



*the* **GENERAL<sup>®</sup>.RADIO** *Experimenter*

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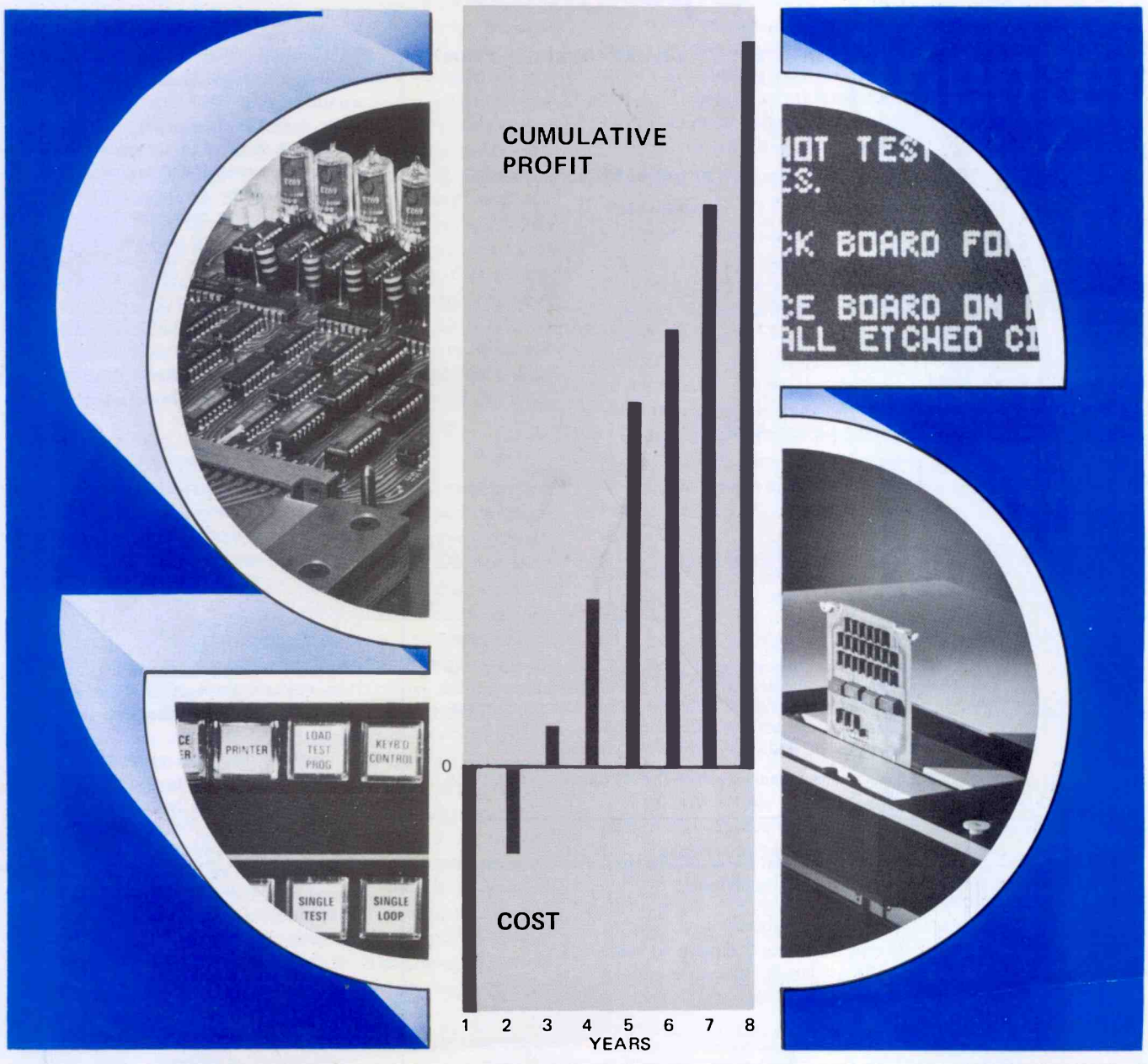
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THE  
GENERAL RADIO



# Experimenter

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GENERAL RADIO  
**Experimenter**



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**THE COVER should indicate to all readers that General Radio has proved the profitability of investing in a computer-controlled logic-circuit tester.**

According to a forecast by the U.S. Department of Labor, issued early in 1970, the services and skills of engineers and technicians will continue to be in heavy demand during the next decade. The rate of growth of demand conceivably can be twice that of all working people.

