for use as relays, potentiometers, choppers and isolation for high voltages. For complete technical data, please write: Raytheon Canada Limited, Commercial Sales Division, Waterloo, Ontario.

RAYTHEON CANADA
LIMITED

WATERLOO, ONTARIO

RAYTHEON

For complete details check No. 30 on handy card, page 69

industry personnel


R. F. Russell


S. R. Harling


A. G. Temple


D. Reynolds


L. A. Borth


W. F. Haehnel


W. Wallace


W. P. Tobias

Eight appointments at Litton announced

Litton Systems (Canada) Limited has announced the following appointments:

R. F. Russell as procurement manager, **S. R. Harling** as material controller, **L. A. Borth** as engineering manager, **W. F. Haehnel** as systems test manager, **A. G. Temple** as production manager, Electro-Mechanical, **W. Wallace** as quality control manager, **D. Reynolds** as plant services manager and **W. P. Tobias** as chief accountant.

Mr. Russell was educated in England and has had 15 years purchasing experience.

Mr. Harling was also educated in England and has had 12 years experience in production and material control activities.

Mr. Borth, a graduate of Queen's University and the University of Toronto, has 14 years experience in the electronics development field.

Mr. Haehnel, a graduate of the University of Toronto, has served on the engineering staff of U. of T. and has 10 years experience in the electronics development field.

Mr. Temple received a technical education in England and has 15 years experience in the manufacture of precision instruments.

Mr. Wallace received a technical education in Scotland and has held managerial positions in the quality control field for the past 10 years.

Mr. Reynolds is a graduate of St. Andrews University, Scotland (BSc.). He was formerly employed by Avro Aircraft Limited as assistant service manager.

Mr. Tobias is a graduate of the U. of T. (B. Comm.) and a Certified Public Accountant.

Whiteley joins Lynch Communications

John T. Whiteley has joined the engineering staff at Lynch Communication Systems Inc. and will be engaged primarily in product and modification engineering. Mr. Whiteley was formerly with the British Columbia Telephone Company in Vancouver, British Columbia. Prior to that he was with the Associated Electrical Ind. Ltd. in London, England, for three years and on the Fraser River Board in Victor, British Columbia. He received his Bachelor of Applied Science in Electrical Engineering at the University of British Columbia.

Currie receives director's post in U.S.

G. Barron Mallory, President of P. R. Mallory & Co. Inc., announced the appointment of **Robert A. Currie** to the newly established post of Director of Public Relations, effective November 6. Mr. Currie's offices will be at the Mallory Company's headquarters in Indianapolis.

Mr. Currie was with the Bell Telephone System in both the United States and Canada for more than 10 years, and recently he has administered a large part of the New York Telephone Company's state-wide

Sola Basic Products names manufacturing manager

Reginald B. Bozek has been named manufacturing manager of Sola-Basic Products, Ltd., Toronto, Ont. Mr. Bozek will be responsible for all phases of production and engineering. The new manufacturing manager, 31, had been production manager of Oki & Willadsen, Ltd., since 1959 and had previously been chief engineer for Coldstream Refrigerator Manufacturing Co. of Winnipeg. A graduate of the University of Saskatchewan, Bozek holds the bachelor of science degree in electrical engineering and has studied in the field of business management.

Eight businessmen elected to Board of Governors

The Hon. Robert Macaulay, Q.C., Minister, Department of Economics and Development, announced recently the appointment of eight prominent Ontario businessmen to the Board of Governors of the Ontario Research Foundation.

The appointments include: **E. H. Ainley,** Treasurer, National Trust Company Ltd.; **J. D. Barrington,** President, McIntyre Mines; **Paul McNamara,** President, Federal Equipment of Canada Ltd.; **W. F. McLean,** President, Canada Packers Ltd.; **C. A. Pollock,** President, Dominion Electrohome Industries Ltd.; **E. R. Rowzee,** President, Polymer Corporation Ltd.; **V. W. T. Scully,** President, The Steel Company of Canada Ltd. and **W. O. Twaits,** President, Imperial Oil Ltd.

The foregoing appointments announced by Mr. Macaulay will bring the Board to maximum statutory figure of 25 members drawn from science and industry.

Hill becomes marketing manager for Can. Westinghouse

The appointment of **Edward W. Hill** as marketing manager for the Canadian Westinghouse Switchgear and Control division has been announced. His previous post was manager of the company's Utility Department. Mr. Hill joined Westinghouse in 1948, following graduation from the University of Toronto.

Hewlett-Packard forms Canadian sales company

Hewlett-Packard Company recently announced the formation of a Canadian sales company to handle the sale of Hewlett-Packard products in Canada.

The new company, Hewlett-Packard (Canada) Ltd., will have its principal office, warehouse and service facility in Montreal with branch offices in Ottawa and Toronto. It began operations January 1, according to **W. Noel Eldred,** Hewlett-Packard's vice-president of marketing.

Mr. Eldred also announced that **Ralph Haywood** has been appointed manager of Hewlett-Packard (Canada) Ltd.

Haywood was formerly eastern regional manager of R-O-R Associates, a Canadian electronic sales representative firm. Prior to joining R-O-R Associates in 1955, he was with the research and development staff of RCA Victor in Montreal. He is an electrical engineering graduate of the University of Manitoba in Winnipeg.

S. Parsons

P. Dernick

R. C. Enright

R. Haywood

Enright added to Deskin staff

A. Deskin Sales Corp. have announced the addition of **R. C. (Bob) Enright** to their sales staff. Mr. Enright has spent the last 10 years in the Industry at Philips Electronics, Canadian Arsenals, and most recently with Cannon Electric. He will be servicing all accounts in the Southern Ontario area and brings with him a wealth of knowledge in the electronic component field.

In line with this announcement Deskin Sales Corp. would like to point out that they are now located at 3180 St. Clair Ave. E., Scarborough.

Dernick named division manager

Peter Dernick, P.Eng., was appointed manager of the Computer & Data Processing Divison of Instronics Limited. Mr. Dernick has had many years of experience in the digital computer field with Computing Devices of Canada.

Former Canadian engineer appointed to U.S. firm

Appointment of **Stuart Parsons** to the post of general manager and member on board of directors for Remanco, Inc., Santa Monica, California, manufacturer of dynamic radar simulators and microwave test equipment, was announced by Ronald W. Ryall, president.

Parsons formerly was associated with Litton Systems, Inc. of Woodland Hills, Calif. as director, applications engineering — Guidance and Control Systems division; Computing Devices of Canada, Ottawa, Canada, as vice-president. engineering; and with the National Research Council of Canada, Ottawa, Ontario, as radar development engineer.

A graduate of the University of Saskatchewan where he received a degree in physics, Parsons is also a member of the Institute of Aerospace Sciences and the Institute of Navigation.

Instrument Division manager announced

A. Cameron (MIRE) was named manager of the Instrument Division of Instronics Limited. Mr. Cameron has extensive experience with the Defense Research Board as a technical officer. He has joined Instronics Limited from the Prince Albert Radar Laboratory of DRB, where he was responsible for much of the operation and maintenance.

Raytheon names Gates as manager

Robert E. Gates of Franklin, Mass., has been named manager, Field Application Engineering for Raytheon Company's Industrial Components Division. Mr. Gates will direct application engineering services for the division's industrial and military end-use customers.

Before joining the division's engineering department in 959, Mr. Gates was plant engineer for Sylvania Electric (Canada) Limited and application engineer for Radio Valve Company of Canada. A native of Fort William, Ontario, he served in the Royal Canadian Air Force during World War II. He received a Bachelor of Applied Science degree in engineering physics from University of Toronto.

Bentob joins Andrew staff

Meyer T. Bentob has joined the sales engineering staff of Andrew Antenna Corporation, Ltd., Whitby, Ontario, as an applications engineer. Mr. Bentob, formerly of Canadian-Marconi Company, has had wide experience in antenna system design and development work, both in England and Canada. He will temporarily headquarter in Montreal and serve Andrew customers in the Montreal-Ottawa areas.

Hind heads Edo (Canada) Ltd.

Ralph R. Hind was elected president of Edo (Canada) Ltd., Cornwall, Ont., at a meeting of the board of directors. He succeeds Archibald M. Brown, who was elected chairman of the board.

Mr. Hind has been vice-president and general manager of Edo (Canada) Ltd. since the founding of the firm in 1957. A native of Weyburn, Sask., he studied engineering at Rutherford College in England and served as an officer in the Royal Canadian Navy for 17 years before joining this company.

R. E. Gates

R. R. Hind

A. Cameron

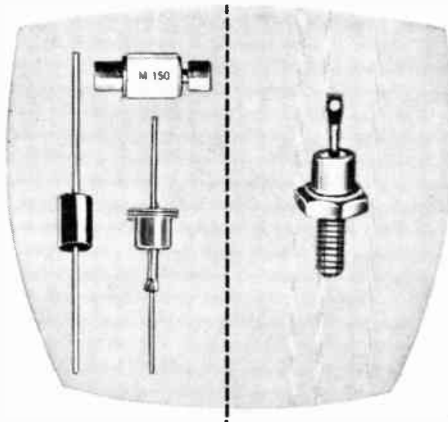
P. S. Moric

Supplies sales rep for Automatic Electric

Paul S. Moric was appointed sales representative — Supplies Products serving the Province of Alberta for Automatic Electric Sales (Canada) Limited. Mr. Moric joined Automatic Electric's Edmonton sales office in February, 1960.

Low Current Silicon Rectifiers

22 types, with ratings from 0.15 amps to 1.50 amps; 100 to 2800 piv.

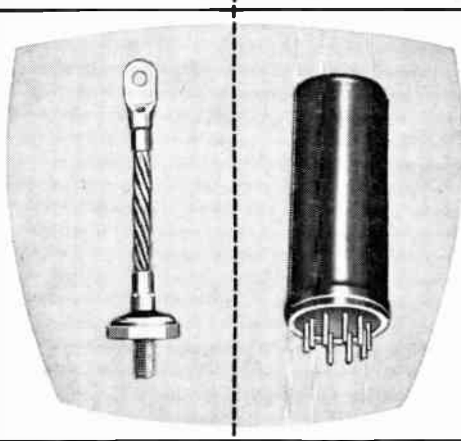


Medium Current Silicon Rectifiers

36 types, with ratings from 2 amps to 35 amps; 100 to 600 piv; many with choice of positive or negative base polarity.

High Current Silicon Rectifiers

36 types, with ratings from 50 amps to 1000 amps; 100 to 600 piv; most with choice of base polarity.

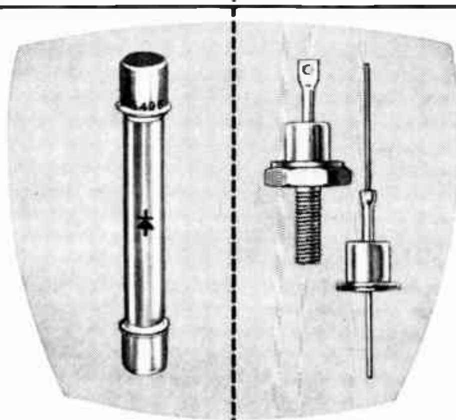


Tube Replacement Silicon Rectifiers

Long life, cool-operating, compact units replacing 95% of all popular vacuum tube rectifiers. PIV ratings from 1600 to 10,400; dc output current ratings, 250 to 750 ma.

High Voltage Cartridge Silicon Rectifiers

Ferrule mounted and axial lead series, each in 18 different types; 600 to 16,000 piv.

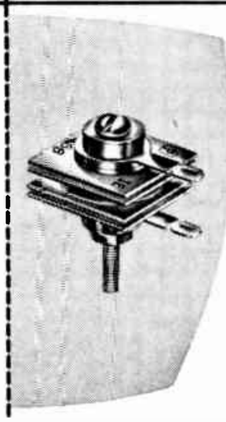


Silicon Voltage Regulators

Regular series: 93 types in ¼, 1, and 10 watt classifications; 5.6 to 100 volts breakdown. Special series: 17 types, 1 watt, 6 to 105 volts breakdown; excellent performance at low cost.

7 invitations

to invention in circuit design... seven lines of Tarzian semiconductor products offering dependable performance at realistic prices, plus interested and informed application engineering service and production and development facilities to help you solve special problems or meet special requirements. Tell us your need or send for our newest catalogs, or both.



Klipvolt Surge Suppressors

136 types, polarized, single phase and three-phase non polarized; maximum discharge currents from 0.25 to 33.0 amps. New application data catalog.

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World's Leading Manufacturers of TV and FM Tuners • Closed Circuit TV Systems • Broadcast Equipment • Air Trimmers • FM Radios • Magnetic Recording Tape • Semiconductor Devices

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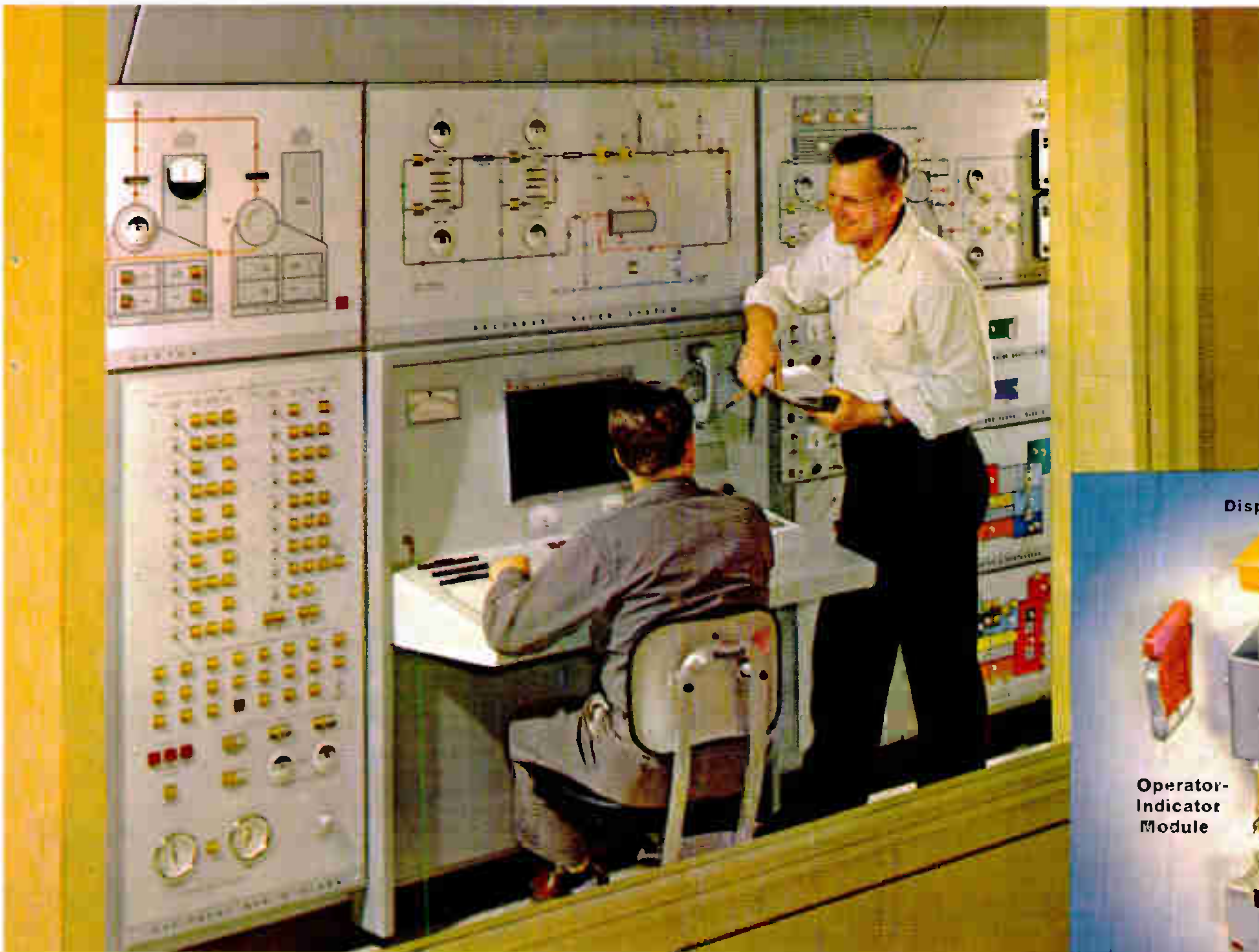
MICRO SWITCH Precision Switches



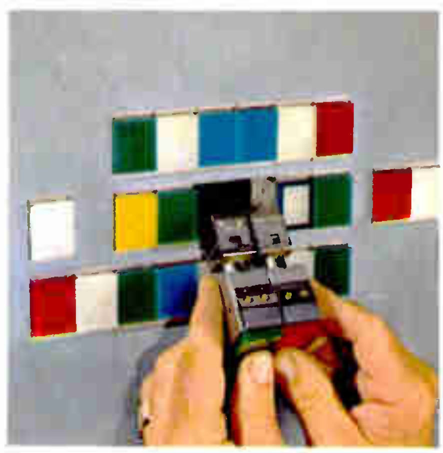
Save 50% on space. Indicator and switching unit are combined in one device to save panel space.

Start your panel design with the

Reliability, Styling and Flexibility of

MICRO SWITCH lighted push-button switches

The flexibility of MICRO SWITCH "Series 2" lighted push-button switches enables you to precisely tailor your control panel to your requirements. Hundreds of switch and indicator combinations can be assembled by simply snapping together the correct modular parts. Their clean, modern styling complements your panel design without dominating it. Most important, any of the 18 switch units you select has MICRO SWITCH reliability. That's why these "Series 2" switches serve on some of the most crucially important control panels in the world. Call your nearest Honeywell office or write Honeywell Controls Limited, *Precision Components Division*, Toronto 17. Ask for Catalog 67.

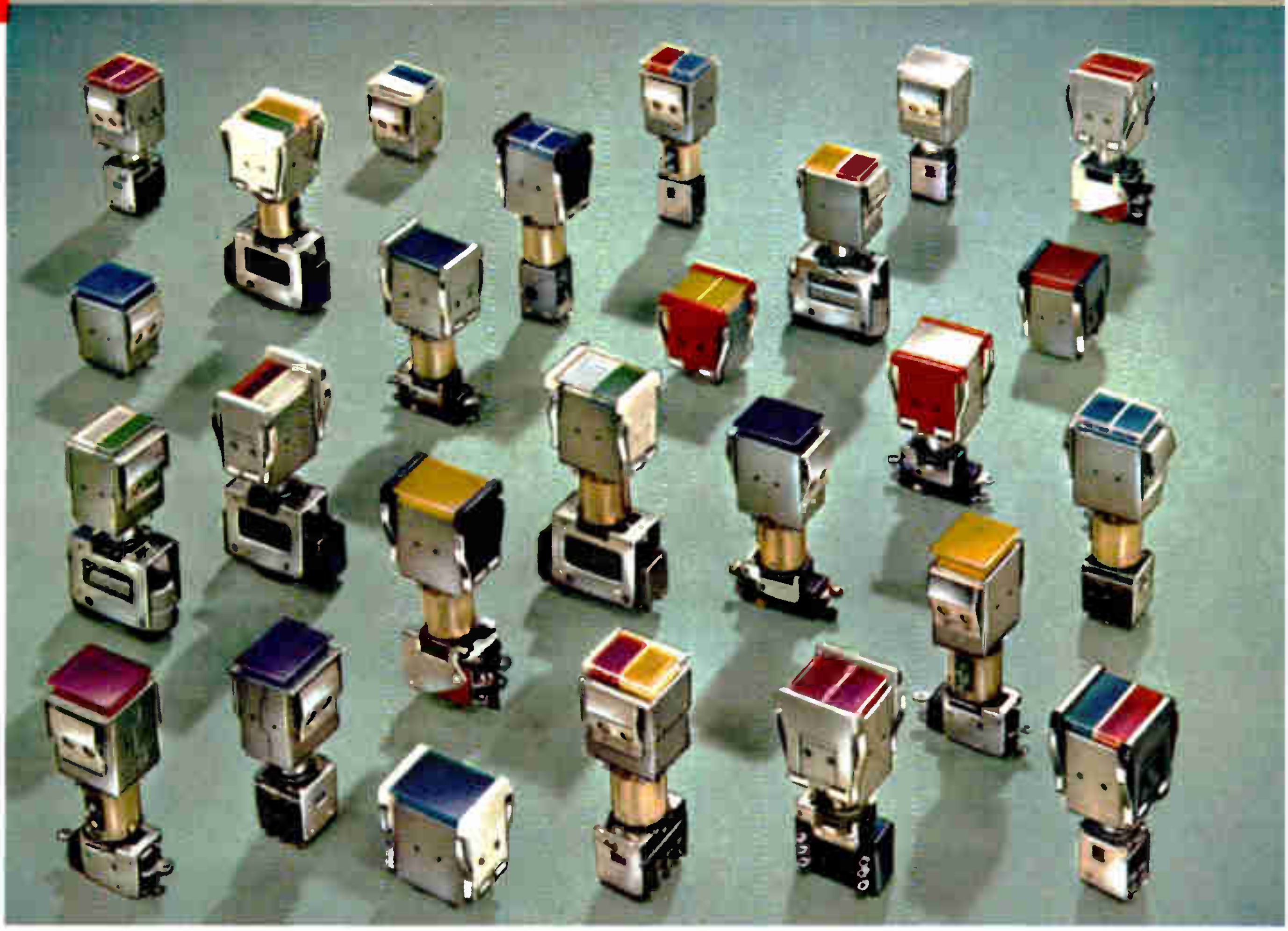


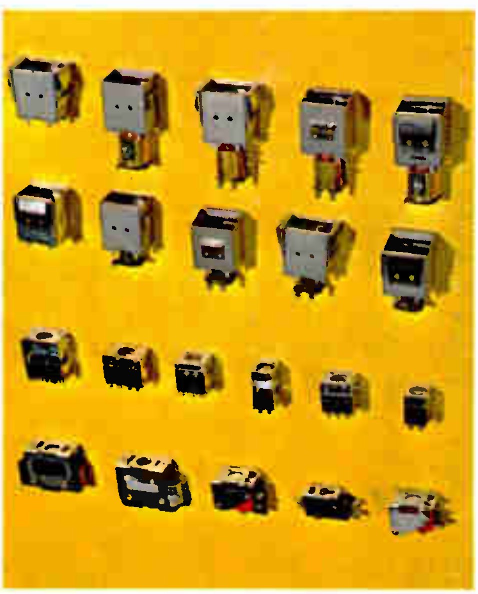
It's a snap! Modular parts snap together and then snap into panel slots without tools.

Honeywell
MICRO SWITCH Precision Switches

HONEYWELL INTERNATIONAL
Sales and service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

MICRO SWITCH Precision Switches





Hundreds of switch and indicator combinations ...with MICRO SWITCH reliability

The functional color combinations on "Series 2" switches can be split laterally or longitudinally. Up to four colors can be used behind each display screen. Projected color makes it possible for the display screen to change color to indicate a change in the circuit.

Available switching units include hermetically sealed units, small but rugged long-life types and space-saving subminiature assemblies. Momentary-contact or alternate-action units are available in a choice of circuitry to exactly match requirements. Insist on MICRO SWITCH reliability by specifying "Series 2" push-button switches for your panel. You may obtain prompt engineering help by calling your nearest Honeywell office or writing Honeywell Controls Limited, *Precision Components Division*, Toronto 17, Ontario. Ask for Catalog 67.

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Sales and service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

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MICRO SWITCH Precision Switches

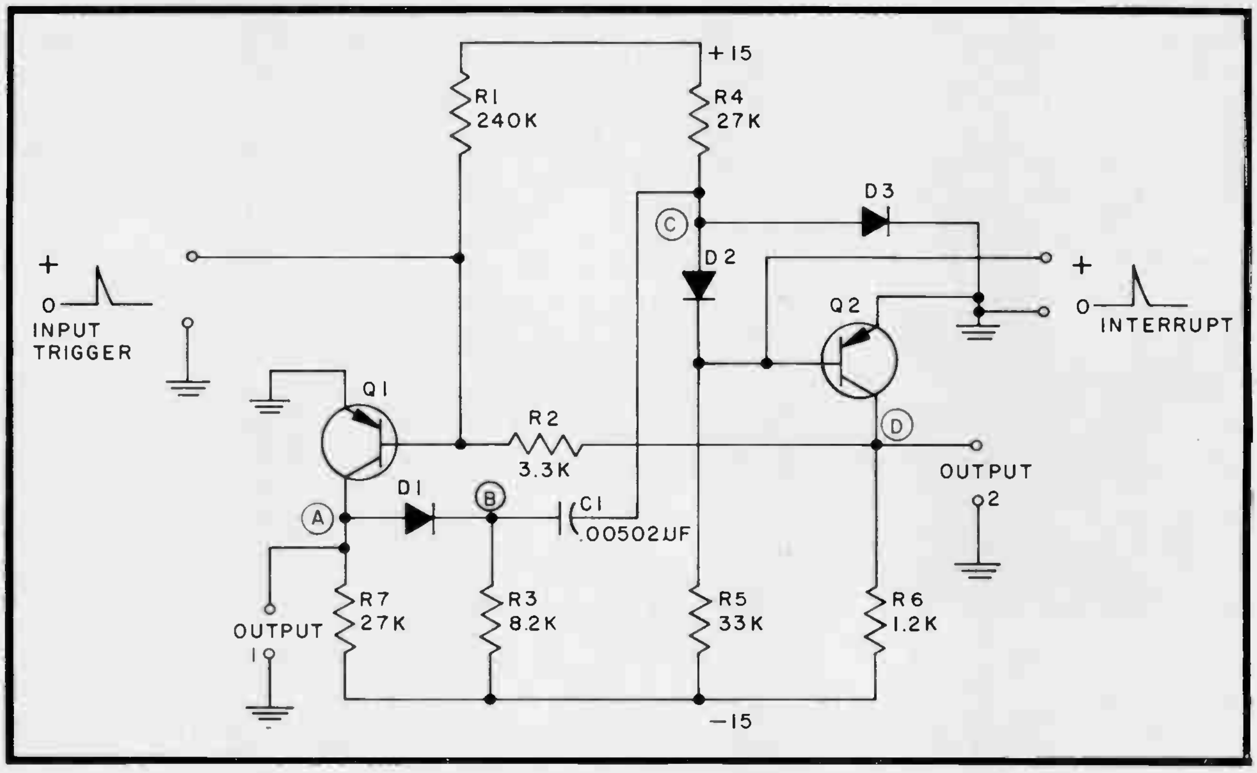


Figure 1. Circuit diagram of the new RC-coupled mono-stable flip-flop. Transistors used are type 2n664. (patent applied for)

SWITCHING CIRCUITS

A new RC coupled monostable flip-flop

. . . new monostable flip-flop features fast waveforms and is unaffected by large changes in dc line voltage

by J. Rywak*

(first publication of a paper read at the Canadian IRE Electronics Conference, October 1961)

Introduction

In conventional two transistor monostable circuits the RC timing network is connected directly between the collector of one transistor and base of the other. Such fixed coupling makes the circuits very susceptible to triggering by noise, or spikes, in power supplies. The collector leakage currents, which affect the capacitor charging current, cause variation in the "operate time" with variation in temperature. The recovery of the timing network. after operate cycle, is usually of the order of 10 per cent of the operate time and hence such monostable flip-flops are not ready for retriggering until after the elapse of this additional time.