The department foresees a shortage in supply of this critical group because of the decreasing enrollment in engineering studies. A determined effort must be made on the part of industry to upgrade all technical and semi-technical personnel to provide more efficient performance, thereby helping to close the gap between manpower needs and manpower accomplishments.

At the risk of stating the obvious, we would like to stress to our readers and their managers the need also to upgrade the use of machines and the *machines* themselves, releasing the human beings for more essential planning and thinking tasks. It is for this very reason that companies like General Radio recently have been devoting much of their research, innovation, and development talents to the production of automatic test equipment that will relieve technical personnel from repetitive and tedious tasks. This will permit more constructive and efficient use of their capabilities.

There is another basic reason for using machines: *Profit*. Industry finds that many applications of machine control to routine tasks save money, after the short period of time required to earn back (in most applications) the original capital investment in tooling. Too often, however, the men with the strongest instinct to do things better, faster, and more efficiently do not have sufficient background in finance to convince management of the ultimate wisdom of spending money, and sometimes lots of it, for machine assistance. It is to them we have addressed the first article in this issue.

Through the years of teaching fellow workers the ways to approach management for capital funds, we have found no better way than to present the proposal in terms of the probability of payback in a comparatively short time with realizable profits following immediately. We hope that you will be able to apply this principle to your own procurement problems.

*C. E. White*

C. E. White  
Editor

# The Economy of Computer-Controlled Measurements\*

## Introduction

Is your production schedule limited by manual tests of items completed or in process? Have you noticed that your inspection people are unable to retain efficiency as they routinely and monotonously check, check, check? Perhaps you've begun to give some thought toward changing your test methods, revising or replacing your old test equipment, and improving the efficiency of your inspectors. The idea of employing computer-assisted test equipment has been in your mind for some time but you don't know how to justify, to a hard-nosed management, the costs of the added facilities.

Your problem is no different from that which faced our production engineers at General Radio some time ago, when they decided to change from manual to computerized production-test operations. We thought, therefore, that a short discussion of the technique used by the engineers to convince GR management to finance the change would be of interest and value to our readers. The examples given use current cost and test-rate data and are presented for different quantities of digital logic boards to illustrate the application of the technique.

## Why Economic Considerations?

The *engineering* decision to use costly test instrumentation is not very difficult since it is usually based upon technical considerations only. The *financial* decision, however, is usually made by an entirely different group of people, continually alert to the material needs and operating costs of an organization. Because of the ability of technical and financial minds to cross-fertilize each other and to reach a common understanding, progressive industrial organizations originated a rational approach to capitalization of facilities several years ago. They named it "cost-effectiveness" and it became a useful management tool. More important, it forced production engineers, in need of test equipment, to speak the language of accountants and broadened the appreciation each had for the other. Engineers began to speak in terms of total investment, discounted rate of return, depreciable life and tax shields. Accountants became equally appreciative of component failures and failure rates, of labor time to maintain equipment and to inspect production components, of equipment interfaces and software, and of precision of tolerances.

Another advantage of this cross-fertilization of ideas was to change the focus of management's attention from what *has*

*been* invested in equipment to what *should be* invested in equipment. Yesterday's investment decision resulted in savings we are experiencing today, but can a new investment today result in even greater savings tomorrow?

These terms and techniques are illustrated below as they might be used to calculate a cost-effectiveness solution to the problem of testing digital logic boards. *Our* solution was the GR 1790 Logic-Circuit Analyzer.<sup>1</sup> The typical data used are based upon experience with GR logic circuits constructed with 12 to 60 14- or 16-pin digital IC's on printed-circuit boards.

## The Old Way

Prior to the installation of the GR 1790 system in our manufacturing facility, we used hard-wired test fixtures for each board to be tested. Preparation of these fixtures required a design and fabrication period of 1 to 4 weeks per board, normally averaging 2 weeks. Test times using these fixtures were reasonably short (5 to 10 minutes), but the lack of significant diagnostic information resulted in troubleshooting and repair times of 20 to 40 minutes.

Total costs for this approach are shown below, assuming the minimum times given above, a quantity of 10,000-boards/year made up of 50 different board types, and a board failure rate of 33%.

| WITH ORIGINAL TEST FIXTURES                                     |  |       |          |
|---|--|-------|----------|
| Preparation:  |  |       |          |
| (50 types/yr) (2 wk/type) (40 h/wk) (\$4/h)                     |  |       | \$16,000 |
| Test:   |  |       |          |
| (10,000 bd/yr) (5 min/bd) ( $\frac{1}{60}$ h/min) (\$4/h)       |  |       | 3,333    |
| Troubleshooting and Repair:                                     |  |       |          |
| (3,333 rejects/yr) (20 min/bd) ( $\frac{1}{60}$ h/min) (\$4/hr) |  |       | 4,444    |
|   |  | Total | \$23,777 |

## The Forecast

Our production engineers estimated that, after introduction of a computer-controlled test system, preparation of the test programs and test fixtures would take 24 hours per board type. Actual test time per board, by relatively unskilled labor, would be 30 seconds. Since rejected boards would be accompanied by a troubleshooting printout from the computer, time to diagnose and to repair the rejects was expected to decrease from 20 minutes to 12 minutes.

\*As applied to procurement and application of the GR 1790 Logic-Circuit Analyzer, described on page 7.

<sup>1</sup>Fichtenbaum, M. L., "Computer-Controlled Testing Can Be Fast and Reliable and Economical without Extensive Operator Training," *Electronics*, January 19, 1970.

Based upon these estimates, costs (in 1968) were calculated:

#### WITH COMPUTER-CONTROLLED TEST SYSTEM

|   |       |         |
|---|-------|---------|
| Preparation:  |       |         |
| (50 types/yr) (24 h/type) (\$4.00/h)                                |       | \$4,800 |
| Test:   |       |         |
| (10,000 bd/yr) (30 s/bd) ( $\frac{1}{60 \times 60}$ h/s) (\$1.65/h) | 138   |         |
| Troubleshooting and Repair:   |       |         |
| (10,000 X .33 bd/yr) (12 min/bd) ( $\frac{1}{60}$ h/min) (\$4.00/h) | 2,640 |         |
| Total   |       | \$7,578 |

Hence the total direct-labor savings made possible by use of the computer-controlled test system were estimated to be \$23,777 - \$7,578 = \$16,199/year. Management approved the installation after reviewing these figures and studying a funds-flow analysis similar to that of Tables 3 and 4.

#### The New Era

Use of the 1790 Logic-Circuit Analyzers in the manufacturing facilities confirmed the production engineers' forecast. The preparation time was significantly reduced, since only a simple mechanical interface and an easy-to-write test program were required for each new device. These are normally prepared in 1/2-2 days depending upon the complexity of the board to be tested and, in our experience, averaged 1 day/type. The actual test time was reduced to milliseconds, but the time required to insert and remove the board being tested kept the total test time at an average of 30 seconds. The GR 1790 makes convenient the inclusion of diagnostic suggestions in the test program so that troubleshooting time may also be reduced. The time required, however, to effect a repair (replace an IC, remove a solder bridge, etc) kept the troubleshooting/repair time to an average of 6 minutes. Actual total costs for the same quantities used in the forecast to management are

#### WITH THE GR 1790 LOGIC-CIRCUIT ANALYZER

|   |       |         |
|---|-------|---------|
| Preparation:  |       |         |
| (50 types/yr) (1 d/type) (8 h/d) (\$4/h)                          |       | \$1,600 |
| Test:   |       |         |
| (10,000 bd/yr) (30 s/bd) (1/3600 h/s) (\$2/h*)                    | 167   |         |
| Troubleshooting and Repair:                                       |       |         |
| (3,333 rejects/yr) (6 min/reject) ( $\frac{1}{60}$ h/min) (\$4/h) | 1,333 |         |
| Total   |       | \$3,100 |

\*Relatively unskilled labor cost - 1969.