The new monostable flip-flop

The monostable flip-flop shown in Figure 1 can tolerate "spikes" in power supplies up to 90 per cent or more of the supply voltage and the only leakage currents affecting the timing capacitor are the reverse currents of diodes D_1, D_2 and D_3 which usually are much less than one microamp. Also, the timing network has very rapid recovery, being about 2 per cent of the operate time.

Quiescent State

Referring to Figure 1, during standby Q_1 is ON and Q_2 is OFF. Since $R_4 < R_5$ point (C) is above

*See page 29

ground by the magnitude of the voltage drop through D_3. Because the voltage drop across D_2 is the same as that across D_3 the base of Q_2 is at ground potential and hence Q_2 is held OFF. Q_1 is held ON in saturation by R_2 and the negative potential of the collector of Q_2.

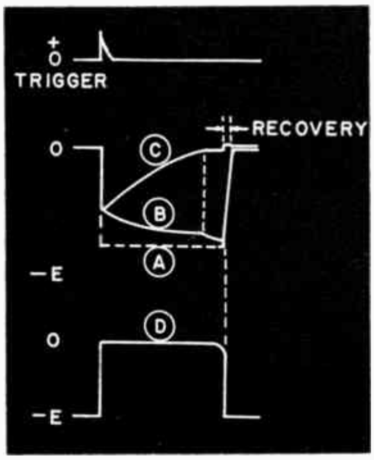


Figure 2. Representative waveforms of the circuit given in Figure 1.

Operate State

With the application of a positive trigger to the base of Q_1 this transistor is turned off permitting point (A) to fall to −15 volts. Because $R_3 < R_4$ points (B) and (C), being coupled together through the timing capacitor, fall to about −8 and −7 volts respectively causing diodes D_1, D_2 and D_3 to become reverse-biased. With the base of Q_2 being no longer help up at ground potential by D_2, transistor Q_2 is turned ON into saturation by R_5. Point (D) rises to approximately ground potential and, through R_2 and R_1, causes the base of Q_1 to be held slightly positive with respect to ground and consequently, Q_1 to be held in its OFF state. The flip-flop is now in its triggered, or "operated" state. For the circuit to function as just described:

$$R_5 > R_4 > R_3 \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

The timing capacitor now begins to charge through R_3 and R_4; point (B) falls towards −15 volts and point (C) rises towards +15 volts as may be seen in Figure 2. When point (C) passes ground potential D_2 becomes forward-biased and after a short period completely replaces the base current of Q_2 which had been flowing through R_5. With Q_2 cut OFF point (D) drops towards −15 volts causing Q_1 to be turned ON. As point (A) rises towards ground D_1 becomes forward-biased causing point (B) to rise as well. Because of the capacitive coupling, point (C) rises along with (B) producing, through D_2, an even more rapid decrease in the base curent, and hence collector current, of Q_2. This regenerative action produces a rapid reset of the circuit. As point (C) is driven above ground diode D_3 becomes forward biased permitting the timing capacitor to be discharged to ground. It may be seen that the maximum discharge current of the capacitor is limited only by the maximum permissible collector current of Q_1 and the forward resistances of Diodes D_1 and D_3. Hence very rapid recovery is realized with the new arrangement.

Timing equation

As may be seen in Figure 3 (a) the capacitor voltage waveforms have two distinct portions and the charging currents are shown as i'_3 when diode D_2 is still reverse-biased and i''_3 during the period when the base current of Q_2 is being replaced by the current of D_2 up to the instant when regeneration and reset occur.

In Figure 3 (a) the circuit and charging current waveforms during the ON time of the circuit are shown. Attention is directed to the fact that only the beta of Q_2 is influential during the i''_3 portion of the charging current. The beta of Q_1 has virtually no effect.

With the initial and final values of i'_3 as given in Figures 3 (b) and 4 the following timing equation may be deduced:

$$(2) \quad t_T = C\left[(R_3 + R_4)\ln\frac{2R_4}{R_3 + R_4} + R_3 \ln \frac{1}{1 + R_4\left(\frac{1}{\beta_2 R_6} - \frac{1}{R_5}\right)}\right].$$

It is shown in Figure 4 that $I_{b2} \approx \dfrac{E}{\beta_2 R_6}$ because the collector voltage of Q_2 is slightly modified by the base current of Q_1 flowing through R_6 just prior to regeneration. The effect of the base current of Q_1 on t_T is negligible.

Transients in power supplies

The common monostable flip-flop is most susceptible to positive-going transients, or spikes, in the negative voltage supply. With the new circuit a positive-going spike in the positive voltage supply only increases the current through D_3 (See Figure 1) and has no effect on Q_2 at all. For such a spike to trigger regeneration it would have to be sufficiently large that it would increase the current through R_1 to a point where it would be approaching the values of the base current of Q_1. Negative spikes in either the positive or negative power supplies would have to contain sufficient energy to discharge the timing capacitor by an amount approximately equal to that of the forward drop of diode D_2 in order to permit Q_2 to turn ON.

For a positive going spike in the negative power

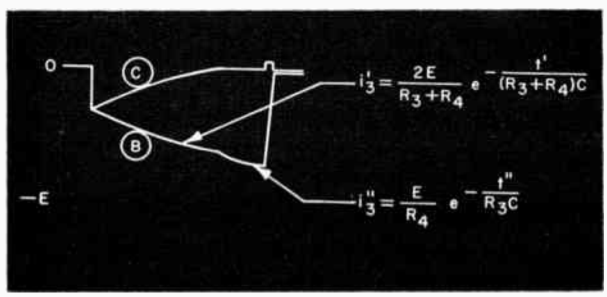
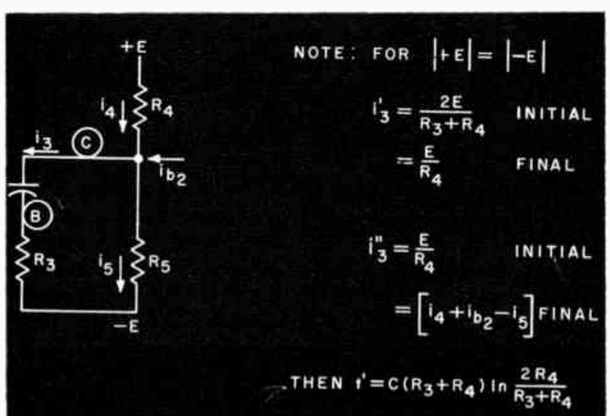


Figure 3a. (above) Timing capacitor charging currents. Figure 3b. (below) Charging circuit network and expressions for initial and final conditions.



supply the flip-flop will trigger when Q_1 is turned OFF. As may be deduced from Figure 5 the spike will have an immediate influence on the base of Q_1 through resistors R_2 and R_6; the capacitor will not absorb any of the energy content of the spike as it does for the negative going spikes.

With a positive going spike superimposed on the negative power supply the voltage, for the duration of the spike, becomes $-E^1$ as shown in Figure 5. It may be observed that there exists a value for $-E^1$ where the current i_2 flowing through $R_2 + R_6$ approaches the value of current i_1 flowing through R_1 at which time the base current i_{b1} of Q_1 will have decreased to the point where Q_1 will begin to turn OFF permitting the flip-flop to trigger. The relationship of the currents surrounding Q_1 at this time are shown in Figure 5. It is to be noted that in the final expression showing the amplitude of the spike e_{tr} at which the circuit triggers only the beta of Q_1 has any significant influence.

$$(3) \quad \text{i.e.} \quad e_{tr} = E\left[1 - \frac{1}{R_1}\left(\frac{R_2 + R_6}{1 - \left[\frac{R_2 + R_6}{\beta_1 R_T}\right]}\right)\right].$$

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If in the design of the circuit, the resistor values are so chosen that when Q_1 is cut OFF by a spike the reference points (B) and (C) cannot fall below ground, then no regeneration can take place.

Hence:

$$E\frac{R_3}{R_4} = E^1$$

or (from Fig. 5)

$$(4) \qquad E\frac{R_3}{R_4} = \frac{E}{R_1}\left[\frac{\beta_1 R_T(R_2 + R_6)}{\beta_1 R_T - (R_2 + R_6)}\right]$$

therefore

$$(5) \qquad \beta_1 \min \geqslant \frac{R_1 R_3 (R_2 + R_6)}{R_1 R_3 R_T - R_4 R_T (R_2 + R_6)}.$$

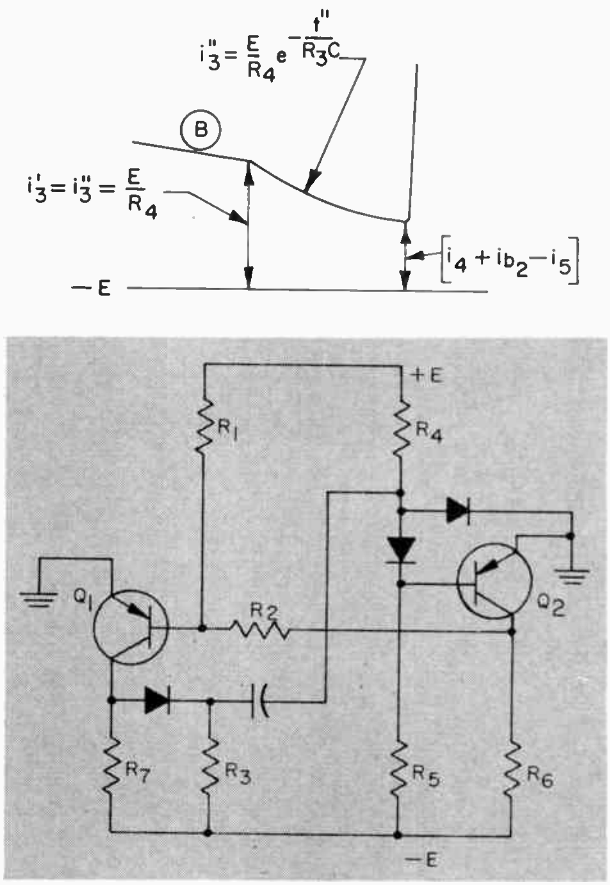
From the above it may be observed that if the denominator is made equal to zero then the circuit will not trigger even for infinitely large values of β_1, and if (5) is satisfied the circuit will not trigger with β_1 min either.

$$(6) \qquad \frac{R_4}{R_3} \leqslant \frac{R_1}{R_2 + R_6}.$$

Typical circuit design:

Figure 5 and equation (3) may be used as a guide in the design of the new monostable flip-flop from which it may be seen that terms R_1 and $\beta_1 R_T$ should be maximized and term $(R_2 + R_6)$ minimized.

Conditions to be satisfied are:



AT TIME OF RECOVERY $V_{(C)} = 0$

HENCE $i_4 = \frac{E}{R_4}$ SINCE $\left[i_4 + i_{b2} - i_5\right] = \frac{E}{R_4} e^{-\frac{t''}{R_3 C}}$

$i_5 = \frac{E}{R_5}$ $t'' = R_3 C \ln \frac{1}{1 + R_4\left(\frac{1}{\beta_2 R_6} - \frac{1}{R_5}\right)}$

$i_{b2} \approx \frac{E}{\beta_2 R_6}$

$t_T = t' + t''$

$$\therefore \quad t_T = C\left[(R_3 + R_4)\ln\frac{2R_4}{R_3 + R_4} + R_3 \ln\frac{1}{1 + R_4\left(\frac{1}{\beta_2 R_6} - \frac{1}{R_5}\right)}\right]$$

Figure 4. (top) theoretical waveform, (center) switching system (bottom) switching equations.

$$(a) \qquad R_5 > R_4 > R_3$$

$$(b) \qquad \frac{R_1}{R_2 + R_6} \geqslant \frac{R_4}{R_3}$$

$$(c) \qquad \frac{R_1 R_3 (R_2 + R_6)}{R_T R_1 R_3 - R_4 (R_2 + R_6)} \leqslant \beta_1 \min$$

Component limits:

FOR "+VE" GOING TRIGGER IN −E

TRIGGERING OCCURS WHEN Q_1 GOES OUT OF SATURATION

THEN $E' = \beta_1 i_{b_1} R_T$ WHERE $R_T = \frac{R_3 R_7}{R_3 + R_7}$

$i_2 = i_{b_1} + i_1$

OR $\frac{E}{R_2 + R_6} = \frac{E'}{\beta_1 R_T} + \frac{E}{R_1}$

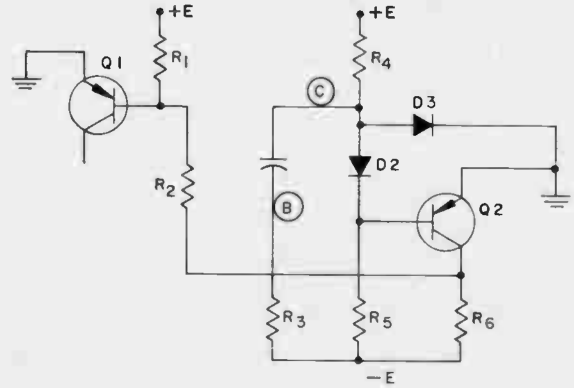
MONOSTABLE TRIGGERS WHEN:

$$|E'| = \frac{E}{R_1}\left[\frac{\beta_1 R_T (R_2 + R_6)}{\beta_1 R_T - (R_2 + R_6)}\right]$$

OR SPIKE AMPLITUDE $e_{tr} = E - E'$

$$\text{THEN } e_{tr} = E\left[1 - \frac{1}{R_1}\left(\frac{R_2 + R_6}{1 - \frac{R_2 + R_6}{\beta_1 R_T}}\right)\right]$$

IN DESIGN OF CIRCUIT MAXIMIZE R_1 AND $\beta_1 R_T$ MINIMIZE $(R_2 + R_6)$



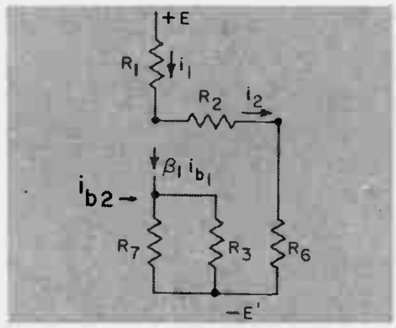


Figure 5. Transient triggering equations and (lower right) equivalent circuit.

$\beta_{min} = 30,\ \beta_{max} = 60$

Diode Leakage $= 10\ \mu$ amp max

$I_{co} = 60\ \mu$ amp max

$I_{c_{max}} = 200$ ma

$|+E| = |-E|$

Required "operate" time:

$t_T = 100\ \mu$ s.

The value of R_6, across which the output is taken, is dependent upon the requirements of the load that is to be driven. Therefore, as a starting point: R_6 may be assumed to have a value of 1.2K.

For Q_2 to saturate $R_5 = B_2 \min (R_6)$

$= 30\ (1.2) = 36\ K$

Use $R_5 = 33\ K$

The value of R_1 should be the maximum possible

Hence $R_1 = \frac{E}{I_{co\ max}} = \frac{15}{.06} = 250\ K$

Use $R_1 = 240\ K$

During recovery I_{c} should be largely the capacitor discharge current hence R_T, which is the parallel combination of R_3 and R_7, should not be too small. However, for the reference point (C) to drop several volts below ground when the flip-flop is triggered, R_3 should be substantially less than R_4.

During standby the minimum current through R_4 ($I_{4 min}$) is:

$I_{4\ min} = \frac{E}{R_5} + I_{co\ max}$

$= \frac{15}{33} + .06 = 0.515$ ma

Hence $R_{4\ max} = \frac{15}{0.515} = 29.2\ K$

Use $R_4 = 27\ K$

For the requirement that R_3 be substantially less than R_4 it may be assumed that the potential at (B) and (C) immediately after triggering will be equal to

$-\frac{E}{2}$

Therefore $\frac{R_3}{R_3 + R_4}(2E) = \frac{E}{2}$

$R_3 = 9.0\ K$

Use **$R_3 = 8.2\ K$**

Condition $R_5 > R_4 > R_3$ is therefore satisfied.

The value of R_7 must be such that $I_{co\ max}$ flowing through it will produce a potential at (A) (the collector of Q_1) equal to or more negative than the most negative potential at (B). This is necessary so that diode D_1 is reverse-biased during the "operate" period of the circuit. The most negative value of point (B) occurs when the charge on the capacitor has built up to the point where (C) is at ground and the base current of Q_2 has decreased sufficiently to initiate regeneration. In Figure 4 it is shown that the current through R_3 at that instant is

$$[I_4 + I_{b2} - I_5]$$

$$\text{Hence } V(B) = R_3\left(\frac{E}{R_4} + \frac{E}{\beta_{2\,max} R_6} - \frac{E}{R_5}\right) - E$$

$$= 8.2\left(\frac{15}{27} + \frac{15}{60(1.2)} - \frac{15}{33}\right) - 15 =$$

$$\mathbf{-12.48\ volts}$$

$$\text{Therefore } I_{co\,max}\,(R_7) \leqslant [I_4 + I_{b2} - I_5]R_3$$

or $$R_7 \leqslant \frac{(.308)(8.2)}{.08} = 31.5\,K$$

Use $\boldsymbol{R_7 = 27\ K}$

For rapid recovery it is essential that the capacitor be discharged as quickly as is safely possible. Hence the maximum discharge current will be:

$$I_{c\,max} = \frac{E(R_3 + R_7)}{R_3 R_7} = 200 - \frac{15(8.2 + 27)}{(8.2)(27)} =$$

$$\mathbf{197.6\ ma}$$

From

$$\frac{I_{c\,max}}{\beta_{1\,max}} + \frac{E}{R_1} = \frac{E}{R_2 + R_6}$$

$$R_2 = \frac{E R_1 \beta_{1\,max}}{I_c R_1 + E\beta_{1\,max}} - R_6$$

$$= \frac{15(240)(60)}{200(240) + 15(60)} - 1.2 = 3.22\,K$$

Use $\boldsymbol{R_2 = 3.3\ K}$

Since

$$\frac{R_1}{R_2 + R_6} = 53.3 \text{ and } \frac{R_4}{R_3} = 3.3$$

requirement that $\frac{R_1}{R_2 + R_6} \geqslant \frac{R_4}{R_3}$ is met

$$\text{From (5)}\quad \frac{R_1 R_3 (R_2 + R_6)}{R_1 R_3 R_T - R_4 R_T (R_2 + R_6)} = 0.76$$

Then requirement (5) is also met.
For 100 μS operate time (using eqn. (2)):

$$C = \frac{t_T}{(R_3 + R_4)\ln\frac{2R_4}{R_3 + R_4} + R_3 \ln\left[\frac{1}{1 + R_4\left(\frac{1}{\beta_2 R_6} - \frac{1}{R_5}\right)}\right]}$$

$$= \frac{100 \times 10^{-9}}{(8.2 + 27)\ln\frac{2(27)}{8.2 + 27} + 8.2\ln\left[\frac{1}{1 + 27\left(\frac{1}{60(1.2)} - \frac{1}{33}\right)}\right]}$$

$$= \mathbf{0.00502\ uf}$$

It may be observed here that of the 100 μS. operate time the term

$$(R_3 + R_4)\ln\frac{2R_4}{R_3 + R_4}$$

accounts for 76 μS and the term

$$R_3 \ln \frac{1}{1 + R_4\left(\frac{1}{\beta_2 R_6} - \frac{1}{R_5}\right)}$$

accounts for 24 μS. It should be noted that the second term is dependent slightly on β_2. In the above calculations $\beta_2 = 60$ was used. If $\beta_2 = 30$ had been used the operate time would be 80 μS of which the first term again would contribute 76 μS while the second term would contribute only 4 μS.

At the end of "operate" time the flip-flop begins to reset when the collector voltage of Q_2 (point (D)) drops by approximately $\frac{R_2 E}{R_1}$ volts below the saturation voltage. Hence β_2 should be measured at a collector voltage of about 0.5 and collector current of $\frac{E}{R_6}$.

Conclusions and observations:

In Figure 6 are shown oscilloscope photographs of the waveforms of the timing capacitors. In both, Figure 6(a) and 6(b), the rising waveform is applicable to the upper side of the capacitor [point (C) in Figure 1] and the falling waveform is that of the lower side, [point (B)].

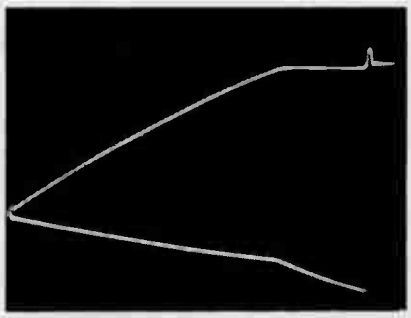


Figure 6a. Timing capacitor charging waveforms. Upper curve — point 'C', lower curve — point 'B'. (scan time = 100μS. Amplitude — point 'C' = 7V. and point 'B' = 2.7V. **Value of B_2 = 60.**

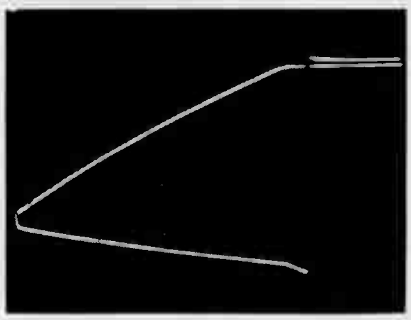


Figure 6b. Waveforms as above, but **B_2 = 60.**

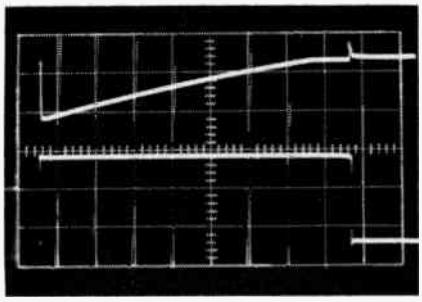


Figure 7. Upper curve — charging waveform at point 'C', lower curve — output waveform at point 'D'. Grid calibration: 10µS/div., 5 volts/div.

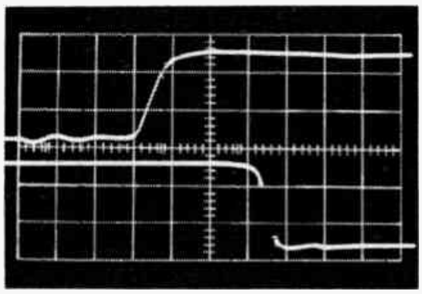


Figure 8. Upper curve — leading edge of output in Figure 7. Lower curve — trailing edge of output in Figure 7. Grid calibration: 0.1µS/div., 5 volts/div.

In Figure 6(a) and 6(b) the betas of Q_2 at $V_c = 0.5$ volts and $I_c = 12.5$ ma were selected to be 60 and 30, respectively, within about 5 per cent tolerance. It may be seen that there is reasonable agreement with predicted operate times. In both displays the first portion of the charging curve is about 72 µS: during this period all diodes are reverse-biased and the timing capacitor charges through R_4 and R_3. However, when the upper curve reaches ground potential and I_{b2} begins to influence the charging current it is at this point that β_2 enters into consideration. Calculations predicted this second portion of the delay to be 24 µS for $\beta_2 = 60$ and 4 µS for $\beta_2 = 30$ and Figure 6 verifies these calculations reasonably well.

The duration of the monostable flip-flop recovery, or discharging of the timing capacitor after reset, is clearly seen in Figure 6 as a small blip in the upper waveform lasting just under two µS. The flip-flop is ready for retriggering immediately thereafter.

If a fine control for the "operate" time is required R_4 can be made variable. Care must be taken that over the full range of R_4 the principal relationship $R_5 > R_4 > R_3$ is not violated. The "operate", or ON, period of the circuit may easily be interrupted at any time with the application of a positive pulse to the base of Q_2. The normal regenerative reset and recovery quickly discharges the capacitor in the manner already described.

Because both transistors are disconnected from the timing circuit during the "operate" period a secondary output from the collector of Q_1 may also be taken. It should be noted, of course, that Q_1 may not be loaded as heavily as Q_2.

In Figure 7 the upper waveform is the same as in Figure 6(a), only different scope sensitivity are involved and the lower waveform is the output voltage (D) at the collector of Q_2. The small rounding off at the upper right corner of the waveform shows the collector of Q_2 coming out of saturation just prior to regeneration and reset.

Shown in Figure 8 is the expanded waveform recorded at 0.1 µS per scale division and it can be seen that both the rise and fall times are well under this value when using 2N644 transistors. The maximum jitter that was observed on the trailing edge of the 80 µS pulse was about .04 µS or 0.05 per cent.

COMPUTING AMPLIFIERS

A design analysis of the operational amplifier

. . . detailed analysis shows scope and limitations of operational amplifier . . .

by V. Malolepszy *

SUMMARY

A design analysis, which establishes parameter values for the Operational Amplifier as a function of required computation accuracy is presented herein. The role of the Stabilizer as a part of the computing amplifier is emphasized and several design aspects concerning performance of the Operational Amplifier are discussed. Factors determining the figure of merit of an Operational Amplifier are given and numerical examples are presented.

1. Introduction

The importance of the operational amplifier as a basic building block in analog computers is well known and its broad application to other electronic fields has been widely published. However this design analysis, which establishes parameter values of the operational amplifier as a function of required computation accuracy is mostly limited to general considerations. In computing systems, which require hundreds of operational amplifiers exact specification of the amplifier perfor-

*See page 34

mance is required to avoid unnecessary costly over-design and development problems (i.e. amplifier instability), making a careful analysis of such amplifiers very important.

The present study gives a breakdown of computing errors, their relationship to computing accuracy and discusses factors having a bearing on the error magnitude. On the basis of the results obtained, the parameters of the operational amplifier are calculated. The results of the analysis can also be used to calculate the accuracy of computation using a given amplifier, when its parameters are known.