Table 1  
Typical Annual Labor Savings  
(Based on GR experience)

| Bd/yr   | Number of different board types |          |           |            |          |           |
|---------|---------------------------------|----------|-----------|------------|----------|-----------|
|         | 10% Reject                      |          |           | 50% Reject |          |           |
|         | 50                              | 100      | 500       | 50         | 100      | 500       |
| 1,000   | \$14,800                        | \$29,200 | \$124,400 | \$15,200   | \$29,600 | \$144,800 |
| 10,000  | 18,500                          | 32,900   | 148,100   | 22,200     | 37,600   | 151,900   |
| 100,000 | 55,400                          | 69,800   | 185,000   | 92,700     | 107,100  | 222,300   |

Hence, the total direct-labor savings made possible by the GR 1790 in this example are \$23,777 - \$3,100 = \$20,677/year.

The typical quantities (and hence the labor savings) will obviously differ with industry and product. Table 1 gives the value of annual labor savings for 3 quantities of boards, 3 numbers of different types of boards, and 2 failure percentages. These figures are based upon the same rates used in the preceding example.

The saving in labor costs is only one calculation in the cost-effectiveness approach. It is also important to consider the expenses and savings over a period of time of concern (the cash flow) and to discount future funds to reflect their present value.\*\*

The obvious initial expense is the purchase price of the system. Additional costs include time spent attending training courses and acquiring proficiency in writing test programs and using the system, plus normal operation and maintenance costs.

The labor savings calculated above are reduced by the 50% Federal corporate tax rate, as are other internal expenses and savings. Included on the savings side of the ledger is depreciation, a non-cash expense that acts as a tax shield. Analysis of the depreciation of the GR 1790 appears in Table 2.

Table 3 gives the funds-flow analysis for an eight-year period. The Net Operating Advantage is shown at the bottom of each column. Table 4 presents an analysis of the funds-flow after taxes for the same eight-year period. It is obvious from Table 1 that use of a larger number of different types of boards or a larger quantity of boards would significantly affect the final calculation. For example, if this study had been based on 100 different types of boards instead of 50, the Payback Period would have been about 8 months and the Discounted Rate of Return would have been approximately 150%.

\*\*The application of accounting principles, which reflects the time value of money.

Table 2  
Depreciation Calculation for GR 1790  
(Sum-of-the-years-digits method)

|                   |          |                      |
|-------------------|----------|----------------------|
| Original cost:    | \$32,500 |                      |
| Salvage:          | -4,000   | Useful life: 8 years |
| Depreciable cost: | \$28,500 |                      |

| Year | Digits | Depreciation | 50% Tax Shield |
|------|--------|--------------|----------------|
| 1969 | 8/36   | \$ 6,300     | \$ 3,150       |
| 1970 | 7/36   | 5,500        | 2,750          |
| 1971 | 6/36   | 4,700        | 2,350          |
| 1972 | 5/36   | 4,000        | 2,000          |
| 1973 | 4/36   | 3,200        | 1,600          |
| 1974 | 3/36   | 2,400        | 1,200          |
| 1975 | 2/36   | 1,600        | 800            |
| 1976 | 1/36   | 800          | 400            |
|      |        | \$28,500     | \$14,250       |