2. Summary of the design analysis of unstabilized operational amplifiers

The operational amplifier without drift stabilization is illustrated in Figure 1. An analysis of this basic

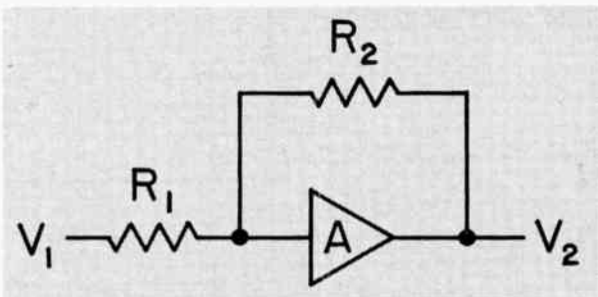


Figure 1. Basic diagram of operational amplifier.

system yields the following important transfer equations.

Voltage at the output of Operational Amplifier:

$$-V_2 \cong \underbrace{\frac{KV_1}{}}_{\text{nominal output}} + \underbrace{\frac{1}{1+\beta A}KV_1 + R_2I_g + \Delta I_g R_2 - (1+K)(d_1+d_2+d_3) + V_N}_{\text{error}} \qquad (1)$$

where:

V_1 = signal voltage

V_2 = total output voltage

d = drift referred to the amplifier input: $d_1 + d_2 + d_3$;

d_1 — drift due to DC supply voltage variation
d_2 — drift due to heater voltage variation
d_3 — drift due to aging

V_N = noise voltage

I_g = grid current

R_1 = summing resistor

R_2 = feedback resistor

A = open loop gain

$$\beta = \left(1 + \sum_{n=1}^{n=p} \frac{R_2}{R_n}\right)^{-1}$$

$$V_2 = \underbrace{-KV_1}_{\text{nominal output}} + \underbrace{\frac{1}{1+\beta A}KV_1 + R_2I_g + \Delta I_g R_2 - (1+K)d + V_N}_{\text{error}} \qquad (2)$$

Results of the analysis can be summarized as follows:

1. $-KV$. The desired output signal equals $-KV_1$, all other terms represent error.
2. $\frac{1}{1+\beta A} KV_1$ — error due to finite amplifier gain and input-feedback network configuration. It can be reduced by increasing the amplifier gain or by feedback resistor selection, if it is permissible.
3. R_2I_g — error due to grid current, which can be balanced off.
4. $\Delta I_g R_2$ — error due to change of grid current; depends on tube properties; it can be made small by proper selection of tube and/or circuitry ("starved" stage). The effects of I_g and ΔI_g on the output voltage are independent of the amplifier gains (open loop or effective gain).
5. $(1 + K)d$ — total drift at the amplifier output, depends on the amplifier active element circuitry and the effect of the first stage is most significant. The output drift is nearly independent of the amplifier open-loop gain and is nearly proportional to the effective gain of the amplifier. In this unstabilized type of amplifier no special provision exists to diminish this error.
6. V_N noise at the output; this depends mainly on the noise factor at the input stage including pick-up in the wiring.

It is necessary to point out that in practical amplifiers V_2 is a function of frequency, and accuracy of computation will be influenced by this quantity.

3. Summary of the design analysis of the DC stabilized operational amplifier

The DC stabilized operational amplifier contains a DC amplifier and a stabilizer (drift correcting unit), as illustrated in Figure 2.

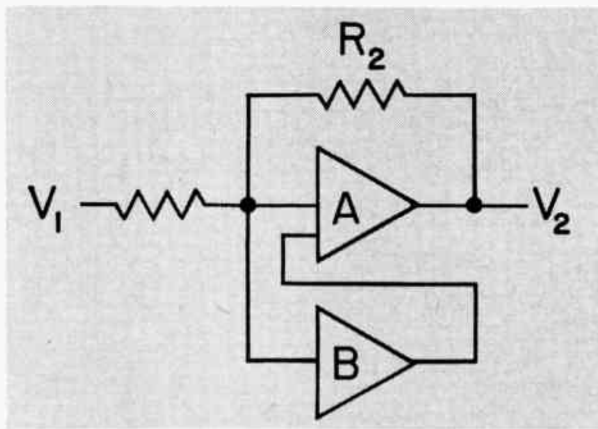


Figure 2. Diagram of chopper stabilized operational amplifier.

The design analysis of the stabilizer

The stabilizer contains a driftless AC amplifier, modulator, demodulator input and output filters as shown in Figure 3. The effect of the stabilizer upon the operational amplifier circuit is generally summarized as merely a drift reduction in a ratio equal to the overall DC/DC gain of the stabilizer. The design analysis of this circuit reveals that its effect is much more complex than this simple picture would suggest and the stabilizer gain should be much higher than that required for reduction of drift. The stabilizer must also fulfill the stability criterion of the operational amplifier. To secure absolute stability of the feedback system the slope of response characteristic of the

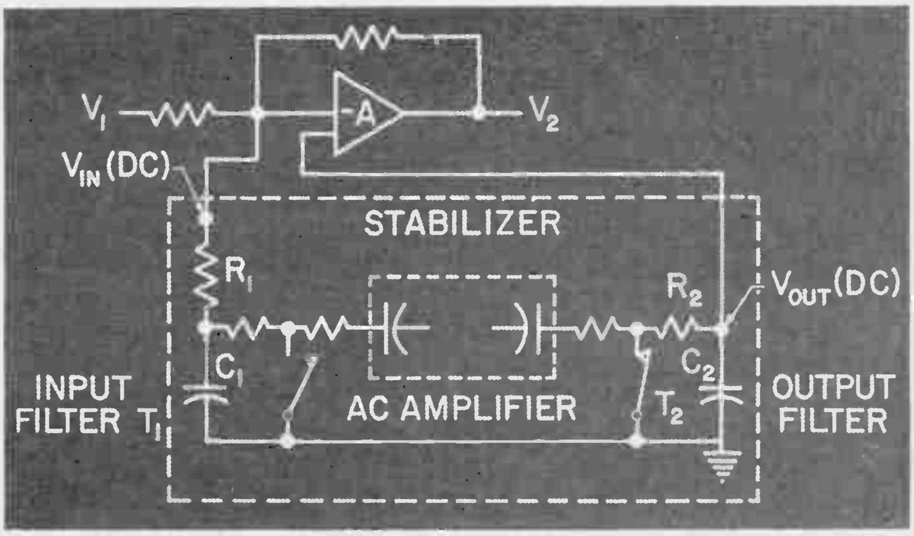


Figure 3. System diagram for the chopper stabilized operational amplifier.

amplifier should not exceed 6 db/octave. This is achieved by means of suitable filters (see: General Response of the operational amplifier with stabilizer, Figure 4). The other function of the filters is to suppress any signal in synchronism with the chopper frequency, using an "input" filter and to reduce the demodulator ripple by means of the output filter. The stabilizer should fulfill the following conditions:

- Reduction of drift according to required ratio:

Output drift of DC stabilized operational amplifier : $d_{out} = \dfrac{(K+1)\,d}{B+1}$

where: B = **DC/DC gain of the stabilizer.**

(K + 1) d = drift of unstabilized operational amplifier.

the other symbols are as defined in formula (1).

Required stabilizer gain: $B > (K+1)\dfrac{d}{d\,out}$

- Sufficient suppression of the signal frequency in synchronization with the chopper frequency (to prevent modification of the drift by means of the signal information).

$$\frac{1}{T_1} = \frac{1}{R_1C_1} = W_1\,\text{cut-off} \leqslant \frac{W(\text{chopper})}{10}$$

$$T_1 \geqslant \frac{10}{W_{chopper}} = \frac{10}{2\pi f\,\text{chopper}} = \frac{5}{\pi f\,\text{chopper}}$$

where: $T_1 = R_1C_1$ = time constant of the input filter. (see Figure 3).

- Sufficient suppression of the chopper ripple: acceptable output ripple content (part of total error) = V_o ripple

the ripple content at the stabilizer output:

$$Vs = \frac{V_{0\,ripple}}{K+1}$$

required attenuation of the chopper frequency = N

$$N = \frac{\text{Stabilizer Output without smoothing capacitor}}{V_s}$$

$$= \frac{d}{Vs}$$

To achieve the above attenuation, the cut-off frequency of the output filter is given by:

$$f_{cut\text{-}off_2} = \frac{f_{chopper}}{N}$$

$$\frac{1}{2\pi f\,\text{cut-off}_2} = T_2 > \frac{N}{2\pi f_{chopper}}$$

$$T_2 = R_2C_2 > \frac{N}{2\pi f_{chopper}}$$

where: $T_2 = R_2C_2$ = output filter time constant (see Figure 3).

- Requirements for proper shaping of the Amplifier gain and phase characteristics in order to fulfill the stability criteria as indicated in Figure 4.
  - (a) To avoid the change of shape of the DC Amplifier characteristic because of the stabilizer:

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$f_1\,\text{cut-off} < f_{\text{cut-off DC Amplifier}}$

  - (b) To have the stabilizer gain characteristic dropping uniformly at approximately 6db/octave:

$T_2 > BT_1$

- Drift information should not be changed by means of the stabilizer.
  - (a) The amount of distortion and phase shift should be independent of the drift amplitude.
  - (b) The output filter must be able to follow drift variations:

    f_2 cut-off $> f_{\text{drift rate of change}}$

Summary of the results of the Design Analysis of the Operational Amplifier with Stabilizer.

Equation 3, below, is the basic transfer equation of the operational amplifier with the stabilizer. Reference should be made to Figure 3.

$$(3)\quad V_2 \; \underbrace{= -KV_1}_{\text{nominal output}} \; + \overbrace{\frac{1}{1+\beta A}KV_1 + I_gR_2 + \Delta I_gR_2 - \frac{K+1}{B+1}d}^{\text{error}} - \overbrace{-(K+1)d_V + (K+1)V_s + (K+1)V_h + V_N}^{\text{error}}$$

where: $(K + 1)\,V_s$ = output to chopper ripple and

$(K + 1)\,V_h$ = output due to rectification of hum and pick-up noise in the stabilizer.

d_v = Stabilizer DC drift referring to the stabilizer input.

V_s = Chopper ripple at the stabilizer output.

V_h = hum and power supply ripple and pickup noise at the stabilizer input.

The above equation indicates that the stabilizer reduces error due to drift by the factor B + 1, but has no effect on the error due to grid current or its derivative.

If drift occurs in the stabilizer circuit it can be referred to the stabilizer input as the drift voltage d_v. As is shown in equation 3, d_v is only a function of K and is independent of A and B.

The stabilizer presence has no effect on the noise level of the operational amplifier, because of the practical narrow frequency band of the stabilizer.

4. Summary of considerations in design of the operational amplifier

From the above design analysis several conclusions may be drawn, and the following comments are applicable:

- *Stabilizer gain versus operational amplifier performance*

The drift of the operational amplifier can be reduced by increasing the stabilizer gain, as it is shown in equ. (3). In connection with boosting the stabilizer gain a word of warning is necessary. A gain increase of the stabilizer may adversely effect the stability of the operational amplifier (this is self-explanatory in Figure 4) especially if $f_{\text{cut-off}}$ of the DC amplifier is low and the time-constands R_1C_1 and R_2C_2 have significant values. On the other hand the stabilizer gain boost does not necessarily mean an improvement of performance of operational amplifier itself. It should be realized that drift is only a part of the total error and when the gain of the stabilizer increases, the other factors, independent of stabilizer gain i.e. error due to finite gain of the amplifier start to predominate. The drift error will generally be diminished to a small fraction of the total error, therefore very large values of stabilizer gain do not particularly improve the performance of the operational amplifier.

The power supply variation versus drift of the operational amplifier

Analysis of the operational amplifier indicates that drift is primarily due to changes of the parameters of active elements within the amplifier mostly in the first stage, with variations of DC supply, heater voltage and component aging also contributing. These sources of drift can be minimized, and in a good design, a condition can be reached where the component due to aging is the pre-dominant one present.

In summary total acceptable drift:

$d_{total} =$	d_1 +	d_2 +	d_3	$= d\ max =$
	drift due to DC supply variation	drift due to heater voltage variation	drift due to aging	acceptable maximum

It is obvious that to have d_3 large, d_1 and d_2 must be kept small. This can be achieved by means of power supplies properly regulated. The $\pm E_{bb}$ supply stability is the most important in the input stage (the main source of drift), which if "starved" requires currents of the order of a fraction of a milli-ampere. Regulation of heater voltage to within 1 per cent does not impose any serious practical difficulty or significant cost increase. Underrunning heaters tend to produce good results.

Drift versus time measurements usually indicates that after approx. 200 hrs. (depending on the type of active element) the drift levels-off with relatively small random variations and long term operation without frequent balancing can be expected. Every effort should be made to cancel as much of the power supply effect as possible. In the case of the stabilized operational amplifier, the effect of power supply variations is less ominous due to the action of the stabilizer, but even in this case, it is good policy to diminish the drift due to the power supply by means of appropriate design of the latter.

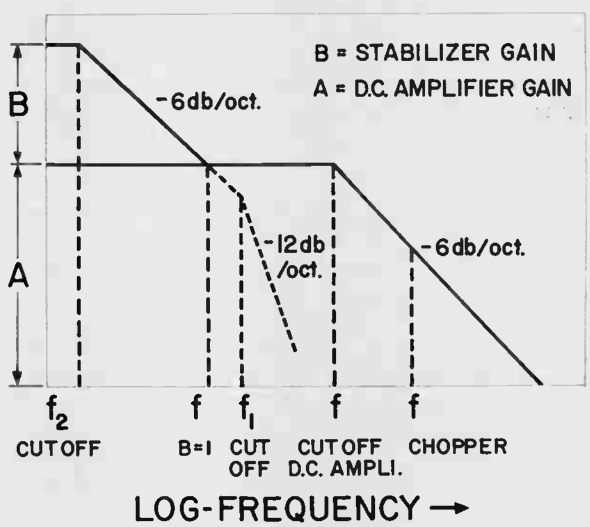


Figure 4. Frequency response asymptotes for the chopper stabilized amplifier.

Overall DC gain versus operational amplifier performance

High overall DC gain *AB* (see equation 3) of the operational amplifier so often quoted as a figure of merit is evidently not the decisive factor of the operational amplifier performance.

In case of the stabilized operational amplifier working in a summing role, the moderate stabilizer gain diminishes drift to such a small value that total error is approximately equal to the error due to the finite gain employed. The error due to this finite value is a function of *A* and not *B* (see equation 3), therefore the value of A is the important criterion not the product AB. The ultimate limit of accuracy is imposed primarily by the elements of the input and feedback networks. Good quality resistors have 0.1% to 0.01% accuracy, however, their values drift with age, temperature and humidity so total D.C. gain *AB* of order of several tens of millions has little practical meaning owing to limits imposed by passive elements, grid current, rectified a-c pickup form chopper, hum pickup, amplifier noise, and so forth . . . this is indicated in Appendix 1. Similarly in the case of the stabilized amplifier connected an integrator, it is not the product AB, but the integrating capacitor which ultimately limits the accuracy of computation. (See Appendix 3.) Although many capacitors have very high leakage resistance, their capacity variation with temperature represents a limiting condition. In two examples presented in Appendix 3, the error due to finite gain AB is 0.0015% and 0.0023% in case of short and long time integration respectively.

More rigid computing system requirement demand operational amplifiers with high DC amplifier gain 'A' and small drift per unit time referred amplifier input. Similarly, appraisal of any operational amplifier should be based on knowledge of *A* and not product of A and B alone, as is so often done.

Effect of configuration of summing and feedback networks on computing accuracy of the operational amplifier

As it is shown in equation 1 the error due to finite gain is a function of the input network configuration (see Appendix 2). Therefore the total error, as well as the accuracy of computation depends also on the number of summing resistors as well as the ratio of their values in respect to the feedback resistor.

Conclusions

In large analog computers the operational amplifier accounts for a significant percentage of the total cost. It is therefore most important to design the amplifiers to fulfill adequately the computer requirements. It must be emphasized that TOTAL ERROR is the main design criterion or figure of merit, not gain *A* x *B* or drift. Of this TOTAL ERROR the drift is only one of the general factors and with a stabilizer of moderate gain it became insignificant compared to the sum of the other factors. Gain of DC amplifiers without stabilizer *A* should be sharply differentiated from total gain *AB*. due to the importance of *A* especially in case of unstabilized amplifier performance. Unnecessarily large values of *A* x *B* involve an unwarranted cost penalty and in practical feedback systems can cause system instability.

Appendix 1

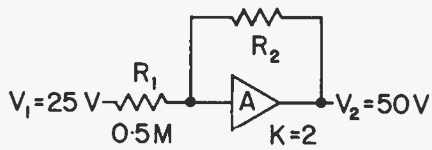
Two numerical examples, using less sophisticated formulae than in eq. (1) and (3) are presented:

(1) *Operational Amplifier without Stabilizer*

$$-V_2 \approx KV_1 + \frac{1}{1+\beta A}KV_1 + R_2I_g + \Delta I_g R_2 - (1+K)d; \qquad (4)$$

where symbols have the same meaning than in case of eq. (1). Assume: $K = 2$; E_T (total error) $\leqslant V_2 \times 0.2\%$. Calculation will be made for 50 v output:

$$50 \text{ v out} \times 0.2\% = 0.1 \text{ v} = 100 \text{ mV}.$$



(E = error)

all errors referring to output:

total error. $E_T = 100$ mV

see eq. (4).

R_2I_g $\quad 10^6\,\Omega \times 10^{-10}$ $\quad A = 1$ mV

I_gR_2 $\quad 10^{-10}.1 \times 10^6$ $\quad = 1$ mV

= 1% E_T, balancing not important, may be measured or given by manufacturer. 1 mV, 1 mV

− $(1+K)d$; assume: 10 mV referring to input is average value for medium quality DC amplifier. 30 mV

32 mV

EKV_1 balance available: 100 mV − 32 mV = 68 mV.

$EKV_1 = 68$ mV

$$E = \frac{68}{10^3KV_1} = \frac{68}{10^3 \times 2 \times 25} = 0.00136$$

$$E\% = 0.136\% \, |E\%| \approx \left|\frac{100}{1+\beta A}\right|$$

$$A = \frac{100}{\beta E\%} = \frac{100 \times 100 \times 10^3}{33 \times 136} \approx 2200$$

A = necessary voltage gain at the maximum computing frequency to get required accuracy.

(2) *Operational Amplifier with Stabilizer.*

$$-V_2 = KV_1 + \frac{1}{1+\beta A}KV_1 + I_gR_2 + \Delta I_gR_2 - \frac{K+1}{B+1}d - (K+1)d_B \qquad (5)$$

$$K = 2;\ E_T = V_2 \times 0.02\%.$$

Calculation for 50 v output.

errors referring to output:

total error $E_T = 10$ mV

$R_2 I_g = 10\%\ E_T$ (should be balanced-out)0

$\Delta I_g R_2 = 10^{-10}A \times 10^6\Omega = .1$ mV 0.1 mV

$$\left| -\frac{K+1}{B+1} d \right| = \frac{2+1}{50+1} \times 10\text{ mV} \approx 0.6\text{ mV}$$

assuming $B = 50$

$|-(K+1)d_B| = (2+1) \times$

demodulator drift. $\dfrac{}{B} = \dfrac{27\text{ mV}}{50} =$ 1.5 mV

(assuming drift in demodulator = 27mV).

(subtotal of the items above: 3.2 mV)

EKV_1 balance left: 10-3.2 = 6.8 mV 6.8 mV

$EKV_1 = 6.8\ mV$

$$E = \frac{6.8\text{ mV}}{KV_1} = \frac{6.8}{10^3 \times 2 \times 25} = 0.000136$$

$E\% - 0.0136\%$

$$A \approx \frac{100}{\beta E\%} = \frac{100 \times 100 \times 10^4}{33 \times 136} = 22\ 000$$

$A \geqq 22{,}000$

(at max. frequency to be computed).

Appendix 2

The D.C. Amplifier error due to finite gain and the input network configuration:

(circuit of Figure 1 applies.)

error due to finite gain A of the D.C. Amplifier =

$$E_V = \frac{\dfrac{R_1+R_2}{R_1 A}}{1+\dfrac{R_1+R_2}{R_1 A}} = \frac{1}{\dfrac{R_1 A}{R_1+R_2}+1} =$$

$$\frac{1}{1+\dfrac{R_1}{R_1+R_2}A} = \frac{1}{1+\dfrac{1}{1+\dfrac{R_2}{R_1}}A} = \frac{1}{1+\beta A};$$

$\left(1+\dfrac{R_2}{R_1}\right)^{-1} = \beta$ by definition;

percentage error: $\left|E_V\%\right| = \left|\dfrac{100}{1+\beta A}\right|$

assuming: $A = 30{,}000$ $R_2 = 1$ M $R_1 = 0.5$ M

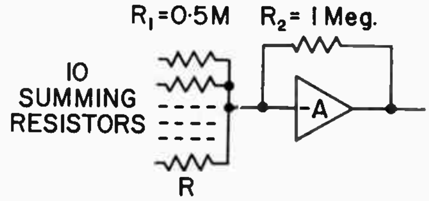
$$\beta = \left(1+\frac{R_2}{R_1}\right)^{-1} = (1+2)^{-1} \approx 0.33$$

$$\left|E_V\%\right| = \left|\frac{100}{1+33\times 10^{-2}\times 3\times 10^4}\right| \approx$$

$$\frac{100}{1+10^4} = 0.01\%$$

$$\beta = \left(1+\sum_{L=1}^{L=n}+\frac{R_2}{R_i}\right)^{-1} = \left(1+10\frac{R_2}{R_1}\right)^{-1} =$$

$$21^{-1} \cong 0.05$$



Assuming $A = 30{,}000$

$$|E_V\%| = \frac{100}{1+5\times 10^{-2}\times 3\times 10^4} = 0.07\%$$

As it is shown above, the error $|E_v|$ increased approximately 7 times due to the change of the input network configuration. It is theoretically possible to compensate for this error by means of adjustment of the feedback or individual summing resistor values. However such adjustment is very tedious and not always practical.

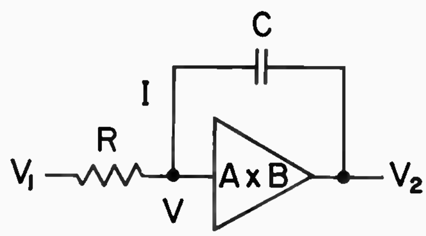
Appendix 3

Operational amplifier-integrator considerations

1. *Integrator Output—general case*

1.1. Nominal putput of ideal integrator

(See diagram below) is:



$$V_2 = V\text{ nominal} = \frac{1}{RC}\int_0^t V_1\,dt.$$

assuming $V_1 =$ const V nominal $= \dfrac{V_1 \times t}{RC}$

1.2. Breakdown of errors at the integrator output.

▶ Error due to offset, drift, chopper pick-up, noise, etc.

This error voltage is integrated in the same way as a signal:

$$E_d = \frac{d \times t}{RC}$$

where d is the error signal referred to the integrator input.

▶ Error due to grid current

$$E_{gc} = \frac{I_g R}{RC} t = \frac{I_g t}{C};$$

▶ Errors due to finite gain of the amplifier and leakage of integrating capacitor.

Knowing that $V_2 = -AB\ V$ (6)

and applying the nodal method at summing point:

$$\frac{V - V_0}{R_l} + (V - V_0)sC - \frac{V - V_1}{R_1} = 0 \quad (7)$$

substituting equ. 6 in equ. 7

$$-\frac{V_2}{V_1} = \frac{1}{\frac{1}{AB} + \frac{sCR}{AB} + sCR + \frac{R}{R_l} + \frac{R}{R_l AB}} \cong$$

$$\cong \frac{1}{\frac{1}{AB} + sCR + \frac{R}{R_l}} = \frac{\frac{1}{\frac{R}{R_l} + \frac{1}{AB}}}{\frac{CR}{\frac{R}{R_l} + \frac{1}{AB}} s + 1}$$

substituting $\frac{1}{\frac{R}{R_l} + \frac{1}{AB}} = n$ and $\frac{CR}{\frac{R}{R_l} + \frac{1}{AB}} = m$:

$$-\frac{V_2}{V_1} = \frac{n}{mS + 1}. \quad (8)$$

The Laplace transform of the step function $u(t)$ is $1/S$, and correspondingly in case of ideal integration:

$$V_2 = V\text{ nominal} = -V_1 \frac{n}{mS}$$

in case of ordinary integration:

absolute error: $\epsilon_{\text{absolute}} = |V\text{ nominal} - V_2| =$

$$= \left| V_1\left(\frac{n}{mS} - \frac{n}{mS + 1}\right)\right|$$

Using the Laplace transform pairs and the approximation

$$e^x = 1 + x + \frac{x^2}{2!}:$$

$$E_V \text{ absolute} = V_1 n\left(\frac{t}{m} - \frac{t^2}{2^{m2}}\right)$$

$$\text{fractional error: } \epsilon_{\text{frac.}} = \frac{t}{2m} = \frac{t\left(\frac{R}{R_l} + \frac{1}{AB}\right)}{2CR} \quad (9)$$

▶1. Percentage error due to finite gain (assuming $R_l = \infty$):

$$E_V\% = \frac{t \times 100}{2CBAR}$$

▶2. Percentage error due to the leakage resistance of integrating capacitor (assuming $AB = \infty$):

$$E_V\% = \frac{t \times R}{2CRR_l} = \frac{t}{2CR_l}$$

2. *Short Time Integration*

For an ordinary analog computing system a typical integration time is generally of the order of minutes. For this length of time, the effect of leakage of integrating capacitor is relatively small. To take advantage of the amplifier capability the output signal after integration should be in range of tens of volts.

Assume: integration time $t = 60$ seconds, input signal $V_1 = 1.5$ volts, input resistance $R = 1$ Meg., integrating capacitor $C = 1\mu F$, polystyne capacitor, 100 PPM/°C, capacitor leakage resistance $R_l = 5 \times 10^5$ Meg per μF., total D.C. gain $A \times B = 2 \times 10^6$; stabilizer DC/DC gain = 75; drift, *ac* chopper pick-up, noise referred to the amplifier input $d = 100$ μvolts; grid current Ig = 10^{-10} Amp.

(*i*) V nominal $= \frac{1}{RC} V_1 t = \frac{1.5 \times 60}{10^6 \times 10^{-6}} = 90$ volts

(ii) drift error $d_v = \frac{d \times t}{RC} = \frac{100 \times 60}{10^6} = 6$ m volts

percentage error $d_v\% = \frac{12 \times 100}{10^3 \times 90} = 0.007\%$

(iii) error due to the grid current:

$$E_{gc} = \frac{I_g t}{C} = \frac{10^6 \times 60}{10^{10}} = 6 \text{ m volts}$$

percentage error $E_{gc}\% = 0.01\%$

(iv) error due to finite gain:

$$\text{percentage error } E_{fg}\% = \frac{t \times 100}{2CBAR} =$$

$$= \frac{60 \times 10^2}{2 \times 2 \times 10^6} = 0.0015\%.$$

(v) error due to the capacitor leakage resistance:

$$E_l\% = \frac{t \times 100}{2\ CR_l} = \frac{60 \times 10^2}{2 \times 10^{-6} \times 5 \times 10^{11}} = 0.006\%.$$

The sum of above errors is approximately 0.03% and an increase of B or AB will not make a practically useful improvement in the error value. Increase of the stabilizer gain will diminish drift but will not cancel the error due to the chopper pick-up and noise. Further increase of AB will diminish error due to finite gain, which is already negligible in comparison to error from other sources. Other factors like the grid current (if larger than 10^{-10} Amp) and tolerance of R and C will mostly contribute to total error.