Table 3  
Funds-Flow Analysis – Type 1790

|   | 1969              | 1970            | 1971            | 1972            | 1973            | 1974            | 1975            | 1976            |
|---|-------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| <b>EXPENSES</b>   |                   |                 |                 |                 |                 |                 |                 |                 |
| Cash Outlay (Purchase)                                    | \$32,500          | \$ —            | \$ —            | \$ —            | \$ —            | \$ —            | \$ —            | \$ —            |
| Cash Inflow (Salvage)                                     | —                 | —               | —               | —               | —               | —               | —               | (4,000)         |
| Production Engineering                                    |                   |                 |                 |                 |                 |                 |                 |                 |
| \$1000 first year, \$500 there-<br>after (50% tax shield) | 500               | 250             | 250             | 250             | 250             | 250             | 250             | 250             |
| Maintenance   | 500               | 500             | 500             | 500             | 500             | 500             | 500             | 500             |
| <b>Total Expenses</b>                                     | <b>33,500</b>     | <b>750</b>      | <b>750</b>      | <b>750</b>      | <b>750</b>      | <b>750</b>      | <b>750</b>      | <b>(3,250)</b>  |
| <b>SAVINGS</b>  |                   |                 |                 |                 |                 |                 |                 |                 |
| Test/Repair Labor Savings<br>(50% Tax Shield)             | 10,338            | 10,338          | 10,338          | 10,338          | 10,338          | 10,338          | 10,338          | 10,338          |
| Depreciation (50% Tax<br>Shield from Table 2)             | 3,150             | 2,750           | 2,350           | 2,250           | 1,600           | 1,200           | 800             | 400             |
| <b>Total Savings</b>                                      | <b>13,488</b>     | <b>13,088</b>   | <b>12,688</b>   | <b>12,338</b>   | <b>11,938</b>   | <b>11,538</b>   | <b>11,138</b>   | <b>10,738</b>   |
| <b>NET OPERATING ADVANTAGE</b>                            | <b>(\$20,012)</b> | <b>\$12,338</b> | <b>\$11,938</b> | <b>\$11,588</b> | <b>\$11,188</b> | <b>\$10,788</b> | <b>\$10,388</b> | <b>\$13,988</b> |

Table 4  
Funds-Flow After Taxes

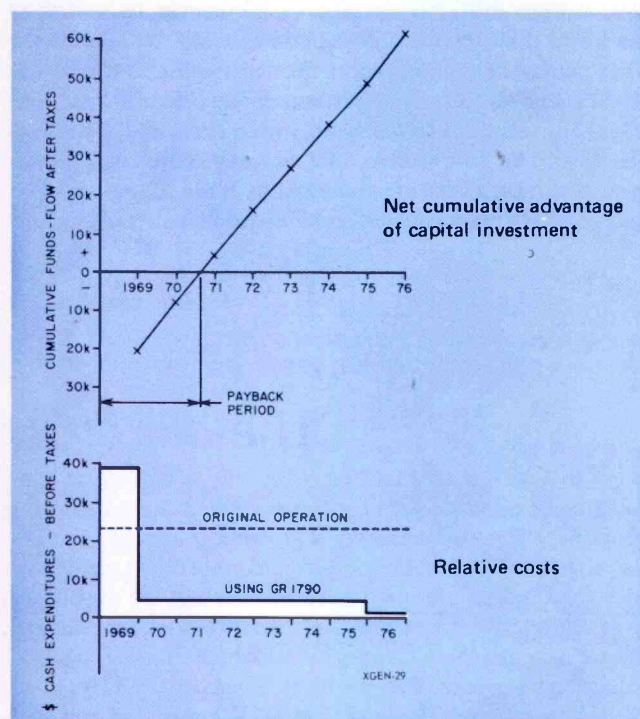
| Year | Annual     | Cumulative | Payback<br>Ratio |
|------|------------|------------|------------------|
| 1969 | (\$20,012) | (\$20,012) | —                |
| 1970 | 12,338     | (7,674)    | —                |
| 1971 | 11,938     | 4,264      | 0.13             |
| 1972 | 11,588     | 15,852     | 0.49             |
| 1973 | 11,188     | 27,040     | 0.83             |
| 1974 | 10,788     | 37,828     | 1.16             |
| 1975 | 10,388     | 48,216     | 1.48             |
| 1976 | 13,988     | 62,204     | 1.91             |

Payback Period = 2.6 years

Discounted Rate of Return = 56%

A standard discount table was used to calculate the Discounted Rate of Return, which was 56%. This percentage can be related to a corporate goal for return on investment to screen out undesirable projects or programs.