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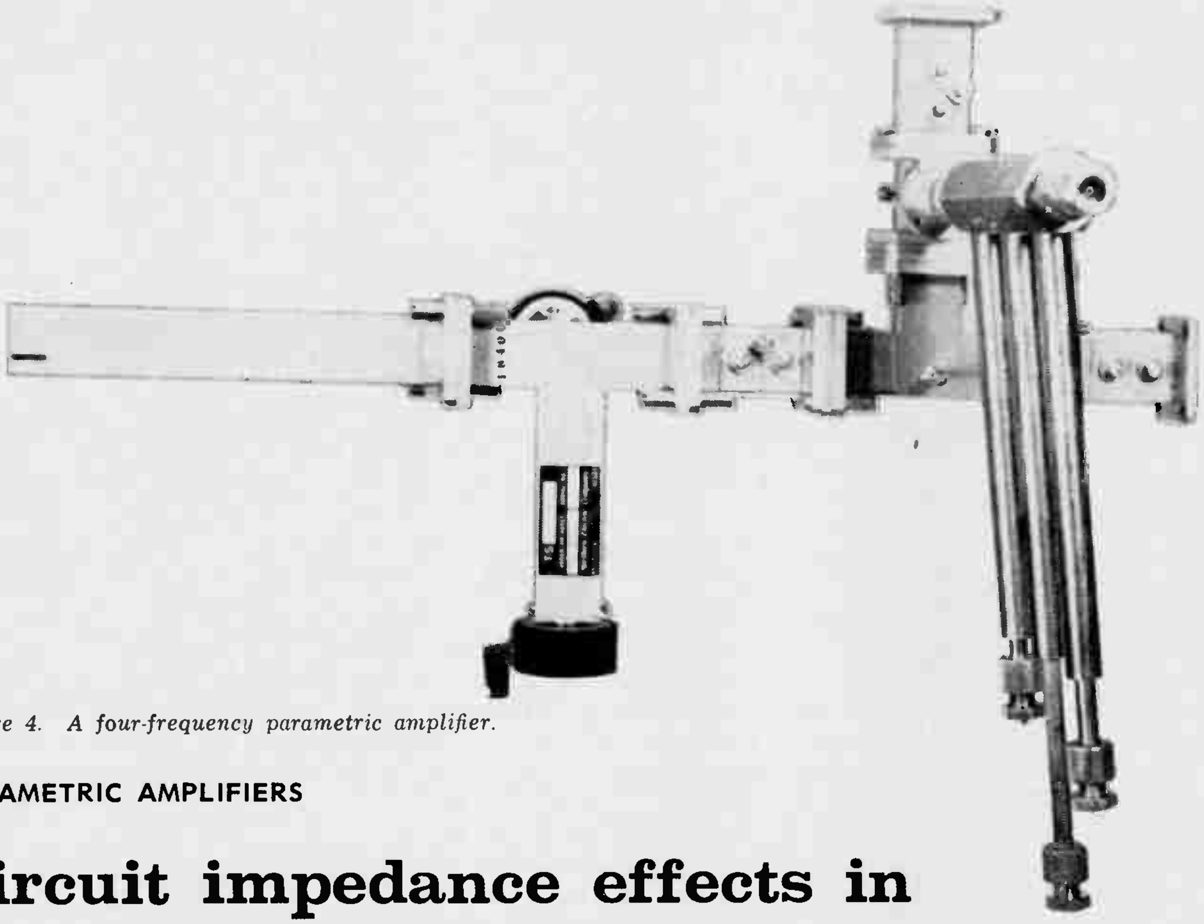

Figure 4. A four-frequency parametric amplifier.

PARAMETRIC AMPLIFIERS

Circuit impedance effects in a non-degenerate parametric amplifier

. . . article uses energy relationships to investigate properties of parametric amplifiers operating in various modes . . . bandwidth and tuning considerations are outlined . . .

by D. G. Vice, P.Eng.

Abstract

From the general energy relations which have been developed for non linear reactive elements under the influence of a high frequency pump and lower frequency signal, it is shown that the terminating impedances presented to each of the various sideband and harmonic frequencies determine the characteristics of the resulting device.

It is the purpose of this article to derive some expressions for energy relationships under various sideband frequency terminating impedance conditions, and then show how these effects are demonstrated in a practical circuit. Bandwidth and tuning considerations are also included in the discussion.

Introduction

Parametric amplifiers are now finding very wide acceptance in radio frequency receivers both for radar and communications purposes, because of the low noise advantage which they offer at UHF and higher frequencies. The early stability problems have been largely solved by the use of new and improved non-reciprocal ferrite devices. And later circuit developments and refinements are making tuneable amplifiers practical.

The idea of producing gain at microwave frequencies in a two terminal diode which is normally thought of as being a passive element, let alone achieving contributions to input noise which are much less than for a simple matched resistor, has captured the interest and imagination of many radio engineers. As a result, a large number of excellent devices have been produced and thoroughly described theoretically in the literature. It is noteworthy that in general, the development of the theoretical models and their properties has preceded that of working models with a significant lead. Consequently, the job of the design engineer has been the realization of these theoretical circuits and conditions, and the attainment of the predicted performance characteristics.

The purpose of this article is to summarize briefly the properties of a parametric amplifier, as governed by the characteristics of the circuits which are em-

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1. fp+s is matched to its output.
2. fs is matched to the varactor input.
3. fp—s is decoupled from the network.
4. fp is, to some extent tightly, coupled to the varactor.

When these conditions are satisfied the amplifier will have maximum gain as given in equation (9).

$$(9) \qquad \frac{Wp + s}{Ws} = \frac{fp + s}{fs}$$

The results of an amplifier constructed to demonstrate an upper sideband upconverter are given in Table 1.

Table 1
Upper Sideband Upconverter

Gain	8.5 db
Bandwidth	16 Mc/s
Input VSWR	1.4:1
Noise Figure	.5 db approx.
Center Frequency	863 Mc/s

Ideally the gain should have been 11.2 db. The loss is attributed to imperfect coupling and circuit losses. This type of amplifier offers stable, low noise, potentially broadband amplification, and would be preferred in use except for the limited gain available, which is often insufficient to adequately mask the following receiver noise contribution.

The physical amplifier consister of waveguide bandpass filters at fp and fp+s connected to a mount containing the varactor, and a low pass filter connected in series with the coaxial signal input to the varactor much as shown in the circuit model of Figure 1.

Lower sideband upconverter

A parametric amplifier with quite different characteristics can be built by matching fp—s to its output and reactively terminating fp+s and all higher order modulation products. Equations 5, and 6 then reduce to 10, and 11.

$$(10) \qquad \frac{Wp}{fp} + \frac{Wp - s}{fp - s} = 0$$

$$(11) \qquad \frac{Ws}{fs} - \frac{Wp - s}{fp - s} = 0$$

This artifice of restriction of the Manley and Rowe relations to only the desired frequencies does not necessarily mean that they play no part in the gain mechanism, indeed the effect of idling currents at these frequencies may be essential to the realization of the properties predicted by the relations. [2]

By similar arguments to those used for the upconverter, Wp is found to be positive, Wp—s is found to be negative, but in this case Ws is found to be also negative. Therefore, power at signal frequency is delivered from the varactor to the input circuit, and hence *negative* resistance is reflected at the signal input terminals.

Following the suggestion of Uenohara [2] this negative resistance can be thought of as emanating from a secondary mixing process between pump and pump + signal. This notion is useful for intuitive understanding.

The amplifier built to demonstrate the properties described was very similar to the upper sideband amplifier except that in this case the idler filter was tuned to fp—s instead of fp+s.

The performance figures which were obtained with the amplifier are shown in Table 2.

Table 2
Lower Sideband Upconverter

Gain	18 db
Bandwidth (3 db)	20 Mc/s
Input VSWR	1.2:1 max.
Noise Figure	2.0 db max. RF/IF
Center Frequency	860 Mc/s

The maximum frequency conversion gain available is derived in the same way as for the upper sideband upconverter. In this case the value will be given by the first factor in equation (12).

$$(12) \qquad \frac{Wp - s}{Ws} = \left(\frac{fp - s}{fs}\right) \cdot \left(\frac{Rg - (-Rv)}{Rg - Rv}\right)^2$$

This value of gain will be nearly achieved when the lower sideband is matched to its circuit, that is, the conjugate of the varactor impedance at the idler frequency is presented as the idler termination, and the upper sideband is completely suppressed. This is also seen to be the condition for the maximum negative resistance at signal input. When these conditions have been met, the final determination of gain is made by the signal generator impedance, i.e. the input tuning. To illustrate this, assume that in a simple case the real part of the impedance reflected to the input generator is $-R_v$, and the conjugate of the reactive part has been cancelled out by the generator tuning. The gain due to this negative, resistance will be the reflection coefficient on the input line as might be measured by VSWR method. It must be kept in mind, between that for a negative resistance, the reflection coefficient is the reciprocal of the reflection coefficient

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for the same VSWR measured for a positive resistance. To convert to power gain the square of the reflection coefficient is used. This part of the gain is given by the second factor in equation 12, where Rg is the generator resistance.

The total amplifier gain is given, by the product of the frequency conversion; and negative resistance gain. All that is required to achieve the desired amount of gain, is to alter Rg to the appropriate value by some tuning means; for example a double stub tuner, or a quarter wave slug type transformer.

One port non-degenerate amplifier

It is desired to use this amplifier not as an upconverter but as a signal frequency one port, it is the amplified reflected signal that is coupled out, using a circulator. The up-converted signal at idler frequency is not used, and may be terminated. More sophisticated circuits use the varactor series resistance for the termination, for noise advantage.

In order to achieve the same gain as for the upconverter — a value which will normally be governed by the post receiver noise contribution, then the value of the second factor in equation 12 must be increased. Since the value of —Rv will normally be fixed by other considerations, the gain can be increased by reducing R_x to a suitable value.

Bandwidth and tuneability

This far, the amplifier has been described in terms of the circuit conditions surrounding it, the characteristics being a sort of reaction to its circuit conditions.

There is no inherent bandwidth limitations, other than the probable triangular gain characteristic with decreasing signal frequency. Therefore, the amplifier is capable of operating over whatever band the conditions of the derived energy relations set out can be maintained. Tuneability can be achieved by altering the signal and either pump or idler frequencies over which these same conditions can be maintained.

Tuneability following this basic idea has been demonstrated: by altering the frequency at which the fp—s is matched to its circuit, and the frequency at which the input is tuned, at L band signal, in an amplifier designed for rapid pre-set tuning adjustment. Figures for this amplifier are given in Table 3.

Table 3
Non-degenerate One Port

Gain	18 db
Bandwidth (3 db)	10 Mc/s min.
Input VSWR	1.3:1 max.
Noise Figure (including circulator)	2.5 db max.
Center Frequency	1280 — 1350 Mc/s

The four frequency parametric amplifier

In order to investigate the effect of losses in both upper and lower sideband upconverters, an amplifier was constructed, a little more closely resembling the equivalent circuit of figure 1.

In this case a shunt tee junction in waveguide was used for idler termination, which was matched, through the use of pass band filters, for both upper and lower sideband signals. Any impedance from a matched load to a short or open circuit was possible at either upper or lower sideband. The results were much as expected from the Manley and Rowe power relations.

The gain of a lower sideband converter could be increased or decreased with fp—s and fp+s termination adjustment and the gain of the upper sideband converter could be also increased or decreased in the same way. The quantitative results of this investigation are not yet complete, except for the amplifier described later.

Figure 3 is a photograph of the selectively tuned sideband circuit.

The construction of the sideband load impedance for a parametric amplifier is as follows:

- **First** The tee is matched by means of a screw at the junction for the band of frequencies being used.
- **Second** With a load on the leg designated for fp—s, the fp+s filter is placed to obtain a match at fp—s.
- **Third** With a load on leg fp+s, the fp—s filter is placed for a match at fp+s.
- **Fourth** The whole assembly is placed to satisfy pump coupling conditions, and the amplifier is ready as an upper or lower sideband amplifier with variable sideband termination depending on how it is connected.

Considering once again the upper sideband upconverter, quite an unexpected result is obtained when the upper sideband upconverter is constructed using the selective circuit in such a way as to have power dissipated in the lower sideband. In this case there is possible unlimited gain to the upper sideband, as will be demonstrated.

This peculiar result was first reported so far as is known by David K. Adams[4] in the May 1960 transaction on microwave theory techniques. The writer had been aware of this very peculiar phenomenon early in 1960 quite independently, but at that time no really satisfying explanation of the mechanics involved could be set forth.

Considering the Manley and Rowe relations once again, equations 13 and 14 are written to include fp+s and fp—s.

$$(13)\qquad \frac{Wp}{fp} + \frac{Wp+s}{fp+s} + \frac{Wp-s}{fp-s} = 0$$

$$(14)\qquad \frac{Wp+s}{fp+s} - \frac{Wp-s}{fp-s} + \frac{Ws}{fs} = 0$$

From equation 12, by similar argument used before, power is seen to be flowing into the network at both fp+s and fp—s. From equation (15), below:

$$(15)\qquad \rho^2 = \frac{Ws\text{ in}}{Ws\text{ out}} = \left[\frac{Rg-(-Rv)}{Rg+(-Rv)}\right]^2$$

From 15, it may be deduced that both the value and sign of W_s is determined by the value of Wp+s and Wp—s.

The gain expression for an amplifier which has all four frequencies present is given in equation 16. It can be seen that if Wp—s is not zero, the denominator can become very small, indicating large gain.

$$(16)\qquad \frac{Wp+s}{Ws} = \frac{1}{\dfrac{fs}{fp+s} - \dfrac{Wp-s}{Wp+s}\left(\dfrac{fs}{fp-s}\right)}.$$

Because Wp+s and W_s are both positive, there will be *no negative resistance* reflected to the input, even if the gain becomes very large.

A four frequency parametric amplifier was constructed using the selective sideband arrangement of Figure 3. It is shown in Figure 4. A stub tuner is used at the input to match the input circuit. With a short circuit on the fp—s leg and coupling output from the fp+s leg, the amplifier behaves as the normal upper sideband upconverter. However, when the short circuit is removed, and a tuneable load is substituted, by playing back and forth between the input tuning, and the fp—s tuning, very large gains can be achieved.

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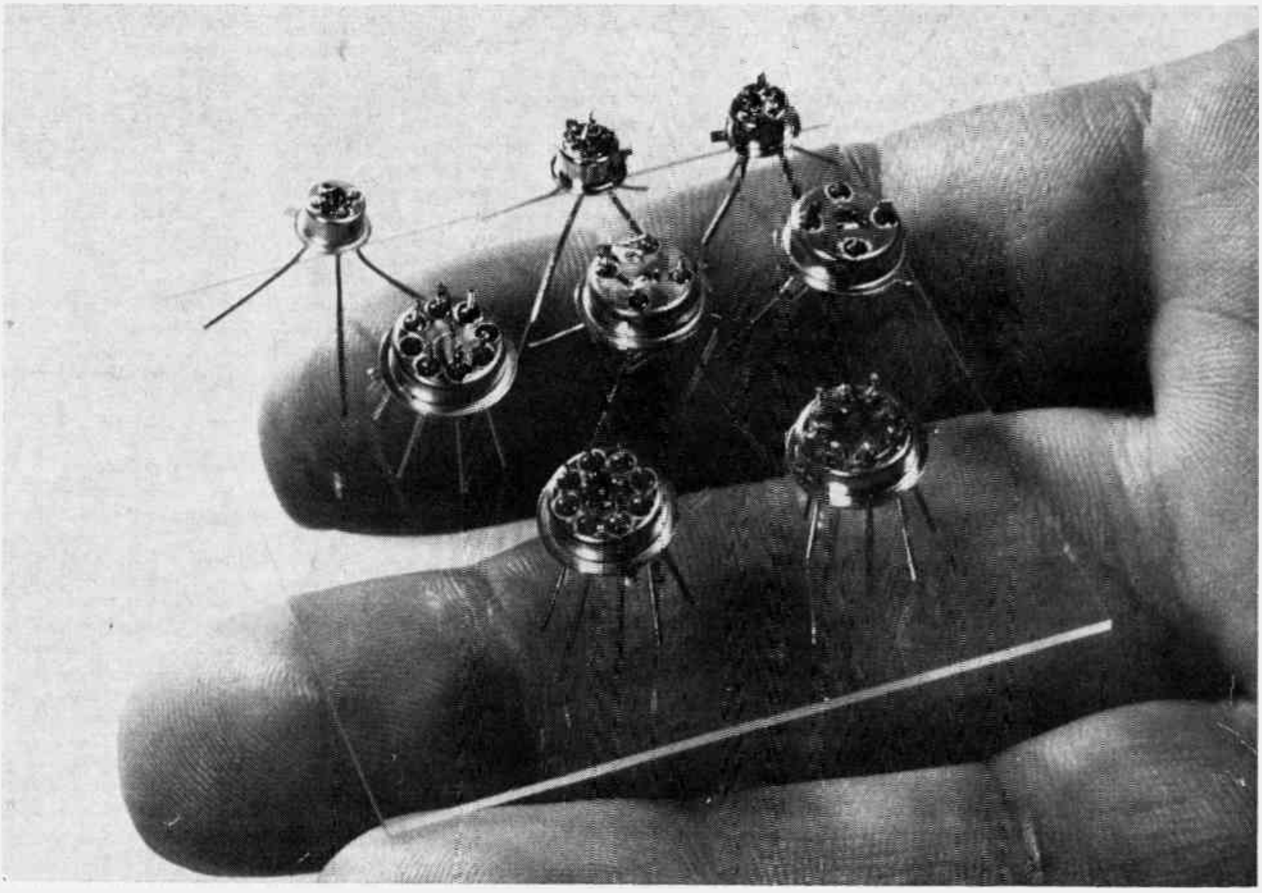


Figure 1. Photograph showing a group of multi-circuits and one thin film circuit (front row, right side).

MICRO-ELECTRONICS

Three approaches to micro-electronics

. . . at present, no single micro-electronics approach will meet the full requirements of the equipment designers. . . . Philco have created three new structure types to give widespread application.

by William F. Long*

(This article was condensed from a comprehensive research report written by Mr. Long.)

Modern equipment design makes an insistant call for the continued reduction in the size of electronic devices and circuits. There would appear, however, to be no single approach to this problem that is capable of meeting all requirements, consequently, a micro-electronics technique ideal for one class of equipment might be non-optimum for another. Evidently, the basic problem of implementing the micro-electronic concept is best approached from a number of standpoints. This permits classes of micro-electronic devices to be developed for a number of engineering areas yet keeps in focus the many different facets of this wide field.

Philco's developments in the micro-electronic field are slanted to present-day equipment needs and to those of the foreseeable future. Detailed system approaches have indicated that three main lines of attack will best serve the industry's requirements and are classified as (a) multi-element circuits, (b) thin film circuits, and (c) solid-state circuits. Research and development in these three areas of technology have resulted in the realization of practical, reliable and highly efficient circuits of many different configurations and uses.

*See page 46

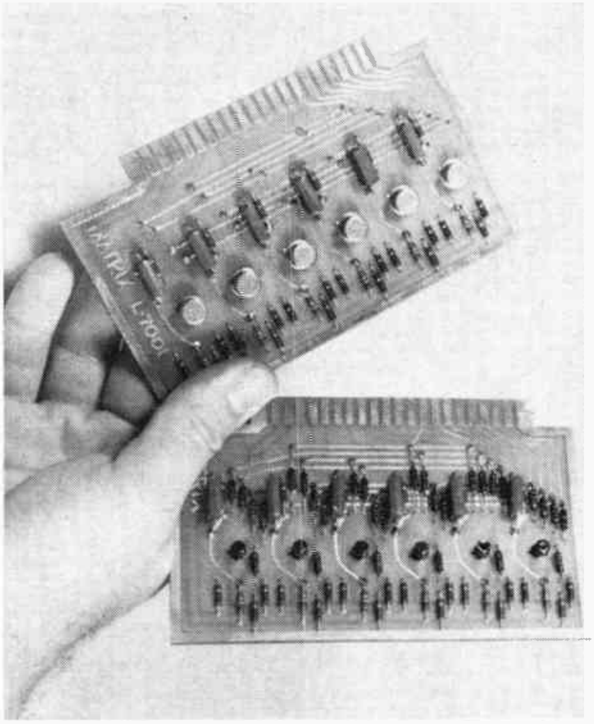


Figure 2. Photograph illustrating economy of external conductors and components using Multi-circuits (upper circuit board) compared to conventional transistors (lower). Both boards have the same electrical performance.

- increased reliability and lower cost . . . fabrication is simplified because the components are not individually sealed.

Systems reliability is also increased because of the internal interconnections within the package. These are welded or soldered and are made under controlled conditions, hermetically sealed and temperature cycled. Such connections are therefore intrinsically superior to those made in the external circuitry.

The mechanical packaging of the components is such that electrical interaction between them is minimized or non-existent. Furthermore, in most instances, lead inductance and stray capacitance are also minimized.

Thermal interaction between components is present in all high-density packaging techniques. For example, the junction temperature of an individual transistor or diode is influenced by the operating temperature of adjacent elements; as is well known, the higher the junction temperature, the greater the value of leakage and reverse currents. In the case of the multi-element concept, the component specifications are designed with this thermal interaction problem in mind. Internal power levels acceptable for reliable operation are determined by thermal drop measurements and "on-load" life tests, thus the magnitudes of thermal interaction between the components is established at the outset and is therefore not subject to the vagaries of conventional high-density packaging.

Multi-element-components are available in a variety of transistor and diode combinations to suit many different applications. A group of these new devices is

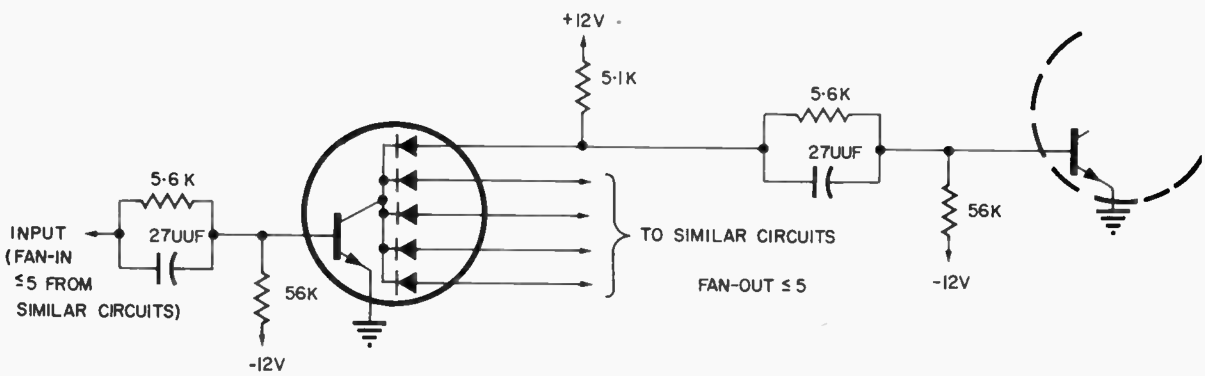


Figure 3. Circuit diagram of basic DTL inverter using Multi-circuits.

This article treats each of the cited techniques in turn and gives an outline of fabrication methods, performance and application.

Multi-element components

In almost all respects the properties of multi-element-components are identical to those of conventional discrete components interconnected in the same fashion. Identical electrical performance of the elements to that of conventional oriented circuits is assured by specifying the ratings, characteristics and performance of each component. An obvious advantage of the multi-element concept is that the components of the package can be selected to suit specific types of application, thereby facilitating the work of the design engineer.

The major advantages of the multi-element-component technique are:

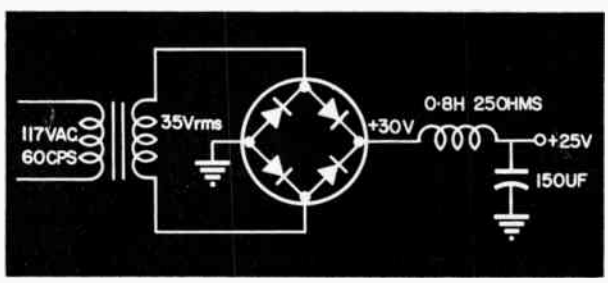
- fewer external connections . . . internal connections between components are made wherever possible.
- small circuit size . . . many components can be placed in a case which normally would contain just one transistor.

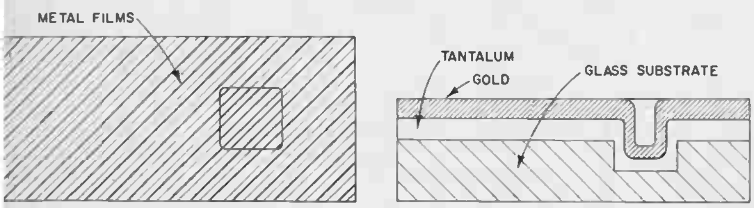
shown in the photograph, Figure 1. The significant reduction of external components brought about by the use of the multi-circuits is graphically shown in Figure 2, where, in addition, the reduction in the number of connections is clearly evident.

Fabrication

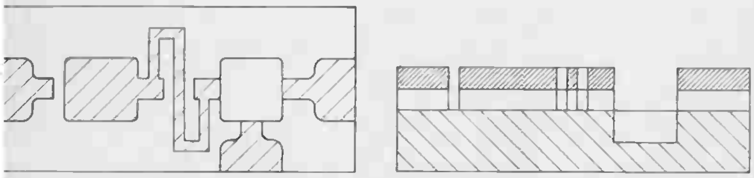
The processes used in fabricating Philco multi-element-components were developed to achieve units of high reliability and lowest possible cost and stem from

Figure 4. Multi-element-circuit used in AC to DC converter.

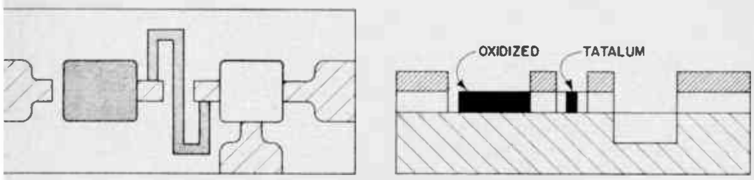




(a) Sputtered tantalum and gold films.



(b) Photo-engraved and etched overall pattern.



(c) Above: addition of etched and anodized resistor and capacitor pattern. (d) Below: inserted active elements and evaporated aluminum counter electrodes and connections.

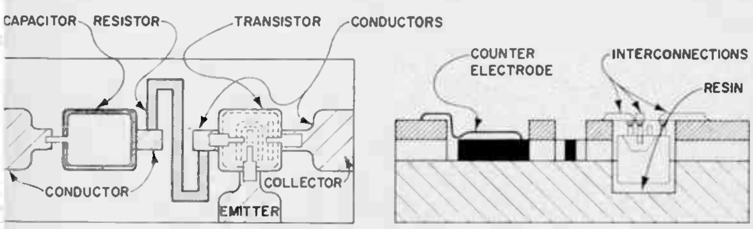


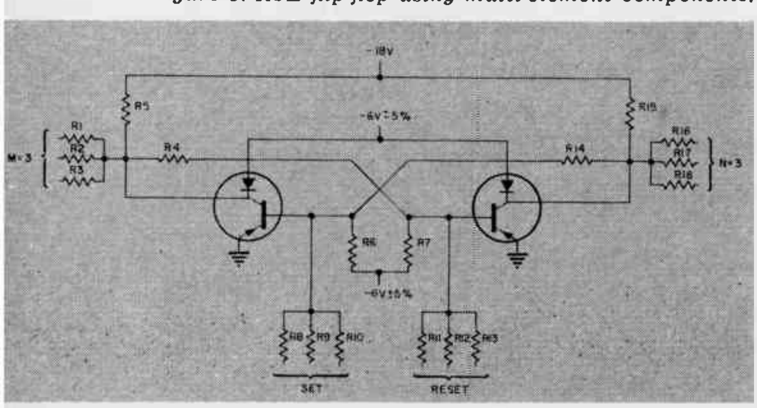
Figure 6. Steps in the manufacture of thin-film circuits.

the basic technology that has been used for the manufacture of million of semiconductors.

The circuit elements available in multi-element-components include precision-etch, alloy, epitaxial and planar configurations. The diodes are made by planar and gold bonding processes which have been tailored to special fabrication needs. In-process testing is an integral part of fabrication, providing high yields with uniform characteristics.

Diodes are made on an automatic machine which performs the following steps automatically after a silicon blank bonded to a TO-5 or TO-18 header is placed in the lead-attacher:

Figure 5. RTL flip-flop using multi-element components.



- gold wire is fed from a spool and stops when the blank is sensed.
- a high current pulse is passed through the wire, forming a P-N junction between the wire and the semiconductor.
- the diode is tested for forward and reverse voltages and leakage currents.
- if the diode is acceptable, the leads are cut and bent and the blank indexed to the next position where the procedure is repeated (up to 8 diodes can be formed on a single blank).
- if the diode is rejected, the wire is pulled away from the junction and clipped . . . the blank is then indexed one fourth of the way to the next station and the bonding procedure repeated.

In order to obtain the same characteristics for common anode elements as are found in the common cathode versions, each diode is formed on a separate, smaller wafer. since the negative terminals of individual diodes must be isolated. The basic gold-bonding process, however is similar to that described above, including the in-process testing.

Applications

As mentioned previously, the multi-element components have a very wide field of application and therefore in this section it is only possible to touch upon a few of these in outline.

The Author

Mr. William F. Long is the manager of the Micro-electronics Department of the Philco Corporation, Lansdale Division.

A basic DTL inverter with a fan-in and a fan-out is shown in Figure 3. This circuit has proved to give reliable operation at high speeds and with good noise immunity.

A typical AC-to-DC converter application of the 4-diode unit is shown in Figure 4. The circuit provides up to 30 volts of unfiltered DC output at a load current of 200mA with a guaranteed minimum conversion efficiency of 75 per cent. At the output of the "L" section filter, an output voltage of 25 volts is available at 200mA of load current with a ripple factor of 0.01.

Cross-coupling two inverter gates forms the RTL flip-flop shown in Figure 5. The flip-flop is capable of driving three loads from each collector. Rise times of the order of 50nS are obtained at an input repetition rate of 2Mc/s. The addition of simple steering networks produces a binary counter with rise times between 45 and 55nS and repetition rates of 1.5Mc/s. The addition of cross-coupling capacitors extends its useful counting range to 5Mc/s.

Thin film circuits

Philco's approach to thin film micro-electronic circuits stresses two important facts: (1) the fewer the number of steps required to make a circuit, the higher the reliability and the lower the cost; 2) a monometallic system for the formation of the basic circuit pattern is more economical and presents fewer problems than a bimetallic system.

Through the use of photo-resist masking for accurate deposition of passive circuit elements, the complexity of the fabrication process has been reduced to a minimum. A single material — tantalum — is used as the basis for passive circuit elements and inter-connections, Because of its high sheet resistivity tantalum is suitable for the formation of resistors; also, this metal can be easily and controllably anodized and is therefore an appropriate choice for the fabrication of two-dimensional capacitors. The use of tantalum as a "wiring" medium virtually eliminates all internal interconnections. In addition, the stability and corrosion resistance of tantalum thin film circuits in a hermetically sealed environment gives assurance of maximum system reliability.

A further advantage of tantalum thin-film circuits is the uniformity achieved in fabrication regardless of the type of circuit involved. It is only necessary to change masks to form different circuit arrangements . . . the process remains the same. Masks can be prepared quickly and inexpensively thus promoting short lead time and directly benefiting engineers in the design phase.

Fabrication

Thin film conductors and components are formed by a series of co-ordinated operations of sputtering, evaporating, photo-engraving and etching. Their electrical characteristics are held to close tolerances by the nature of these techniques. Assemblies of transistors and/or diodes are mounted in the conventional manner or embedded in a resin and interconnected by means of evaporated conductors. Where the circuit is to be hermetically sealed in a transistor case, the substrate is mounted on the stem of the case and solder connections are made between the substrate conductors and the leads of the case. Such a construction is shown at the lower right of Figure 1.

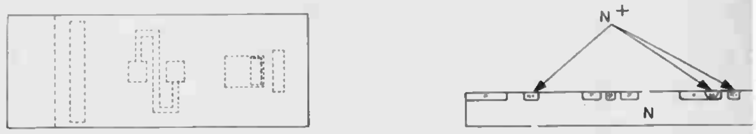
The selection of a suitable substrate material is an important consideration, since this influences the structure of the deposited metallic layer as well as the transfer of heat from the circuits. Thin glass substrates have been found to possess the necessary properties required by the process. Such substrates against a metal backing offer good thermal conductivity, high di-electric strength, chemical inertness, and a smooth flat surface capable of being machined to the very close tolerances required.

Tantalum oxide (Ta_2O_5) reproducibly formed by localized anodization, provides di-electric for the capacitors as well as means for the accurate adjustment of the ohmic value of resistors. When overlaid with gold in selected areas, the resultant film forms the basic high conductivity wiring pattern.

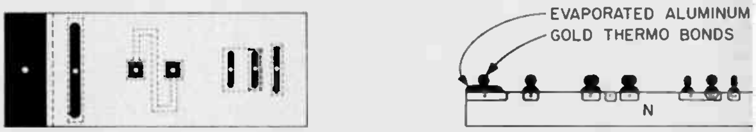
Film deposition

The main process stages for the thin film fabricated units are indicated in Figure 6. Thin tantalum films are deposited on the surface of the glass substrate by sputtering or evaporating techniques. (Figure 6a) Sputtering has been found to be the most successful, producing controllable films of high uniformity and excellent adhesion to the substrate.

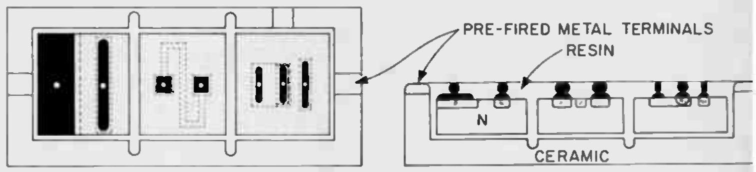
The incorporation of gold and tantalum cathodes in one fabrication system offers a rapid and contamination-free system of depositing the tantalum and gold overlay materials on the substrate in vacuo. This is accomplished by a rotating mechanism which sequentially exposes the glass substrate to the tantalum and gold sputtering process without breaking the vacuum, while continuously monitoring the deposited material. Present machines are capable of processing sufficient substrates to produce 320 one quarter inch diameter thin film circuits from one loading.



(a) Oxide masked, photo-engraved, etched and diffused silicon wafer.



(b) Aluminum evaporated, alloyed and thermo-compression bonded contacts.



(c) (above) Circuit mounted on ceramic wafer with individual components isolated. (d) (below) Interconnected with evaporated aluminum conductors.

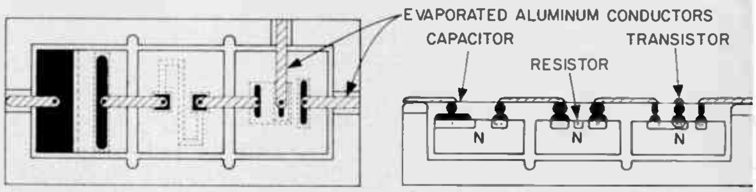
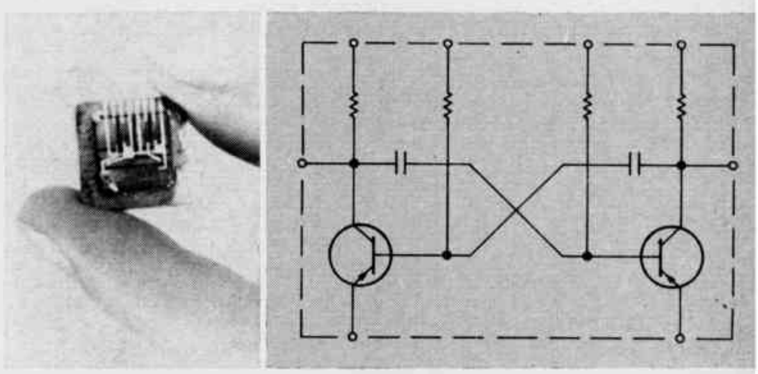


Figure 8. Diagram showing fabrication steps in the manufacture of solid-state-circuits.

Capacitor design

Capacitors are formed by localized electrolytic exidation of tantalum and the evaporation of aluminum or gold counter-electrodes. The voltage capacitance product of these capacitors is approximately 6.5 volt. μF per sq. cm. with a dissipation factor of approximately 0.01 and typical leakage current of 10_{-9} amps. The finished micro-miniature capacitors normally range from 30μμF to 0.05μF, controlled within ± 5 to 10 per cent with breakdown voltages in excess of 30 volts. Typical temperature co-efficient of the fabricated capacitors is 250 ppm/°C.

Figure 7. Circuit diagram and photograph of "thin-film" multivibrator.



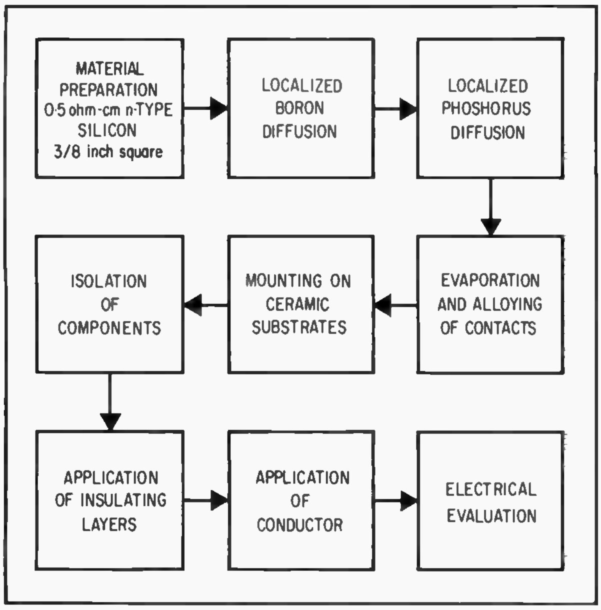


Figure 9. Materials flow chart for solid-state-circuit manufacture.

Representative thin film circuits

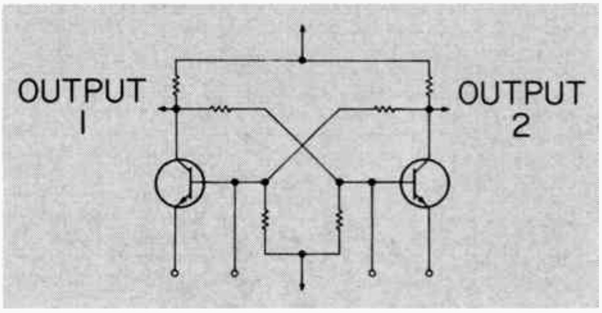
Standard transistor and diode assemblies are either inserted in the substrate (Figure 6d) or mounted on the stem of the case, depending upon the packaging technique. Two approaches to the fabrication and assembly of thin film circuits are illustrated in Figure 1 and 7. The RTL NOR pack in Figure 1 utilizes standard and proven transistor packaging techniques. It contains five resistors on a 0.25 inch diameter glass substrate and a silicon transistor mounted on the stem in a conventional manner. Figure 7 is a multivibrator circuit in which the transistors are embedded in a resin and interconnections are made by evaporation techniques.

Silicon solid state circuits

Silicon solid state circuits represent a higher level of component integration than either of the two classes discussed so far. The unique behavior of solid state resistors and capacitors and the number of processing steps require a more complex design and engineering effort to produce functional blocks with performances comparable to the other micro-electronic approaches.

The solid state circuit approach is particularly well suited to circuit functions accomplished for the most part by active circuit elements and in cases where a single design is required in quantity to meet a single functional specification. The use of such functional blocks in these cases provide equivalent systems performance to that obtainable using conventional circuit practices, and in production quantities may well result in a lower overall system cost.

Figure 10. Circuit diagram and photograph of solid-state-circuit flip-flop.



Fabrication

The fabrication process for silicon solid state circuits developed by Philco makes use of photo-lithographic and oxide masking techniques as indicated in Figure 8. Boron and phosphorus diffusion are used to form circuit elements of the desired configuration in a single wafer of silicon. The complete solid state circuit may be encapsulated in resin or a hermetically sealed package. A fabrication flow chart is shown in Figure 9.

A unilateral system of fabrication is used . . . circuit elements are formed by diffusing into only one side of the silicon wafer. This feature offers outstanding advantages: (1) improved reproducibility, since the variables introduced by aligning optical masks on two sides of the wafer are eliminated; (2) improved power dissipation since the unused side of the wafer can be used to transfer heat away from the unit. In addition, because the circuit elements do not protrude above the surface of the silicon wafer, the device can be surface passivated to provide stability of the electrical characteristics.

To avoid the two-sided structure of conventional transistors (emitter and base connections on one side, collector on the other) a silicon unilateral, transistor has been developed. This transistor has been adopted as the standard active element for this type of micro-electronic solid state circuit.

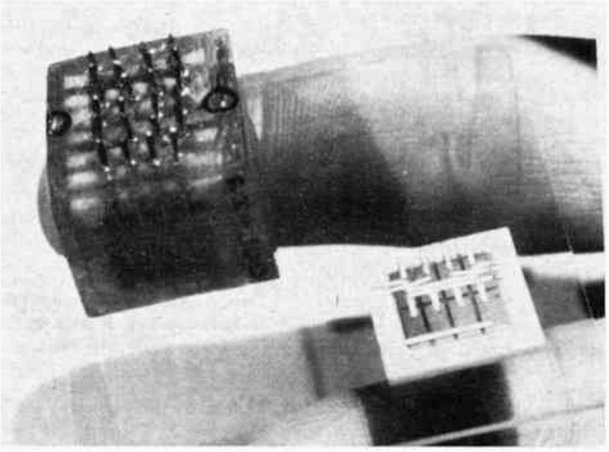


Figure 11. A solid-state-circuit commutator.

A high resistivity N-type silicon wafer is the basic material for the circuit. Active elements are formed in the wafer by separate boron and phosphorus diffusions using oxide masking. Passive elements are formed during the boron diffusion: aluminum contacts are applied to the elements by evaporation. The wafer is mounted on a ceramic substrate. The circuit elements are isolated and aluminum interconnecting strips are deposited over the insulating surface by evaporation. Except for encapsulation, the silicon solid circuit is now complete.

Typical solid state circuits

A silicon solid state flip-flop circuit is illustrated in Figure 10. Used as a binary counter, this circuit can be used at a maximum input rate of 1Mc/s, and can drive eight other units at an input rate of approximately 0.5Mc/s.

Figure 11 shows a silicon solid state commutator matrix containing six solid state circuit wafers. Each wafer contains 16 diodes and four resistors together with appropriate interconnections. The commutator selects any one of 24 inputs and connects it to the outputs.

A new circuit concept for RF amplifier design

by W. A. Rheinfelder*

Introduction

Equivalent circuits correctly used to explain the operation of transistors can be misleading and should be used with considerable care. Often one is led to believe that a circuit like a hybrid-pi permits the accurate calculation of high frequency performance but this is rarely valid. It is often overlooked that all transistor parameters are not only functions of current but also of frequency, and that these values are at best a guide and only applicable over a small frequency range.

An attempt is made herein to explain some of the effects that are not clearly understood through the application of currently used equivalent networks. Also, a new practical circuit design is set forth which has already proved itself by extending high-frequency transistor limits and increasing circuit gain.

Among several effects usually neglected in presently accepted equivalent networks are the internal feedback paths existing within transistors. The base-emitter capacitance $C_{b'e}$, for example, contains a term which is due to internal Miller effect and exists even with the output short-circuited owing to intrinsic collector resistance and high transconductance, g_m. Also, as will be shown, an emitter inductance as small as 10nH in conjunction with a $C_{b'e}$ of 10 pf produces a resistive input component which in a typical case reduces $R_{b'e}$, from 1000Ω to a third of this value at 100 Mc/s. This effect follows at least a 6 db/octave slope and by itself explains the loss of high frequency power gain in transistors in a manner which is quite different from present equivalent circuit concepts.

Similar effects are observed in vacuum tubes, but their magnitudes are much smaller because of the lower g_m. In transistors, the *intrinsic* g_m (g'_m) of the junction can be as high as 500,000 μmhos, or more, although the actual *effective* g_m is much lower due to internal and external emitter impedances. An emitter impedance of only 2Ω, for example, reduces g'_m by roughly 50 per cent and it can easily be shown that with a load resistance of only 10Ω, a voltage gain of 5 is obtained by using g'_m in the standard formula. Since the intrinsic collector resistance of a transistor is usually much higher than 10 ohms, the internal voltage gain and Miller effect — with output shorted — could be very high.

Considerations of this kind lead to very different equivalent circuits; $R_{b'e}$ and $C_{b'e}$ are no longer constants but depend rather on the effectiveness of bypassing the emitter, and can change radically. The same is true for the parallel output resistance and capacitance of the transistor.

Total emitter inductance

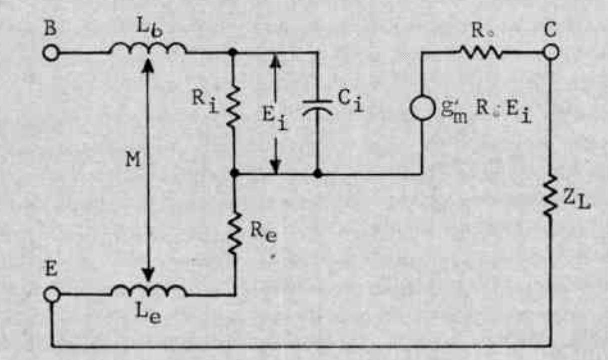
The parameter most severely affecting the high-frequency performance of transistor circuits is the total emitter inductance. This quantity includes (1) the inductance of the bonding lead from the emitter to the header pin, (2) the inductance of the transistor's emitter lead, and (3) the inductance of external leads and parts connected in the emitter circuit. While mechanical improvements can be made to decrease the internal emitter inductance, the advantage gained is small due to the larger inductance normally inherent in external circuitry. Total lead lengths, however, including the emitter lead as well as those of associated circuit parts between the header of the transistor and input ground, do become important considerations. It is necessary, therefore, to develop methods for the removal of the detrimental effects caused by these inductances.

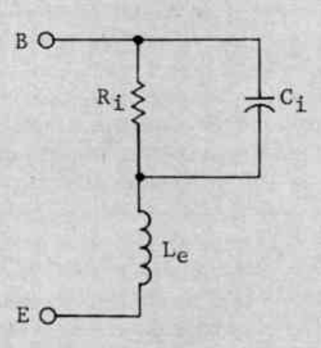
Emitter inductance loss calculations

The total emitter inductance of a typical transistor with short lead length is about 13.5 nH. The reactance at 100 mc is then 8.5 ohms. In series with this reactance there is an ohmic resistance of 0.35 ohm. To examine

*See page 52

Figure 1. (left) Equivalent circuit of transistor. Figure 2. (right) Simplified network neglecting L_b, R_e and M.





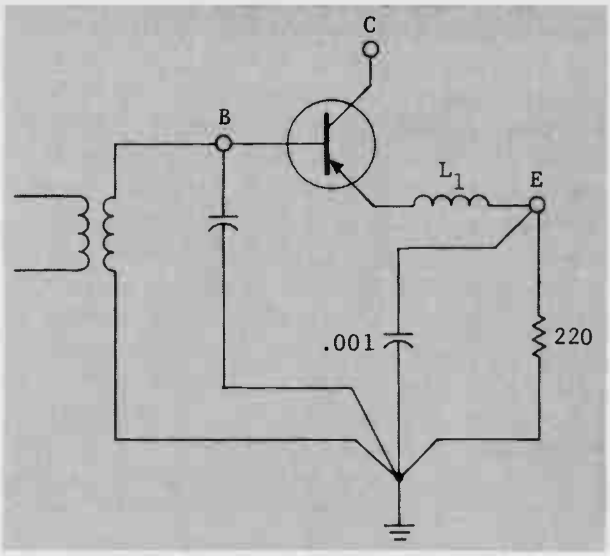


Figure 3. Conventional circuit with emitter by-passing.

the effect of this inductance, the following short analysis commencing with the power gain formula a (1) is undertaken.

$$G_e = \frac{g_m^2 R_{in} R_L}{4}. \qquad (1)$$

Loss in g_m: The loss in g_m is determined by (2).

$$g_m = \frac{g'_m}{1 + g'_m Z_e} \qquad (2)$$

where

g_m = effective transconductance,
g'_m = intrinsic transconductance, and
Z_e = emitter impedance.

With

g'_m = 0.2 mhos and
$Z_e = R + jX_L = 0.35 + j8.5$,

solution of equation 2 yields

$g_m = 0.49\ g'_m$.

The loss in power gain due to loss in g'_m is therefore 6.1 db (from equation 1).

Loss in input resistance R_{in}: The equivalent circuit of the transistor is shown in Figure 1. Neglecting L_b, R_e and M, the circuit simplifies to that of Figure 2. After writing the loop equations for this case and some manipulations, the following expression for the input admittance is obtained.

$$Y = (G_i + jB_i)\left[1 - \frac{g'_m + G_i + jB_i}{g'_m + G_i + j(B_e + B_i)}\right]. \qquad (3)$$

Separating real and imaginary parts, an expression for the input resistance is deduced:

$$R_b = \frac{(g'_m + G_i)^2 + (B_e + B_i)^2}{B_e G_i (B_e + B_i) - B_e B_i (g'_m + G_i)}. \qquad (4)$$

With only a small error, this simplifies to:

$$R_b = \frac{g_m^2 + {}'B_e^2}{B_e(B_e G_i - B_i g_m)}. \qquad (5)$$

Typically the values for a 2N700 transitor are:

g'_m = 0.2 mhos
$G_i = 10^{-2}$ mhos
B_e = —0.118 mhos
$B_i = (6.2)10^{-3}$ mhos.

This assumes a capacitance from b′ to e of 10pf. Calculating R_b from expression 4, the result becomes:

R_b = 330 ohms.

The input resistance has therefore decreased from 1000Ω to 330Ω due to the action of the inductance of 13.5 nH. The loss in power gain, according to (1), is 4.8 db. In summary, the calculated losses for the 2N700 transistor become:

Loss in g_m — 6.1 db
Loss in R_{in} — 4.8 db
Total — 10.9 db at 100 mc.

The intrinsic g_m used in the above calculations was conservatively chosen at 0.2 mhos. In practice, measurements have shown intrinsic g'_m values of up to 1.0 mho. The actual losses in practical circuits, therefore, run much higher than those calculated.

Emitter bypassing

In wide band amplifiers the problem must be solved by short total lead length, but various methods of effective bypassing in tuned amplifiers exist. Figure 3 shows a conventional circuit wherein the emitter bias resistor, of typically 220 Ω, is bypassed with a 0.001 μf capacitor. The internal emitter inductance from the junction to the end of the emitter lead is designated L_1. This conventional circuit is regarded as the reference case and all other circuits are compared to it.

Because the bypass capacitor shown contains series inductance and is therefore a poor bypass capacitor, the thought may arise of connecting a series resonant capacitor in parallel. Such a capacitor may be selected in practice by the well-known method using a grid dip meter, whereby the leads of the capacitor are connected together and the resonance frequency determined. The lead length may be trimmed and the capacitor value selected for a particular frequency. For 100 mc a value

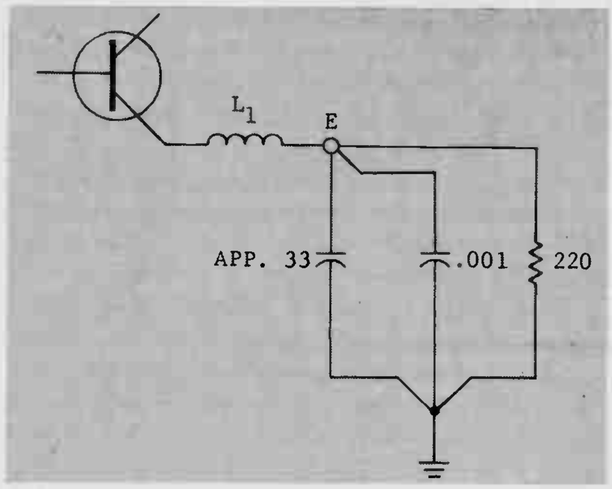


Figure 4. The modified emitter circuit.

of from 30 to 43 pf is obtained. Using the grid dip meter to determine resonance, however, is not a very accurate method: in joining the leads the inductance of the capacitor is increased and also a resonance including L_1 is required. Therefore the final adjustment should be made in the circuit, as shown in Figure 4. It is also found that the inductance of the parallel 0.001 μf capacitor can form a parallel resonant circuit with the newly installed capacitor. This tends to obscure the effect and in some cases the gain actually is decreased. It is therefore necessary to remove the 0.001 ref. capacitor.

This leads to the circuit shown in Figure 5. This arrangement gives a definite increase in gain with the proper capacitor, but the increase is disappointingly small — less than 6 db, while theoretically much larger figures should be possible.

From Figure 5 it becomes evident that the parallel resistance reflects into the series resistance of the series tuned circuit, therefore the Q is very low and the series resistance at resonance very high. Behavior is in effect that of a "lossy" capacitor.

In order to remedy this situation, an rf-choke is used as shown in Figure 6 to isolate the effect of the emitter resistance. Also a variable trimmer is provided because the Q now becomes quite high and a tuning adjustment becomes necessary.

This circuit leads to very acceptable results. An external series coil may be used to reduce the size of the tuning capacitor at low frequencies. Because of the reduction in Q, it is suggested, however, to use the smallest series coil which leads to the desired results.

Stage performance

The Q of the series resonant circuit in Figure 7 is mainly determined by R_1 which is the equivalent emitter series resistance. This is very close to the intrinsic emitter resistance, r_e, and is a function of emitter current. By changing the emitter current the Q of the series resonant circuit can be changed but the resonant frequency is unaffected and remains constant. The circuit shown in Figure 7 effectively uses the intrinsic g'_m of the device, approximately:

$$(6) \quad g'_m \sim \frac{1}{r_e} \sim \frac{J_e}{25} \text{ (for germanium, } J_e \text{ in mA).}$$

With an emitter current of 5 mA $g'_m = 200{,}000$ μmhos. If a circuit could be designed to utilize this high g'_m very high power gains even with small load resistances and the circuit of Figure 7 could be realized.

For the voltage gain, approximately:

$$(7) \quad A \sim \frac{g_m R_L}{2},$$

and for the power gain

$$(1) \quad G \sim \frac{g_m^2 R_{in} R_L}{4}.$$

The values used in the expressions above are the values as measured in practical circuits including effects due to feedback in the emitter. As the feedback is decreased, g_m approaches g'_m, R_{in} increases because of phase shift, and R_{out} decreases as the current feedback is decreased. In a cascade of stages this means that the matching ratio is reduced considerably.

The high gain results in a tendency towards oscillation in small signal amplifiers, due to feedback capacitance from collector to base. It is well known that by mismatching at the output, voltage gain may be decreased a little or no expense in power gain. Typically a load of one fourth the output resistance decreases voltage gain by 8 db at the expense of 2 db in power gain. This 2-db loss can normally be offset by a better interstage network whose losses decrease with the matching ratio. Therefore the overall power gain in a cascaded amplifier configuration may remain unchanged, although the stability is greatly increased.

This means of mismatching is generally used in rf-amplifier design, but with the circuits under investigation the gain may become so high that neutralization is necessary even in the mismatched condition. For example, in Figure 9 the neutralization is taken from the output of the Pi-network to the base and constitutes the so-called capacitive output bridge. All forms of neutralization using an output bridge are load sensitive, and unresponsive to changes in source resistance but this is desirable here because the load is constant and the parameters of the input circuit may vary. Neutralization is adjusted by maximizing the backward loss, the series resistor being adjusted in steps for a sharper null. Neutralization may also be set with a sweep generator by adjusting for symmetrical bandpass characteristics. Both methods lead to the same setting but the sweep method is more desirable in that the bandpass action of all tuned circuits may be observed simultaneously.

A new class of RF amplifiers

The foregoing considerations indicate the development of a new circuit concept for transistor RF amplifiers. It is found that the interstage networks contribute little to the overall selectivity because they must perform the dual function of power transfer matching. In the past such networks have been the sole way to obtain selectivity but with the new circuitry it is evident that their only function is matching. If it is remembered that the new emitter circuits affect the impedances in such a way that the matching ratio is decreased, the need for a matching network becomes less important. The idea therefore arises of an i-f amplifier using RC-coupling between stages and tuned circuits in the emitters. Such a design would be less costly, more stable and more selective. Suggestions such as this however, form only a start and the new concept promises the realization of radical circuit improvements in the future.

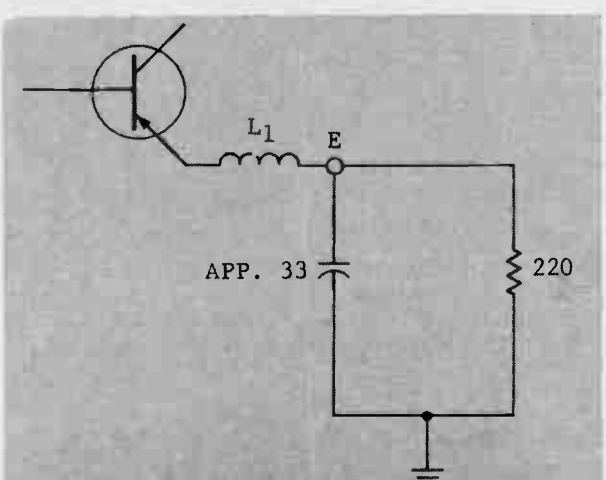
Performance measurements

A typical test circuit for the evaluation of a 2N1692 power transistor at 250 Mc/s is shown in Figure 8. Matching and tuning are provided at input and output. In most cases an adjustable coil of very small inductance is desirable. This is accomplished by the series connection of a trimmer and the total reactance is simply

$$(8) \quad X'_L = X_L - X_C.$$

By this means any small reactance value may be achieved which might be otherwise physically impossible or difficult to control. This technique has been used

Figure 5. Modified circuit eliminating unwanted parallel resonance.



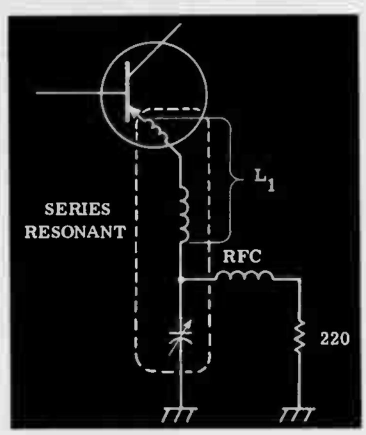


Figure 6. Basic form of the new emitter neutralized amplifier.

Quality radio communications at Collins-Canada

. . . much original engineering design and very tight quality control methods underscore Collins' expanding activity in Canada

by A E. Maine, P.Eng.

High Canadian engineering content in Collins equipment

The following list indicates the considerable amount of Canadian design embodied into communications equipment presently in manufacture at Collins (Canada).

618W-1 (AN/ARC-552A) — 1750 Channel UHF Transceiver for RCAF CF-104 aircraft. Canadian redesign.

618W-2 — 3500 Channel UHF Transceiver being manufactured for delivery to Belgium, Holland, Italy, Japan and West Germany for use in military aircraft. Canadian redesign.

618Y-1 (AN/ARC-504) — Emergency UHF Transceiver being manufactured for fitment to RCAF aircraft. Canadian development.

32MS-1A — SSB Mobile and Fixed Base HF Transceiver being manufactured in Canada for sale to Canadian and export markets. Canadian development.

URC-32 — 28,000 Channel SSB HF Transceiver being manufactured for delivery to RCN. U.S. design.

718A-1 — Emergency VHF Transceiver being manufactured for delivery to DOT. Canadian design.

678B-1B — Portable UHF Test Set. Developed and manufactured by Collins Canada. Sold in Canada and to U.S. and Japan.

678R-1 — UHF Test Equipment. Developed and manufactured by Collins Canada. Sold to U.S.

678W-1 — UHF Test Set. Developed and manufactured by Collins Canada.

313C-1 — Control Test Set. Developed and manufactured by Collins Canada. Sold to U.S.

678Q-1 — UHF Test Set. Developed and manufactured by Collins Canada. Sold to Canadian Government for use by RCAF.

John L. Plant, vice-president and general manager of Collins Radio Company of Canada.

John L. Plant, vice-president and general manager of Collins Radio Company of Canada summed up his company's activities here in Canada in the following way . . . "our refined engineering design together with a quality control system, the toughest in Canada, makes our equipment the "Cadillac" or Rolls-Royce if you like, of the communications industry . . ."

A trip around Collins' two plants in Scarborough impresses the visitor with the substantial means outlayed by the company to achieve the end results expressed by the general manager. Also impressive, is the diversity of projects simultaneously under design or in manufacture. These comprise equipment to cover the HF, VHF and UHF ranges and include airborne communications and navigation systems, point-to-point communications and tropospheric scatter communications. In addition, there is much activity in the mobile and amateur fields in the form of the design and manufacture of a wide variety of transmitters, receivers and transceivers.

The organization of the company is such that the original plant is given over almost entirely to engineering and pilot production: large volume production together with its attendant control ramifications being conducted in the new building approximately one half mile away.

The various facets of engineering are grouped

Figure 1. The Collins "Kineplex" communications center . . . equipment is used to transmit mass of business data to remote computer at head office which returns processed information for daily operation of the plant.

Figure 2. Technician tests Collins transceiver AN-ARC552 (for RCAF) in Production Final Test.

Figure 3. The Collins AN-ARC552A transceiver . . . a Canadian re-design for NATO air forces.

Figure 4. Final Module Test department in the main production plant.

Figure 5. Chassis fabrication shop in the Bartley Drive plant.

Figure 6. Design drafts-man D. Golsby holds mechanical tuning unit in discussion in the main design office.

Figure 7. Engineering technician J. Erbersole checks out Collins type 618-W transceiver in elaborately equipped development laboratory.

together to form a complete design and test facility with direct and easy inter-communication between departments. Detailed design engineering commences in the engineering office which is closely adjacent to the D.O. (Figure 6). Of interest is the fact that rough "breadboards", characteristic of most circuit design activity is hardly in evidence at Collins. This arises because required high performance is tied in very deeply with mechanical excellence and therefore it is the rule that a detailed "paper" design with "pre-production" standard drawing is necessary to get new hardware under way. Most mechanical items for prototypes are manufactured in a development model shop such as that shown in Figure 5. In many electronic facilities, a small assembly and wiring room proves to be adequate for the building of prototypes but Collins have found it to be advantageous to expand this essentially development function to the point where it becomes a small pilot production line. This serves the useful purpose of handling small production runs, but more importantly enables production bugs to be ironed out at an early stage and assists in streamlining the build process for subsequent volume manufacture.

Evaluation and test of prototype equipment is considered to be a vitally important step in the evolution of a piece of new equipment and a comprehensive development laboratory has been established for this kind of work. A photograph of a corner of this room is given in Figure 7 and illustrates the instrumentation set-up needed for the calibration of the Collins type 618-W UHF, 3,500 channel transceiver presently supplied to most NATO air forces.

Figure 8. The main production wiring and assembly area in the Bartley Drive plant.

In regard to the matter of instrumentation, it is noteworthy that a central standards and calibration room has been established and a system put into action where all test equipment is regularly brought in and checked and re-calibrated. All test data is recorded in a card filing system and the facility serves both plants forming part of the company-wide quality assurance provisions. In this latter connection, a development environmental laboratory forms part of engineering and includes a battery of ovens for component temperature testing, humidity and temperature chambers for complete equipments, and a substantial vibration test installation, illustrated in Figure 9.

On the production side, an impression of the extensive manufacturing area may be gained from Figure 8, and the large production test department from Figures 2 and 4. At the end of each assembly line a chart is located which shows the number of manufacturing errors per thousand manufacturing operations. Should the graph line wander above a value of 4 errors per 1,000 operations for the line, an immediate investigation is made by the quality control staff to correct the up-swing. One hundred per cent of manufactured modules and sub-assemblies are vibration and temperature tested prior to function testing and calibration

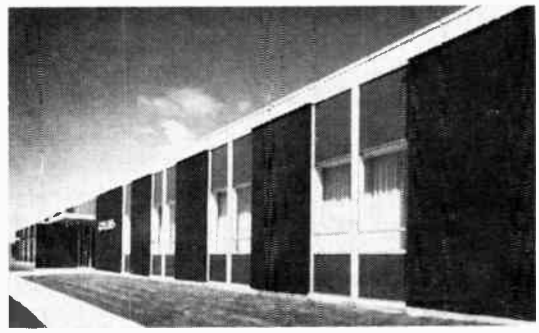
Figure 9. Engineering technician T. J. May (right) of the development department explains to the writer a design feature on transceiver control box just before vibration test on force generator in foreground.

in order that incipient failures in the "infant mortality" region may be brought to light. These shake-down tests typically run for 20 hours and the test equipment is semi-automated.

Incoming parts and materials are checked under statistical quality control practices which accord with the requirements of MIL-Q-5923B, IS(T)101A and PROC-101-1. Translated into practice this means detailed mechanical and electrical function testing of all received items. Sample items and batches are taken at random and subjected to comprehensive test. For example, Figure 10 shows the temperature/frequency characteristic of a miniature sealed crystal being measured . . . the test schedule for this one item ran to six pages, over and above cited military specifications.

In summary, and bearing in mind General Manager Plant's remark that "incorrectly applied, one could inspect oneself out of business" this writer feels that Collins' unceasing war on the unreliability bug is one of the most impressive efforts in this direction he has ever seen. The detailed tour of the Collins plants, a glimpse of which is given in this review, satisfies the writer in his choice of title for this article.

Collins Radio Co. of Canada Ltd., 11 Bermondsey Road, Toronto 16, Ont.



The company was chartered and incorporated in October 1953 with sales offices in Ottawa. In June 1955, the registered offices were transferred to Toronto where manufacturing facilities were established in two modern buildings.

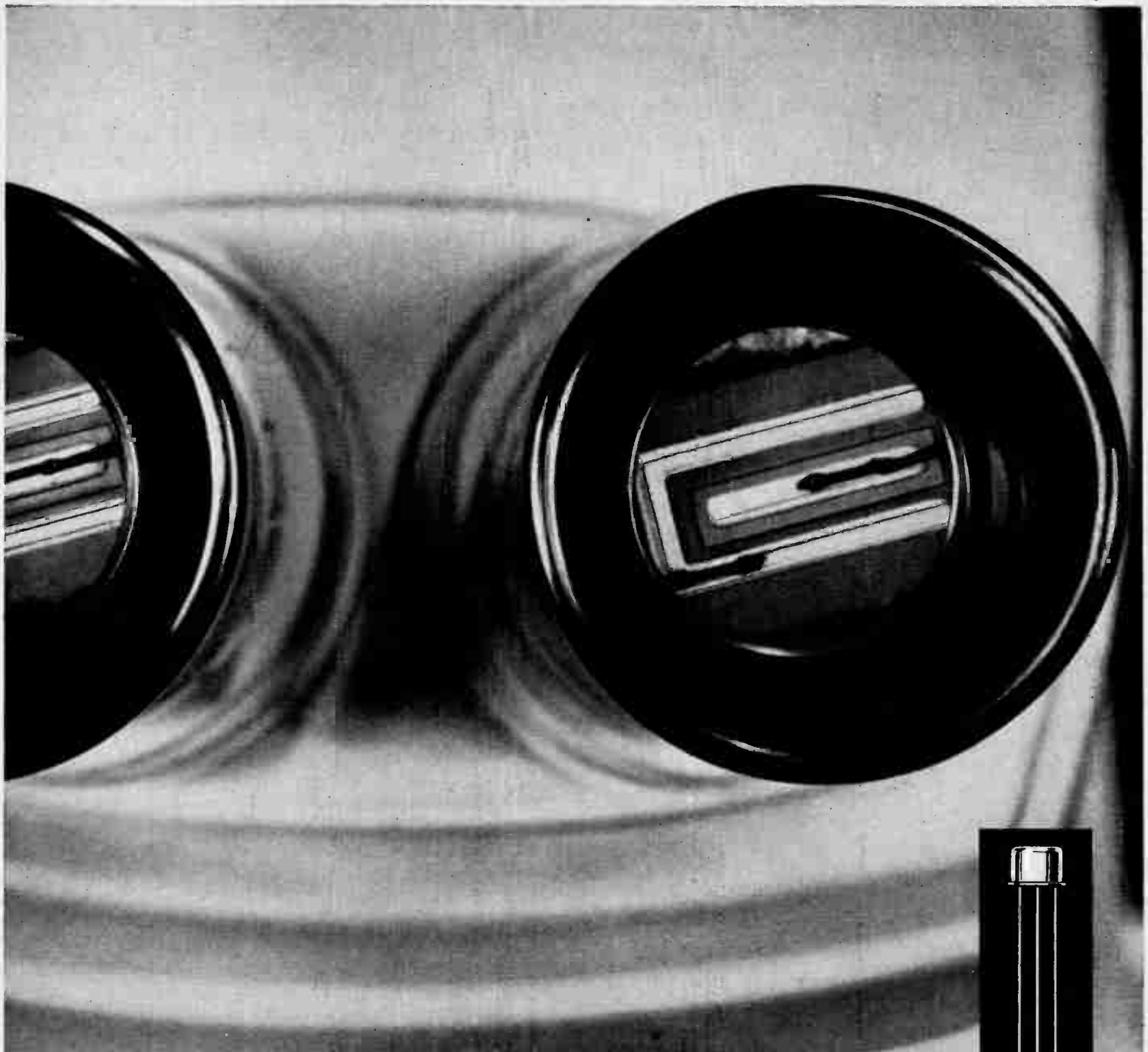
Several production programs were immediately implemented, notably for UHF equipment for the RCN and RCAF and a sub-contract from Western Electric for Tropospheric Scatter Lateral Communication System for DEW Line.

From 1956 to 1960, Collins Canada became a major airborne communication manufacturer for the Department of Defense Production as well as manufacturing equipment for the Department of Transport. Also manufactured was a large amount of the equipment for the Canadian Commercial and World export markets.

In addition to production capabilities, the Engineering Division was strengthened to design Canadian and export products. The first Canadian developed products are now being delivered from Canadian production.

The continued growth of business necessitated further expansion of Engineering and Manufacturing facilities and temporary arrangements were made in two other buildings. In mid 1960, it was decided to consolidate the operation into the two present buildings with a total of 83,000 square feet. Present staff totals 550 of which 100 are engaged in the engineering and development departments.

Figure 10. Routine frequency/temperature tests on crystals being carried out by technician Brett McNulty in the quality control department.



Intricate "machining" of junctions is inspected under powerful microscopes

even miniaturization remains MANAGEABLE...

"*Precision in small things*" best sums up the General Instrument technique—however small the device, however demanding the ultimate application.

Precision and *miniaturization* may seem contradictory aims since the human eye falls somewhat short as a manufacturing tool, below certain size limitations.

At General Instrument *Semiconductor*, where the most intricate "machining" processes are carried out as routine, this is solved by working under a magnification of 600X . . . thus representing each millimeter as nearly two feet!

Only by doing this can the pure gold welds of silicon and germanium wafers to hermetic leads be perfected without risk of microscopic burrs or discrepancies in formation.

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SEMICONDUCTOR CIRCUIT MODULES

For complete details check No. 18 on handy card, page 69

A universal resonant frequency chart

. . . new wide-range chart gives rough answer from 2 c/s to 20 Mc/s with one setting of ruler . . . a second movement of ruler gives close resolution of digits.

by A. E. Maine, P.Eng.

The complication often experienced in wide-range charts is avoided in this nomogram by the use of only two sets of scale calibrations. One set (scales A, D, and F) give directly an approximate answer, often good enough for engineering purposes, and the other scales, in red, enable a much more accurate result to be obtained. In order to show how the chart is used, the following example is considered.

Problem

Find the resonant frequency (f_r) for the values: L = 86mH and C = 1.55µF.

Answer (a) A rule set between the given values (scales A and F) intersects scale D at approximately 420c/s.

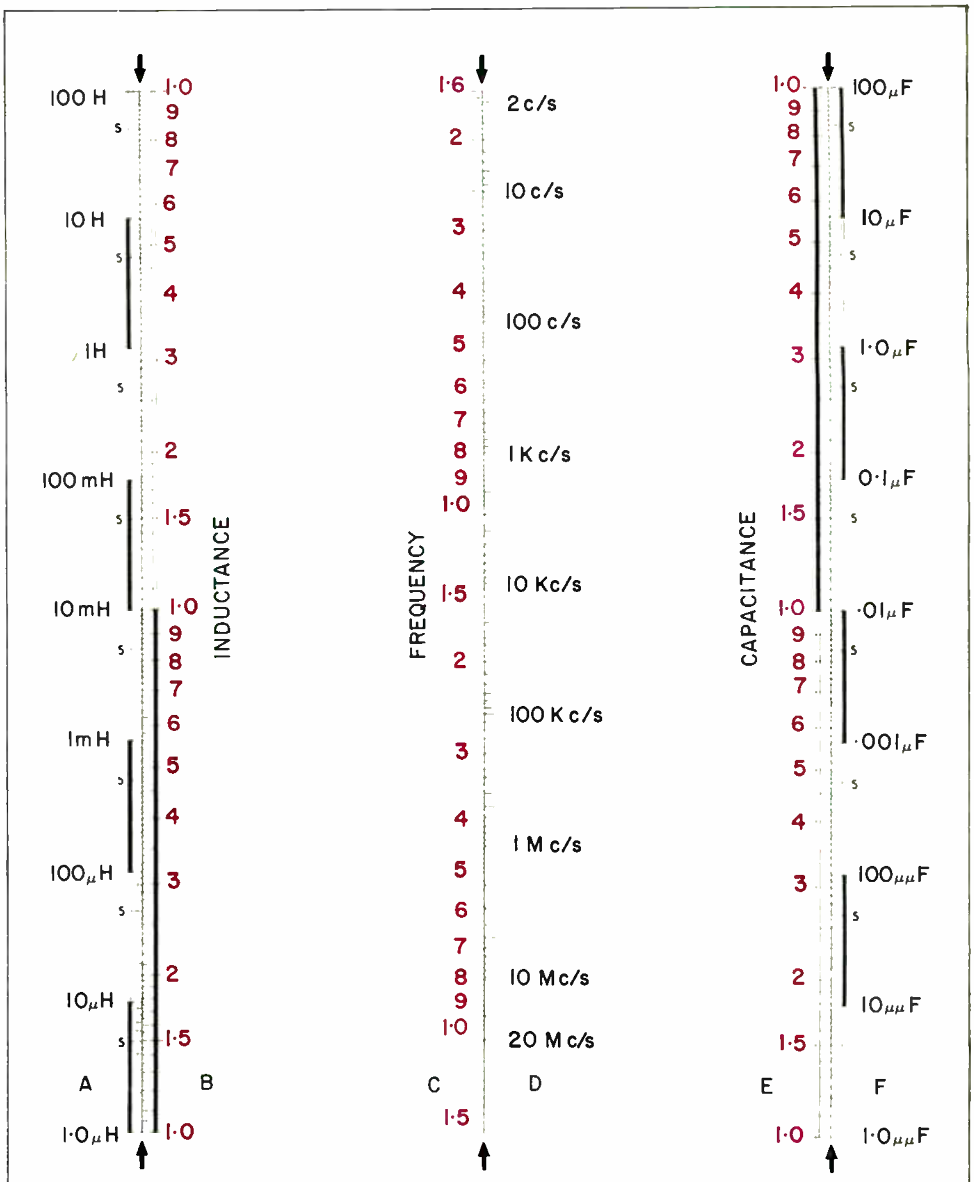
(b) Note that the value of capacitance occurs in a "WHITE" decade and the value of inductance falls in a "BLACK" decade.

(c) Set a rule at the digits of the capacitance values (1.55) on the WHITE decade of scale E, and the digits of the inductance value (8.6) on the BLACK decade of scale B.

(d) The digits of the answer appear at the intersection of the rule on scale C and are 4.35. Therefore, the final answer is 435c/s.

● Always ensure that the decade identification, BLACK and WHITE on scale E matches that of the value located on scale F, and similarly for scales B and A.

● Take scale readings only from the central lines marked top and bottom with arrows.



UNIVERSAL RESONANT FREQUENCY CHART

COMPACT, RELIABLE, RUGGED

EG&G CERAMIC-METAL

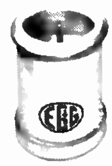
HYDROGEN THYRATRONS—HYDROGEN DIODES—TRIGGERED SPARK GAPS

These miniaturized hydrogen thyratrons were developed for compact modulator design for missile, airborne, and ground-based applications where size and weight are major considerations. Ruggedly built, they will withstand severe shock, vibration and high temperatures. Write for Data Sheet #040.

THYRATRONS

7621/HY-2
Functionally replaces 1258, 3C45 and most 4C35 glass tubes

7620/HY-1
Functionally replaces 4C35, 5C22 and most 5949 glass tubes



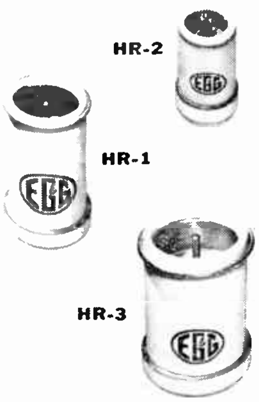
7322 1802
Functionally replaces 5949, 5948 and most 1257 glass tubes

THYRATRON RATING CHART

MODEL	epy v	ib a	Ib mAdc	Ip Aac	Ef Vac ±7.5%	If Aac—max. Ef=6.3v	Eres Vac ±7.5%	Ires Aac—max. Eres=6.3v	Pb	Cathode & Reservoir Warm-Up Time	Dimensions Max. Height-inches	Max. Dia.-inches	Wt. lbs.
7621/HY-2	8,000	100	0.1	2.0	6.3	3.5	*	*	2.7 x 10⁹	0.5 min.	2½"	1⅕"	0.13
7620 HY-1	20,000	500	0.5	8.0	6.3	7.5	6.3	4	10 x 10⁹	5 min.	4⅝"	2⁵⁄₁₆"	0.82
7322 1802	25,000	1,500	1.5	47.5	6.3	16	6.3	6	20 x 10⁹	10 min.	5¼"	3⅝"	2.07

*Hydrogen reservoir connected internally across heater-cathode.
Ambient Temperature Limits −65°C to +125°C, 400°C envelope maximum.

DIODES



HR-2

HR-1

HR-3

High power, high voltage, hydrogen filled diodes designed for use as grid controlled rectifiers, hold-off diodes, inverse clippers and backswing clippers. In spite of their small size and light weight, they are of rugged construction and will withstand severe shock, vibration and high temperatures. Write for Data Sheet #050.

DIODE RATING CHART

Type	Clipper Diode Ratings epx kv	ib a	Ib Adc	Ip Aac	Rectifier Ratings epx kv	ib a	Ib Adc	Heater Ef Vac	If Iac max.	Eres Vac	Ires Iac max.	Cathode & Reservoir Warm-up Time minutes	Dimensions Max. Height-inches	Max. Dia.-inches	Wt. lbs.
HR-2	8.0	9.0	.100	2.0	8.0	1.5	0.25	6.3	3.2	*	*	0.5	2½	1⅕	0.13
HR-1	25.0	250	.125	4.0	20.0	9.0	1.5	5.0	9.5	5.0	3.5	5	4⅝	2⁵⁄₁₆	0.95
HR-3	25.0	500	.500	16.0	25.0	30.0	5.0	6.3	13.0	6.3	4.0	10	5¾	3⅜	2.07

*Hydrogen reservoir connected internally across cathode-heater.
Ambient Temperature Limits −65°C to +125°C ambient, 400°C envelope maximum.

TRIGGERED SPARK GAPS

CERAMIC-METAL MODEL GP-12
Voltage holdoff — 25kv.
Peak current — in excess of 10,000 amperes
Trigger voltage — 7 kv. min.
Electrode to electrode cut-off voltage — 6 kv. min.
Delay time — 0.5 microseconds.
Size: 3½" dia. x 2½". Wt. .73 lb.

These compact spark gaps are designed to replace hydrogen thyratrons in electronic crowbar applications. They have a low trigger energy requirement and a fast follow-through time after application of trigger pulse. Hermetically sealed, they are not affected by atmospheric conditions. Ruggedly built to withstand severe shock, vibration and high temperatures. No filament power required. Complete specifications available on request. Write for Data Sheet #080.

GLASS-METAL MODEL GP-11
Voltage holdoff — 3.5 kv.
Peak current — in excess of 1100 amperes.
Trigger voltage — 7.5 kv. min.
Electrode to electrode cut-off voltage — 1.8 kv. min.
Delay time — 0.35 microseconds.
Size: 0.6" dia. x 0.55". Wt. .016 lb.

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For complete details check No. 12 on handy card, page 69

Industry's business

Continued from page 15

De Havilland wins $1.7 million development contract

The Honorable Raymond O'Hurley, Minister of Defense Production, has announced the first co-operative development of a missile system with a Development Contract awarded The De Havilland Aircraft of Canada Limited for work on the MAULER Air Defense Weapon System, for the United States Army.

The contract which will amount to $1.7 million was awarded through the Department of Defense Production for development of an Infrared Acquisition Unit for the Mauler System.

Mauler is the United States Army's newest forward area air defense missile system under development, designed to destroy supersonic enemy aircraft, short range ballistic missiles and rockets in the battlefield area.

The United States Government, through the Detroit Ordnance District, will share the cost of this development program with the Canadian Government.

Electronic Marketing elected as exclusive Canadian reps

Electronic Marketing Co. of Canada Ltd. recently announced their appointment as exclusive Canadian representatives for United Components Inc. manufacturers of hermetically sealed double diffused silicon rectifiers and silicon switching diodes.

Another firm, Technipower Inc. have also made Electronic Marketing their Canadian representatives. Technipower provides solid state AC-DC power supplies.

Current regulator device

The "Currector" is an entirely new 2-terminal solid-state device possessing current regulation or limiting properties. Its action is analogous to the voltage limiting characteristic of a Zener diode. Fixed current rating are from 1 to 10mA at 10 per cent increments at working voltages up to 35VDC. PIV is 5V. Bi-directional units are available working at ± 35V. Admittances vary with type and lie in the range of 1 to 10 microhms. Dimensions are 1" long by ¾" dia. Axial lead or single-ended types may be supplied.

The Circuitdyne Corp., Laguna Beach, California.

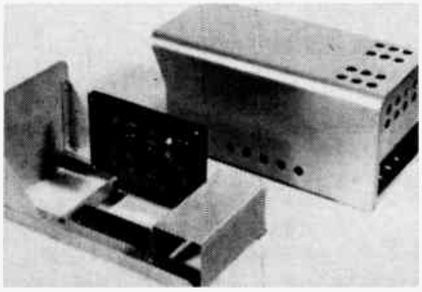
product panorama

For further information on Products use Readers' Service Cards on pages 69 and 70

Prototyping kit

Item 198

Five new instrument and rack mounted chassis, designed to accommodate from six to forty-four standard printed circuit Proto-Cards are now available, off-the-shelf. The all-aluminum CSL Proto-Chassis are supplied as knock-down components, completely pre-



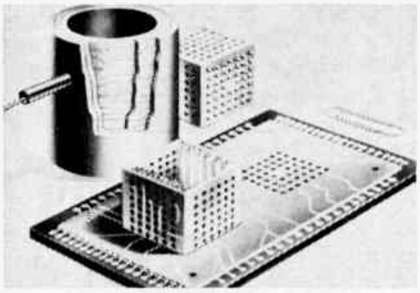
drilled and tapped for easy, rapid assembly with a screwdriver. Only control panel holes and mounting holes for special circuit elements need be drilled. Instrument chassis include a 6-card model with a 6" x 6" front panel and a 10-card model with a 6" x 8" front panel.

Circuit Structures Lab., P.O. Box 36, Laguna Beach, California.

Multi-layer circuits

Item 201

Virtually unlimited design possibilities are provided by new direct-printed circuit techniques. Methods make possible the stacking and interconnection of precision circuits separated by layers as thin as two mils of the new Motson "Mono-Clad" insulation.



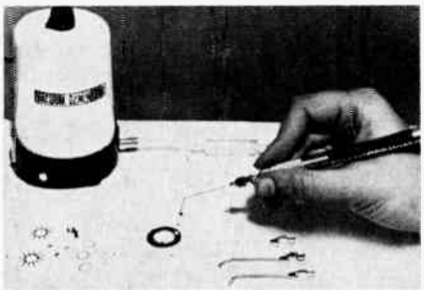
Circuits can be printed on outside and/or inside (including thru hole connections) of geometric shapes such as cubes, spheres, tubes, etc., in copper, silver, nickel, gold and rhodium. Interconnections can be made to any circuit level and printing techniques can carry circuits over edges and around corners.

J. Frank Motson Company, Flourtown, Pennsylvania.

Vacuum tweezer

Item 204

The advanced Vacuum Tweezer consists of a small adjustable vacuum generator that is patented and UL approved, a vacuum pencil, five assorted-size vacuum pick-up tips, five vacuum cups, a 40-inch length of clear Tygon vacuum tubing to eliminate



contamination problems, and a carrying case. Held like a pencil, the Vacuum Tweezer is a precision micro-miniature device that permits lifting, holding, sorting, carrying or depositing of parts at the end of the specially designed vacuum tips.

Ultrasonic Laboratories Ltd., 1780 St. George Ave., Rahway, N.J.

Assembly jig

Item 199

Four independent, 2-inch vertical holders, adjustable to 3¾" width and 8" length, permit operators to assemble electronic components "sandwich style" between Mylar films. Cadmium-plated slides facilitate smooth adjustments for length and depth. Assembled modules are easily removed from the Model FH-202 Film Holder for welding and encapsulation. Price: $31.50 (U.S.) F.O.B. Hawthorne, Calif. Shipping weight: 2 lbs. Immediate delivery. For additional information contact:

Welded Electronic Modules, Inc., 4807 West 118th Place, Hawthorne, Calif.

Micro toroid winder

Item 202

Micro-miniature toroids can now be wound economically for the first time as a result of the perfection of a new class of winding machine, the Telex/Lumen Type 4402. Machine features great simplicity, shuttles having been eliminated. Between 24 and 81 turns of wire can be wound onto cores in the range: 0.23"OD, 0.12"ID, 0.06" thick, and 0.08"OD, 0.05"ID and 0.025" thick. Min. core ID is 0.02" and max. core OD is 0.25". Bifilar windings can be provided and uniform spacing of turns is assured.

Telex/Lumen, P.O. Box 905, Joliet, Ill.

Time base calibrator

Item 205

Conveniently pocket-sized and completely solid-state, the Model 45 is ideal for accurate field or laboratory calibration of oscilloscope sweep circuits. It may also be applied to the axis for use as intensity markers or used as a harmonic multiplier for harmonic ridge type of calibration. When required, the Model 45 may be used with a scope for calibrating audio oscillators by Lissajous technique. Output of 0.25 volts, peak to peak, minimum; Accuracy of frequency at room temperature: 10 MC ±.01%, 100 KC ±.01% and 1 KC ±1%. Size: 3-1/16" x 5½" x ⅞".

Whittaker Electronics Ltd., 1171 Whitmore Avenue, Ottawa 3, Ontario.

Selective plating

Item 200

A number of new, and several improved high-speed selective electro-plating solutions are now available. Most unusual of the new electrolytes are rhenium, ruthenium and a hard (700 Brinnel) nickel-tungsten alloy. These solutions are intended for use with the company's "table-top" electroplating

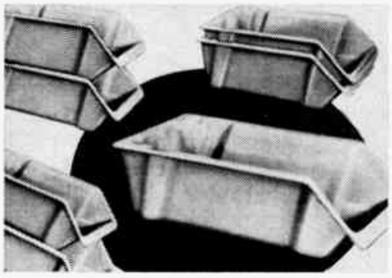
systems. By means of special styluses and power packs, controllable amounts of alloys as well as metals are deposited on selected areas without having to imerse the entire object in electrolyte.

Selectrons Ltd., 153 East 26th St., New York 10, N.Y.

Small parts container

Item 203

A completely new type materials handling container, designated the Stack-n-Nest (R) Hopper Box, is now available. The new container will stack and nest within its own dimensions without reversing ends, as well as stacking on inclined surfaces up to 15°, as shown. The new container also features



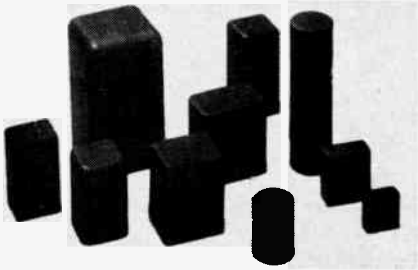
a hopper end, allowing the boxes to be used at assembly areas, as stock pans, and permitting faster transfer of contents. The new trays are 24" long by 11⅜" wide by 7½" deep O.D., and are a one-piece molding of Fiberglass reinforced polyester.

G. B. Lewis Company, 369 Montgomery Street, Watertown, Wisconsin.

Encapsulation cups

Item 206

Non-metallic encapsulation cups of unfilled and glass filled polycarbonate in a wide range of sizes and configurations are now available. This material provides the highest impact strength of all plastics and as a consequence polycarbonate cups have no tendency to crack or deform. They are



suitable for continuous service in temperatures as high as 300°F and as low as –60°F. These cups can be supplied with mounting lugs and drilled or pierced for terminal holes, silk screened or hot stamped as required.

Gibson-Egan Company, P.O. Box 5352, Pasadena, California.

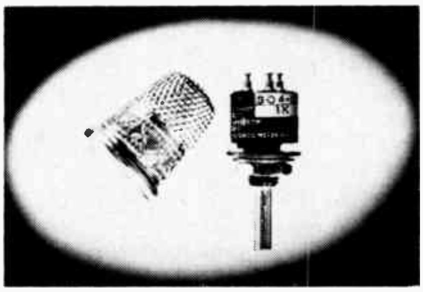
product panorama

For further information on Products use Readers' Service Cards on pages 69 and 70

Sub-min. rotary potentiometer

Item 207

A subminiature rotary potentiometer capable of delivering the ultimate in precision performance while utilizing a minimum of space has been announced by Daystrom. Weighing only 7 grams and with a total overall case length of only ⅜", the new Model 304 is a single turn unit which emphasizes high linearity. The new series meets or exceeds all applicable MIL specs. being capable of carrying 2 watts at 50°C in still air and operating up to 150°C. Resistance range is 10 to 50K.

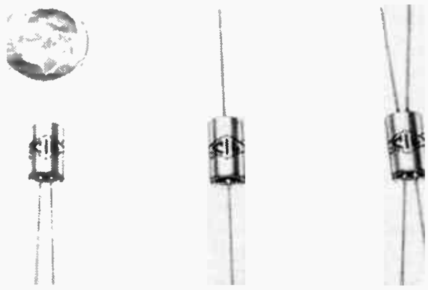


Daystrom Ltd., 1480 Dundas Highway East, Cooksville, Ont.

High 'g' microinductors

Item 210

Unique new ultra fine wire winding techniques, and a new concept in design and construction, enable these new microinductors to withstand more than 10,000 G's! Designed for relatively low current circuitry where extreme mechanical ruggedness and resistance to environmental change is desired, these ferrite-cored inductors are supplied in three styles: "Type 1", with double leads at one end; "Type 2" with single leads at both ends; and "Type 3", with double leads at both ends. All exceed MIL-C-15305A, Grade 1, Class 0.

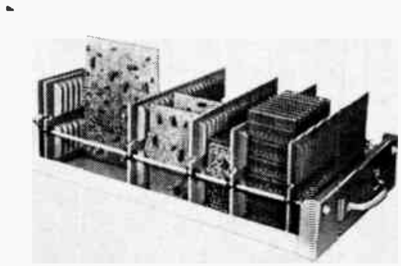


Clippard Instrument Lab. Inc., 7390 Colerain Rd., Cincinnati 39, Ohio.

Circuit storage trays

Item 213

The new storage trays have been specially designed for use in production departments and assembly lines for the safe storage of printed circuit boards. The trays assure safe storage in transit and completely eliminate the problem of edge damage. Trays are adjustable to carry boards from 1" to 19" long and from 1/32" to ¼" thick. Trays feature sturdy light-weight steel construction, grey epoxy finish and are complete with molded plastic dividers. Kits consist of tray and 6 dividers.



Hollis Engineering Inc., Pine St. Extension, Nashua, New Hamp.

Shielded co-ax plugs

Item 208

A specially molded 2-pin plug of standard pin spacing used on most electronic instruments is made integral with a fully screened co-ax lead. In test hook-ups or in permanent installations, shielded "Addaplugs" protect RF signals from interfering with other RF signals. Other variants are available to meet virtually every requirement. Included are Addaplug tips, phone tips and various RF connectors. Co-ax leads with various types of plug at either end can be supplied.

Associated Engineering Corp., 65 Kent St., Brookline 46, Mass.

Compactron rectifier

Item 211

Designated type 2AH2, the new 12-pin Compactron rectifier is designed to supply power to the anode of television picture tubes. The cathode type heater employed enables the tube to handle substantially higher voltages than other rectifiers with filament heaters. Max. PIV rating of the 2AH2 is 30Kv for total DC and peak, and 24Kv in the d.c. component. Max. average d.c. current is 80mA. The new tube has a seated height ⅛" less than conventional tubes and overall height is ⅜" shorter.

Canadian General Electric Co. Ltd., Electronic and Tube Dept., 189 Dufferin Street, Toronto 3, Ont.

Microminiature resistors

Item 214

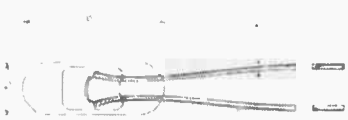
These metal film resistors, which meet all the requirements of MIL-R-10509C are rated at ¼ and ½ watt, and are 0.3" and 0.475" in body length respectively. Resistance range is from 25Ω to 500K at a standard tolerance of 1%. Special tolerances of ½%, 2% and 5% also available. Voltage ratings are 250 for the ¼w unit and 300 for the ½w types. Temperature coeff. (standard) is ±100ppm/°C. Values down to 25ppm/°C to special order. Noble metal films used resist all ambient conditions.

American Components Inc., 8th Ave. and Harry St., Conshohoken, Penn.

Micro spotlight

Item 209

An optical point source, the new spotlight has many other uses such as for read-out devices, medical and industrial light probes, transistor indicators, pointer and meter scale illumination. Tiny unit measures 0.08" long x 0.03" dia. and contains integral lens giving 10 to 1 light intensity in desired direction. The unit, believed to be the world's smallest, gives a total light output of 60 millilumens. The low thermal time constant makes the lamp suitable as a fast light modulator.

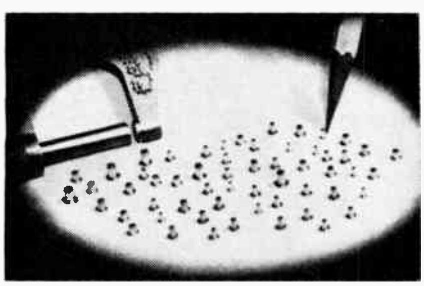


Mel Sales Ltd., 1969 Avenue Road, Toronto 12, Ontario.

Precision eyelets

Item 212

Miniature eyelet sizes in an outside diameter range of from .046" to .100" are available in stock sizes for application in electronic tubes, rectifiers, diodes, electrical switches, printed circuitry and many other electrical components and devices. These eyelets made from pure nickel, stainless steel, copper, brass, or steel nickel plated, have many uses in the manufacture of small components. They are precision made to extremely close tolerances and guaranteed perfect.

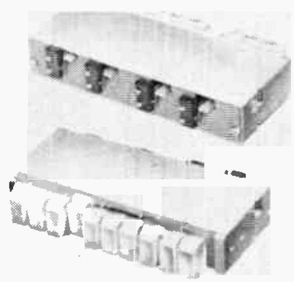


RAMCO Manufacturing Company, 540 Westfield Ave. W., Roselle Park, N.J.

Binary coded switch

Item 215

A new series of Ultra-Switches, designated the 2000 Binary Coded Switch, is now available from Ultrasonic Systems Corp. These are the first modern-styled fully-mechanical push-button switches made for the manual conversion of decimal to various binary code systems. Standard models are designed to convert to the 1-2-4-8 standard binary code; they are easily adapted to other codes such as the Excess-3. Their operation is fully mechanical, they eliminate electronic logic systems.



Ultronic Systems Corporation, 7300 N. Crescent Boulevard, Pennsauken, N.J.

Continued on page 65

the international scene

European engineers of the International Telephone and Telegraph Corporation install a buried transistor repeater for a carrier telephone system in Sardinia, using a new type of coaxial cable that is thinner than a pencil.

U.K., Sweden form telecom company to serve Nigeria

It was recently announced by the L. M. Ericsson Company of Sweden and Marconi's Wireless Telegraph Company Limited of England that they have together formed a new company in Nigeria, to be known as the Nigerian Telecommunications Corporation.

Purpose of the new corporation is threefold; to provide an on-the-spot organization which can deal rapidly and efficiently with all aspects of telecommunication requirements; to promote the expansion of technical education in Nigeria, and to introduce local assembly of some types of telecommunication units rather than import them already assembled

Italy and Argentina admitted to IFIP

Two new nations, Italy and Argentina, have been formally admitted to the International Federation for Information Processing, raising to 19 the total number of member countries in the Federation. Their membership was ratified at a meeting of the IFIP Council in Copenhagen, Denmark.

IFIP is a federation of national professional and technical societies devoted wholly, or in part, to the information processing sciences. Its name was changed from International Federation of Information Processing Societies to International Federation for Information Processing (IFIP) at the Copenhagen Council meeting. Each nation is represented on the IFIP Council by one official delegate. The two new nations join Australia, Belgium, Canada, Czechoslovakia, Denmark, Finland, France, Germany, Japan, Netherlands, Poland, Spain, Sweden, Switzerland, United Kingdom, United States and the USSR.

COTC operations opened between Canada and Argentina

Dr. Arturo Frondizi, President of Argentina, opened direct telecommunications between Canada and Argentina over the facilities of the Canadian Overseas Telecommunication Corporation on November 28, 1961.

Assisted by the president and general manager of COTC, Douglas F. Bowie, Dr. Frondizi transmitted a telex message to Buenos Aires to inaugurate this service.

Mr. Bowie stated that in addition to opening direct telex services the Corporation simultaneously placed into service direct telegraph and telephone operations between Canada and Argentina.

ITT to supply transmitter for communications satellite

A contract to supply the transmitter which will be used by the General Post Office for satellite communication experiments to be conducted this year in co-operation with U.S. authorities has been awarded to Standard Telephone and Cables Limited, an association of International Telephone and Telegraph Corporation.

The equipment will be installed at the site of an 85-foot diameter steerable antenna now being erected in Cornwall, about 250 miles from London. The transmitter will operate in the 200 megacycle communication band and will deliver frequency-modulated output of 10 kilowatts.

The present program calls for the transmitter to be installed and fully operational by April 1962. An active repeater communication satellite to be launched by the U.S. government will enable tests to be conducted on television transmission and two-way speech communication between England and America.

Second order received for world's largest computer

The U.K. parent organization of Ferranti-Packard Electric Limited, Toronto, has received a second order for their giant Atlas Computer. This unit will be installed at the University of London and is expected to accelerate appreciably Britain's scientific research program. This announcement is made just a month subsequent to the announcement of the first Atlas purchase by the U.K. Atomic Energy Authority.

The growing North American interest in machines of the size and capabilities of Atlas is resulting in active consideration by Ferranti-Packard in the Canadian production of this mammoth computer.

Ultrasonic cleaner commands interest at exhibit in Yugoslavia. Fairgoers watch a demonstration of a "diSONtegrator" ultrasonic cleaning machine made by Ultrasonic Industries Inc. The machine which uses high-frequency sound to precision clean thousands of products, was demonstrated in a complete industrial medical center set up as part of the U.S. Exhibition at the Zagreb, Yugoslavia, International Trade Fair.

product panorama

For further information on Products use Readers' Service Cards on pages 69 and 70.

Continued from page 63

Sub-min. hour counter

Item 216

A sub miniature Time Totalizing Meter that accurately indicates elapsed operating time of aircraft and missile electronic equipment and systems is now available. The Parabam Time Totalizing Meter is used to determine reliability, prevent failures and facilitate maintenance procedures. Meter reliability and accuracy under the most severe operating conditions are assured by watchlike design and a spring coupled 28-

volt DC torque motor. Weighs approx. 2 ozs. Has a 1.040" dia. face. Available in two ranges: 1 hour to 1,000 hrs. or 10 to 10,000 hrs.

Alex L. Clark, Ltd., 3751 Bloor Street W., Islington, Ontario.

Sub-min. pulse Xformers

Item 217

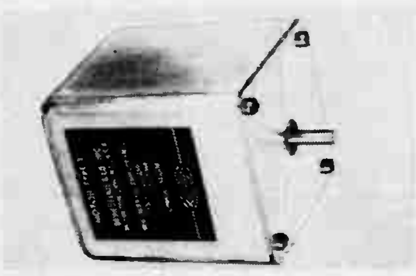
UTC's new PIP series of transistor pulse transformers are physically designed to be extremely compatible with transistors in equipment designs. Subminiature size (5/16" diameter x 3/16" high, 1/20 oz.) allows for maximum component density in equipments. Units are all manufactured and guaranteed to MIL-T-21038 by full environmental testing. There are 9 units in this new series. Characteristic parameter ranges are: Pulse Width: .05 to 10 microseconds; Rise Time: .018 to .4 microseconds; Impedance, in, out: 50 to 200 ohms. Units can be mounted by leads or a clip.

United Transformer Corp., 150 Varick Street, New York 13, New York.

Brushless DC motor

Item 218

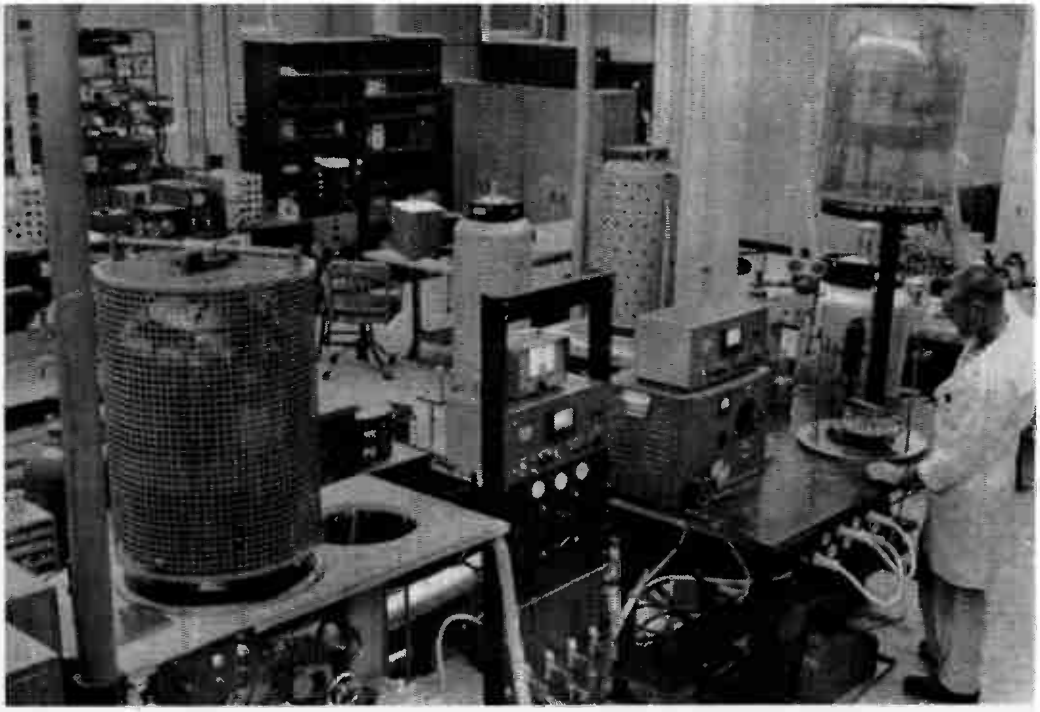
Designated Model "T", these units fulfill the need for reliable, long-life d.c. motors in critical applications where maximum reli-



ability is essential. Usual commutator is eliminated and the commutation process is carried out by a transistor circuit. Life then becomes virtually a function of the bearings . . . models have already run continuously for 15,000 hours. Ratings are from 300mW to 4 watts input and integral gearheads with a choice of speeds are available.

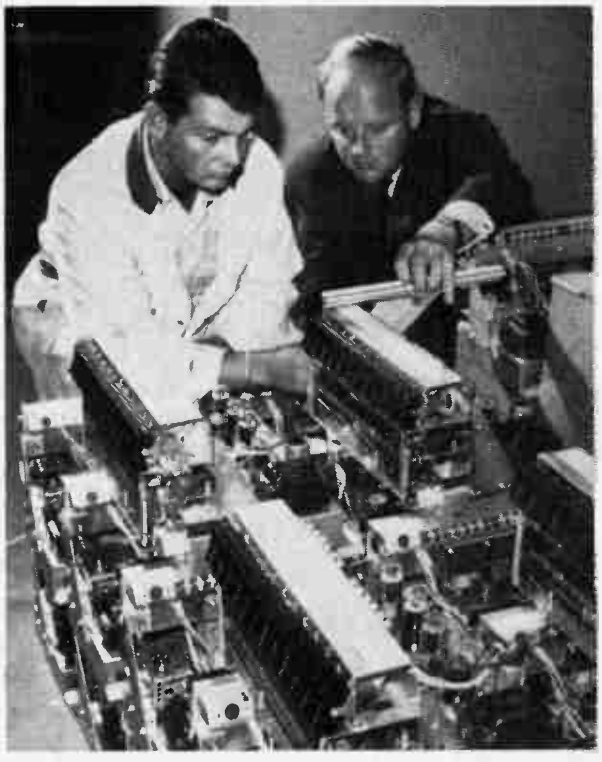
Brailsford & Co. Ltd, 670 Milton Rd., Rye, N.Y.

A technician in the Univac thin-film research laboratory checks over the results of an experiment in coating techniques. Researchers are investigating the magnetic qualities of various metals when vaporized and then condensed to form a "thin-film" on a glass plate. The hood of the bell chamber, where this vaporization and condensation occurs, has been lifted by the technician.



close-up

a pictorial comment of the industry in action



Peter Munk, B.A.Sc., P.Eng., points out some techniques in the assembly of a Clairtone stereo hi-fi to visiting engineer who is in Canada from Switzerland to study Clairtone methods.

An operator at the Rexdale plant of Litton Systems (Canada) Ltd., assembles components on a printed circuit board used in the CF-104 navigation system.

A REMINDER

to those readers who will receive circulation verification post-cards.

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5 Lesmill Road, Don Mills, Ont.

For complete details check No. 22 on handy card, page 69

IT'S NEW!

TR-60

Transistor Checker

Gives direct readings of I.C.O. & B. of all transistors, checks diodes and rectifiers, 4" full view meter—50 UA sensitivity. Battery operated, portable with sturdy metal case. An inexpensive unit with top performance characteristics.

WIRED AND CALIBRATED

ONLY **$34.95**

Picture Tube Tester and Rejuvenator

CRT-38 is specially designed for testing of all types of magnetically deflected picture tubes. Tests tubes up to 110° for quality; all black and white tubes for shorts; rejuvenates; tests color tubes. Housed in a handsome leatherette case. Readings made on 3½" full view meter.

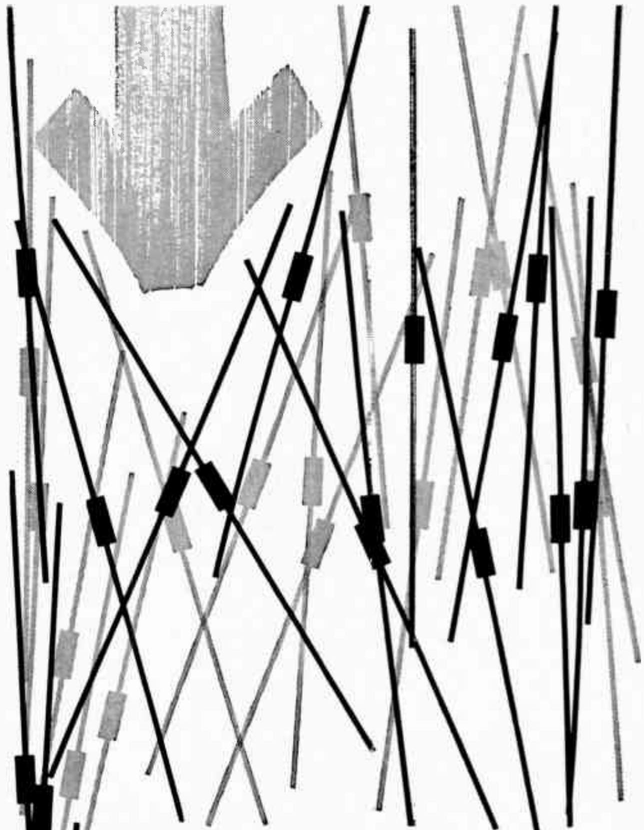
WIRED AND CALIBRATED

ONLY **$44.95**

STARKIT

STARK ELECTRONIC INSTRUMENTS LTD.
AJAX, ONTARIO

For complete details check No. 35 on handy card, page 69



NEW DESIGN FOR MICRO MINIATURE CONSTRUCTION

.15 uh TO 100 uh

IN 35 STANDARD VALUES

1025 SERIES

MICRO MINIATURE MOLDED INDUCTORS

For reliability, for sheer stability, for perfected accuracy and for exceptional miniaturization, Delevan's new 1025 Series of Molded Inductors introduces the industries smallest package design, offering high inductance ranges in ¼ the physical volume of the previous smallest coils having equal inductances. The 35 values in this Series are perfect for modern designing where micro-miniaturization construction is of prime importance.

Size is truly small! .10 inch in diameter and .25 inch in length with inductance ranges from .15 uh thru 100 uh. Color coded to conform with MIL-C-15305B.

Call your distributor now, or write to us direct. We are all stocked with the new 1025's to ship immediately.

Delevan

A SUBSIDIARY OF AMERICAN PRECISION INDUSTRIES, INC.

ELECTRONICS CORPORATION

270 QUAKER ROAD • EAST AURORA, NEW YORK

For complete details check No. 15 on handy card, page 69

For complete details check No. 28 on handy card, page 69

TECHNICAL LITERATURE BRIEFS

Item 219

Epoxy pellets for insulating: bulletin No. 8 describes the use of epoxy pellets for protecting tantalum capacitors and is available from Epoxy Products Division, Joseph Waldman and Sons. Sketches and photographs are used to illustrate each process described. **E. S. Gould Sales Co. Ltd., 19 le Royer St. W., Montreal, P.Q.**

Item 220

Ferrite Circulators: Catalog CR-61 provides data on a series of ferrite circulators available in EIA WR90 waveguide size. Applications and illustrations are included in this 4-page catalog. **Tech Associates, 23 St. Thomas St., Toronto, Ont.**

Item 221

Sidewall hybrids: 12-page, two color catalog, HS61, details more than 100 sidewall short-slot hybrids, covering EIA waveguide sizes from WR15 to WR2100. Illustrations of various styles and terminations are provided. **Tech Associates, 23 St. Thomas Street, Toronto, Ont.**

Item 222

Mercury-wetted contact relays: 8-page catalog describing a new Potter & Brumfield series designated JM, is available. Design details and electrical and physical performance characteristics are featured. **Technical Information Dept., Potter & Brumfield Division of AMF Canada Ltd., Guelph, Ont.**

Item 223

Home interphone system: sales pamphlet SP-6101 has been issued describing the 1A Home Interphone System, which enables a subscriber to attend to many domestic duties with the minimum of inconvenience. **Northern Electric Co. Ltd., 1600 Dorchester Blvd. West, Montreal, P.Q.**

Item 224

"1962 Industrial Electronic Catalog": contains 456 pages of complete listings of nationally known products, cross reference data, electronic tables, definitions and formulae. **Wholesale Radio & Electronics Ltd., 66 Orfus Road, Toronto 19, Ont.**

Item 225

Frequency spectrum span: this folder describing the frequency spectrum of the electronics industry, should be helpful in relating the continuous flow of new developments to their proper significance within this field. **Raytheon Company, Lexington 73, Mass.**

Item 226

Fluorescent ballast catalog: 32-page book, CGEC-983H, contains detailed application information for CGE "Hi-Value" ballasts. Data tables included provide electrical characteristics and physical dimensions for Gold Label, Silver Label and Bronze Label ballasts. **Canadian General Electric Co. Ltd., Industrial Products Div., 940 Lansdowne Ave., Toronto, Ont.**

Item 227

Energy discharge capacitors: electrical and mechanical design criteria on energy discharge capacitors is summarized in a bulletin designated as TSC-208. **Sangamo Electric Co., Springfield, Ill.**

Item 228

Standoffs, spacers and posts: 4-page catalog lists a complete range of these in a wide range of sizes, shapes and materials. Also included is a pricing formula to compute price on any spacer or post, in any combination of material, shape and finish. **Angler Industries, Inc., 75 Winthrop St., Newark 4, N.J.**

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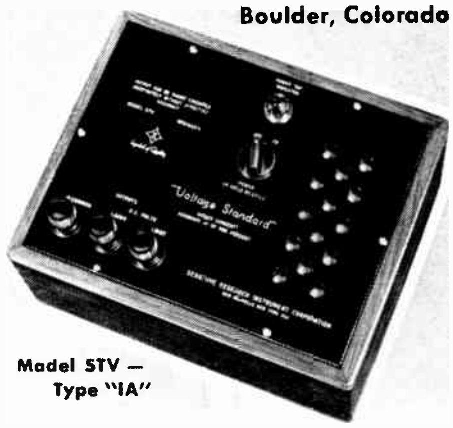
The Model STV is an extremely accurate and stable reference source for use with "null balance" devices such as potentiometers and other infinite impedance comparators. It is at least equivalent in accuracy to the best unsaturated standard cells and is superior in almost all other respects to both saturated and unsaturated types.

While the Model STV is essentially a zero current drain source, it may be operated into any impedance without damage. It can be short circuited indefinitely without affecting accuracy or life expectancy, and it will almost instantaneously regain its original open circuit voltage when the short is removed. For calculating output current, the Model STV may be considered a perfect voltage source in series with a 2000 ohm resistance; thus the maximum current when short circuited is .5 ma. Special units are available for use as Standard Current sources into specific external resistances.

The calibration of all instruments by Sensitive Research is directly traceable to the National Bureau of Standards in Washington, D. C. or Boulder, Colorado



Model STV — Type "IA"

SENSITIVE RESEARCH

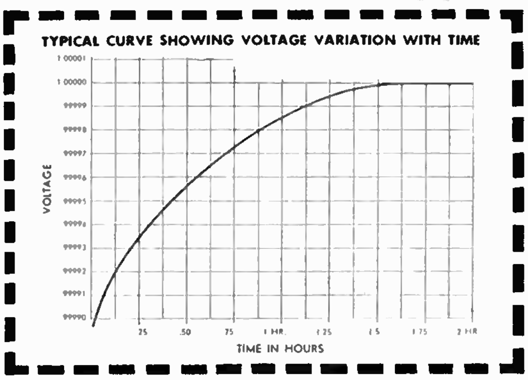
.01% ACCURATE D. C. VOLTAGE STANDARD

The accuracy of the Model STV is unaffected by vibration from transportation, exposure to extremes of temperature, or changes in operating position.

The stability of the Model STV is guaranteed to a minimal ±.01% of certified output. Performance figures obtained to date indicate some units are capable of stabilities of ±.005% for periods in excess of a year. However, so that the voltage standard may be used with great assurance to its best accuracy, a 30-day recertification period is recommended. As a convenience, the instrument is furnished with a screwdriver adjustment so that output may be varied if desired. The nominal output values can be readjusted by the user to within 10 ppm.

The Model STV is furnished with a Sensitive Research certificate giving the measured value of both outputs. Calibration is accomplished by continuous reference, for a period of 30 days, to a bank of N.B.S. certified saturated standard cells. Calibration accuracy is better than 5 ppm.

Special Model STV units can be furnished for operation up to 7.5 volts. Multirange instruments are available with no change in case size, but with somewhat reduced accuracy (dependent upon number of outputs desired). Special DC and battery operated units can be supplied. Correspondence concerning individual applications is invited.



SPECIFICATIONS—Type "1 A"

Input: 100-130 Volts AC; 60 cps; 25 va.

Output: 1.0000 Volt and 1.0185 Volts D.C.

Accuracy: ±.01% of nominal output.

Stability: ±.01% of actual output.

Stability is guaranteed for 30 days. Performance characteristics are warranted for a period of one year.

Line Voltage Stability: .002% of actual output for 100-130 volt input.

Temperature Coefficient: Less than ±.001% per °C between 20°-30°C. (Operates with reduced accuracy beyond these limits, but with its output exactly reproducible).

Operational Life: 25,000 hours minimum.

Size: 9⅝" x 7⅞" x 5".

Weight: 10 lbs.

Price: $280.00

Type "1B"

Rack Panel Mounting Voltage Standard. Specifications same as Type "1A" except mounted on 19" x 5¼" x 5/16" bakelite panel.

Price: $295.00

SENSITIVE RESEARCH

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Symbol of Quality

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

Represented in Canada by: MEL SALES LTD., 71 Crockford Blvd., Scarborough, Ontario

For complete details check No. 32 on handy card, page 69

Defense industry barometer
DDP contract awards

Given below is a list of unclassified contracts for $10,000 or more awarded to Canadian electronics companies by the Department of Defense Production during the month of November. Figures represent total dollar value of one or more contracts in each case. Rental of Communications services is not included.

Firm	Item	Dollar Value
Aircraft-Marine Products of Canada Ltd., Toronto, Ont.	electronic components for control tower installations	$ 62,476
Alberta Government Telephones Edmonton, Alta.	installation of telecommunication equipment	$122,787
Burgess Battery Co., Niagara Falls, Ont.	batteries	$ 22,067
Burndy Canada Ltd., Scarborough, Ont.	electronic components for air traffic control consoles	$ 55,095
Canada Wire & Cable Co. Ltd., Ottawa, Ont.	armored radio frequency coaxial cable	$ 27,341
Canadian Admiral Corp. Ltd. Port Credit, Ont.	radiacmeters, power supply	$340,588
Canadian General Electric Co. Ltd. Ottawa, Ont.	electrical cable, leak detectors	$ 23,382
Canadian General Electric Co. Ltd. Toronto, Ont.	electronic tubes	$181,658
Canadian Marconi Co., Montreal, P.Q.	technical publications	$ 11,567
Collins Radio Co. of Canada Ltd., Toronto, Ont.	maintenance telecommunication spares	$ 33,449
Conway Electronic Enterprises Ltd., Toronto, Ont.	digital voltmeters	$ 25,561
Electric Storage Battery Co. (Canada) Ltd., Toronto, Ont.	batteries	$ 56,651
Electromechanical Products, Agincourt, Ont.	digital decommutator	$ 56,757
Garrett Manufacturing Ltd., Rexdale, Ont.	technical publications	$ 18,600
Gould-National Batteries of Canada Ltd., Toronto, Ont.	batteries	$ 51,759
Honeywell Controls Ltd., Toronto, Ont.	technical publications	$ 54,720
Instronics Ltd., Stittsville, Ont.	electronic equipment, oscilloscopes and accessories	$ 94,563
Lenkurt Electric Co. of Canada Ltd., Ottawa, Ont.	electronic equipment	$ 12,513
Long Sault Woodcraft Ltd., St. Andrews, P.Q.	supply and assembly of rigid radomes	$161,941
Mallory Battery Co. of Canada Ltd., Toronto, Ont.	batteries	$ 14,977
Measurement Engineering Ltd., Arnprior, Ont.	telegraph relay equipment	$ 48,183
Prest-O-Lite Battery Co. Ltd., Toronto, Ont.	batteries	$106,757
RCA Victor Co. Ltd., Montreal, P.Q.	electronic tubes	$ 16,460
Sparton of Canada, Ltd., London, Ont.	sonobuoy transmitters	$2,329,002
Sperry Gyroscope Co. of Canada Ltd., Montreal, P.Q.	marine loran equipments. repair and overhaul of gyro compasses during period ending March 31/62	$ 67,645
Stewart-Warner Corp. of Canada Ltd., Belleville, Ont.	electronic components	$ 19,498
TMC (Canada) Ltd., Ottawa, Ont.	electronic equipment	$ 15,426
Union Carbide Canada Ltd., Toronto and Ottawa, Ont.	batteries, underground feeder cable	$ 61,000
Wind Turbine Co. of Canada Ltd., Waterloo, Ont.	designing and provision of rhombic antenna kits	$ 14,642

Letters to the editor

More promotion for stereo

Dear Sir:

I think Mr. O'Brien raised a most important point in your "EIA News" in the November issue of *Electronics and Communications* regarding the promotion of stereo broadcasting to dealers and the general public.

As a listener, I am very interested in this development and avail myself of the benefits offered by the stereo broadcasting radio stations CFRB and CHFI. However, if I had not had this initial interest, and asked a lot of questions, I doubt that I would have even known that stereo broadcasting was already an established fact. I constantly look over the newspapers' radio sections to see when they are going to mention this important development but up to now, I have failed to notice any. Many of my acquaintances are surprised when I tell them about it.

Promotion of this medium in a way to reach the general public is essential, if it is to succeed.

Sincerely,
C. L. Littler,
185 Bartley Drive,
Toronto 16, Ont.

We get a call for Canadian communications

Dear Sirs:

We are working in 3 different microwave projects to link different cities in Lebanon. The first project is a 120-channel Radio Telephone Link between the cities of Beirut and Tripoli, which will be a public tender closing February 10, 1962.

We kindly request you to get in touch with companies interested in such projects and recommend to us one which can participate in the tender. For your information, please note that two years ago we executed the 72-channel UHF Radio Telephone Link between the cities of Beirut and Damascus . . .

. . . we do hope that we will be able with your help to open the way for Canadian Telecommunication to penetrate this important area, we are, dear sirs,

Yours faithfully,
S. F. Daghir,
D.I.T.A.,
Hout Bldg.,
Beshara - El Khoury St.,
Beirut, Lebanon.

the engineer's

Feature review by A. C. Stonell

"Introduction to the dynamics of automatic regulating of electrical machines" by M. V. Meerov (U.S.S.R.), translated by J. S. Shapiro, published by Butterworth & Co., (Canada) Ltd., 1367 Danforth Ave., Toronto 6, Ont. 411 pp. Price $18.75.

Servomechanism theory cannot be long hidden, even by a title as overpowering as that above, and it rapidly becomes evident as the subject of this book. After the presentation of a lengthy "brief history" of Russian achievements in the field, the author sets off to cover initially familiar ground. It is interesting to view it through Russian eyes, particularly since the "brief history" would lead one to expect a wide ranging and competent exploration. The persistent reader will find rewards, but he will have to work hard for them.

It would appear that the author endeavored to cater both to practising professionals and to students, with the result that the standard of treatment varies somewhat within the book, however, the bias is in favor of the professionals. Despite shortcomings, the book undoubtedly deserves a place in any library of servomechanism texts.

The translation into English has been handled with care, but unfamiliar notation and diagrams, and occasional misprints do not help to make the text readily comprehensible. Fortunately the effect of misprints is not disastrous, their presence is usually obvious. The author himself contributes to the reader's troubles. Possibly through a desire to avoid repetition, explanations of the value and use of particular treatments or approaches are sometimes left until later in a chapter, or are given in a later chapter, or occasionally the reader is left to judge for himself.

One hazard to easy understanding is the author's use of unnecessarily complicated examples, particularly in the early chapters. Specific knowledge of the properties of electrical machines, though not entirely necessary to those using the book as a servomechanism text, would be a decided asset.

Despite these drawbacks, which in time prove superficial, the book is of considerable technical interest. Even in areas commonly covered by standard texts, often new insight may be gained through different methods of presentation. Detailed proofs of higher mathematical theory are usually avoided, although illustrative examples or special cases are sometimes worked to give insight into the nature of mathematical tools. About two-thirds of the book is devoted to linear theory and applications, the remainder to systems with various types of non-linearities.

After an initial differential equation approach, Laplace and Nyquist methods of determining system characteristics are considered. Subsequently a more general approach is taken, based on the continuity

A. C. Stonell was born and educated in England and received his B.A. (mathematics) at Cambridge University. He was a propeller aerodynamicist at both Rotol and De Havilland and later, at Cottage Laboratories, became a senior design engineer working on anti-submarine equipment. Returning to De Havilland Mr. Stonell quickly rose to be Chief Dynamicist on the Firestreak guided missile project. Since his arrival in Canada in 1954, Mr. Stonell has participated in or led a wide variety of projects concerning military systems and electronics. He is presently the Chief Analyst (mathematical) with the De Havilland Special Products Division at Downsview, Ontario.

bookcase

theorem for the dependence of the roots of an equation on its coefficients, which leads to the theory of the so-called D-partition boundary, a mathematical device much used in the remainder of the book. Approximate methods of solution for low order equations, and an interesting discussion of the effect of small parameters on system performance, conclude the section devoted to pure linear theory. Subsequent chapters dealing with the synthesis and methods of improving the stability of servo systems contain useful information, but require careful reading.

Considering the attention apparently devoted in Russia to the theory of non-linear servomechanisms, the relevant section of the book is at first reading somewhat disappointing. Much that is presented therein is covered by other texts, and the standard of presentation varies from lucid explanation in some areas to extended mathematical development in which it is difficult to keep track of the objective in others. The equivalent of the z-transform is used for the analysis of intermittent systems, and the standard phase-plane method is developed in the normal fashion. An extension of the mathematics of this method proves interesting, but lacks examples to aid intuitive understanding. The concluding chapter deals with analysis based on the first harmonic of system response. In general, the impression is gained that the treatment of non-linear problems is barely up to the standard of the remainder of the text. Although the fault is common to the entire book, the lack of worked examples is particularly felt in the later chapters of the work.

Perhaps good advice to the intending reader would be to read the book rapidly first, making notes on the conclusions reached by the author, in order to avoid frustration when the book is read with serious intent. A large Russian bibliography and a short list of books in English is included.

Feature review by Ernest Siddall

"Systems: Research and Design" edited by Donald P. Eckman. Published by John Wiley and Sons, Inc. 440 Park Avenue South, New York 16, N.Y. 308 pages, Price: $8.50 (U.S.)

This publication comprises a banquet address and 12 papers given at the First Systems Symposium at the Case Institute of Technology in April 1960.

As was perhaps unavoidable, it is a miscellany, and the contrasts are more apparent than the theme.

Some parts are on a high philosophical plane and exemplify the basic thinking which is overdue in the present technological explosion. At the other extreme, several pages are devoted to pneumatic control hardware. In between, there are analyses of systems of various types, discussions of operational research into systems and some contributions to control theory and practice.

Chapter 4 is marred by a frightening military discussion of the international political problem.

This book contains some thought provoking material but covers too wide a field too thinly.

Ernest Siddall — Born and educated in Britain. B.Sc. (Engineering) of London University 1939. British Royal Corps of Signals to rank of Major, 1940-1946 (mostly bomb blast instrumentation) until 1951. Atomic Energy of Canada (nuclear reactor control and instrumentation) 1954 until present date. Member of Canadian Government Associate Committee on Automatic Control.

Letters to the editor

We get around

Dear Sir:

I thought you would be interested in hearing that we recently received an enquiry from Athens, Greece, and they mentioned that they had taken our address out of *Electronics and Communications.* It certainly is nice to see this type of distribution.

Yours truly,
M. Binions,
Sales Manager,
Collins Radio Co. of Canada Ltd.

Dear Sir:

I hereby wish to express my sincere appreciation and thanks for your attention in having me receive *Electronics and Communications.* I assure you that I enjoy reading every copy . . .

Yours sincerely,
Guillermo Hernandez Sagarra,
Rear Admiral,
Mexican Navy.

Dear Sir:

Would you please forward to the above address a reprint of the article "Engineers' File Page No. 1" and successive numbers as they become available. Sorry I am rather late in applying for this reprint but unfortunately I am at the end of a long circulation list.

Yours faithfully,
A. Prime,
Research Laboratory,
Amalgamated Wireless (Australasia) Ltd.,
Ashfield, Australia.

Answers to problems!

How often have you pondered over a technical problem only to have someone else, usually an outsider, with a different slant, point out a good solution? We believe this happens every day in our industry and have decided therefore to provide space in *Electronics and Communications* for readers' problems and solutions.

To take advantage of this new service, send problem statements along to the Editor for publication . . . a code number will be used thus keeping the name and address of the sender confidential.

Readers are invited to submit answers to the problems and full acknowledgment will be given for all solutions published.

opportunities

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Reply in strict confidence with resumé of experience, personal data and salary expected to:

Personnel Manager
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Box 874, Winnipeg 1, Manitoba

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Radio Valve Company Limited
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CRTPB newsletter

Continued from page 10

In his report Mr. Pounsett underlined many of the various committees' accomplishments on projects which were finalized during the year, mentioning particularly the Board's work on Specification 136 — the General Services Band specification; Broadcast Procedure No. 6 on the Standards for FM Stereo Broadcasting; and Specification 126 on 150 mc/s Split Channel Service.

Executive Committee Unanimously Re-Elected

The delegates re-elected or re-appointed the complete Executive Committee for the 1962 term. Continuing in office for the coming year will be the President, F. H. R. Pounsett; Vice-President, C. J. Bridgland, Canadian National Telecommunications, Toronto; Advisory Technical Coordinator, R. A. Hackbusch, Hackbusch Electronics Limited, Toronto; Director of Public Relations, R. C. Poulter, Radio College of Canada, Toronto; Secretary-Treasurer, F. W. Radcliffe, Electronic Industries Association of Canada, Toronto; Assistant Secretary-Treasurer, Cowan Harris, EIA of Canada, Toronto; and Assistant Technical Coordinator, R. T. (Dick) O'Brien, EIA of Canada, Toronto.

editorial

The circuit designer

The circuit designer . . . the reliability engineer . . . the systems designer . . . the procurement agent . . . which of these specifies the use of electronic components? Dependent upon circumstances, one or more of the cited professionals take part in this important function but in practically every case the biggest and most important say comes from the circuit designer.

The reliability engineer can feed in failure rates, the systems designer can advise on overall system philosophy and the procurement agent can have his say in regard to inventory preferences and delivery times, but only rarely can the decision to purchase be made without the O.K. of the circuit design engineer. This situation is of course quite right and proper and the thought of supplying the circuit engineer with components arbitarily selected for his tasks in hand is manifestly absurd. Strangely, though, the considerable responsibility carried by the circuit engineer in shaping his company's procurement policies is not always clearly appreciated and a greater recognition of his important "purchasing-direction" role by the component vending companies could well work to their advantage as well as to his.

In particular, component data sheets should be as comprehensive as possible in regard to the information supplied . . . any omission of a temperature coefficient, input capacitance or other less obvious parameter value will probably mean the choice of another product line where such data is supplied rather than the origination of a letter of enquiry for the missing values.

Of very great importance is the question of the rapid supply of small quantities of components. Personal experience over many years has shown that time and time again what gets into the breadboard or prototype usually comes up in volume when the production design is settled. A vendor that cannot supply the ones, twos and threes at short notice is potentially throwing away the 100s, 200s and 300s and maybe even 30,000.

In summary, in this special Circuit Design issue, we have taken the liberty of bringing up two of the biggest beefs that the circuit men come up against. We do this however, in a constructive way since we firmly believe that a greater rapport between the vendors and the designers will increase effectiveness and business all round.

We close with a salute to our un-sung hero, the circuit designer, with the hope that both the component vendors and ourselves can help to make his job easier and more effective in the future.

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2N859	40v	150	0.1	30	120	6
2N860	25v	150	0.1	15	45	6.5
2N861	25v	150	0.1	30	100	7.5
2N862	15v	150	0.1	20	60	8
2N863	15v	150	0.1	40	120	10
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