Alternatively, an arbitrarily chosen discount rate, which approximates the desired internal rate of return, can be used to discount the cash flows. The Present Value of a project is the sum of the discounted cash flows; a positive Present Value indicates a profitable project. The magnitude of Present Value of a project can be related to that of other projects to allow management to make a choice between programs competing for available funds.



For those of you who are not familiar with cash flow discounting we offer a short explanation. We have referred to the time value of money. Because of this factor, expenses (cash outflows) of one period of time cannot be directly compared with income (cash inflows) of another period. The reason for this is that the money we have today can be invested to bring us a return and, therefore, will be worth more at the end of this year, next year, and each succeeding year that the money remains invested. At a discount rate of 10%, \$1 earned three

years from now is worth, to us today, \$1/\$1.33 or \$.75. That is the Present Value of the \$1 earned three years hence: \$.75. The discount rate chosen is usually the desired *internal rate of return*.

Further information is available to readers interested in financial aspects of facility acquirement in a reprint of a talk by W. D. Hill of General Radio to the Planning Executives Institute, October 4, 1968, entitled "Planning Investments in Research and Development."



## Other Applications

At General Radio, the GR 1790 is also used in Incoming Inspection for functional tests of all digital IC's. This inspection has reduced our failure rate of IC's in printed circuit boards from an initial 4-8% to less than 1%. Were these figures included in the cost-effectiveness analysis, the case for the GR 1790 would be even stronger. We did not, however, include these figures in the above example since the primary purpose of the GR 1790 is to test and troubleshoot assembled logic boards, and because relatively low-cost digital IC testers are available. On the other hand, the increasing use of MSI and LSI circuits in standard 16- and 24-pin packages has created additional testing requirements that cannot be met by low-cost digital IC testers. The ease with which the GR 1790 makes these tests assures ready customer acceptance even in its IC testing role. And, of course, printed circuit boards that use many of these MSI packages are in turn so much more complex that the reduction in test and troubleshooting time provided by the GR 1790 far exceeds the savings depicted in the examples above.

## Views of the Manufacturing Manager

The planning and foresight of the production engineers were justified on the basis of simple dollars-and-cents analyses, before and after the fact. Consequently, their view of the world through rose-colored glasses could be excused. But what about the manufacturing manager, close to the assembly line and continually alert to every-day personnel relationships? His reactions to the system were expressed somewhat like this: The test system, like any expensive tool, had to meet a number of basic requirements. It did. These included ease of operation by normally skilled machinists/technicians.

The system was completely useful almost from the moment of installation – familiarization/training time was a minimum. The test capability of the system was broad, sufficient to permit change of interface equipment from component testing to assembly testing within a very short period of time. Vendor service, such as programming advice or advice on instrumentation implementation, was continually available from knowledgeable sources.

The position of the manufacturing manager at GR is not necessarily the same as that of a manufacturing manager at another company. In this case, however, a true vendor-customer relationship existed because of the complexity of design and application problems. Consequently, the solutions to the personnel-interface problems between manufacturing and engineering were worked out smoothly and, in fact, became the basis for the program of service decided upon to implement the sales of the system to industry at large.

## Conclusion

In many ways, our experience in development and application of the GR 1790 supports the theme that innovative metrology is, in fact, the key to industrial progress.\* Industry can gain immeasurably by new ways of saving time and reducing costs and by new technologies and their applications.

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\*The theme of the 1970 Standards Laboratory Conference, sponsored by the National Conference of Standards Laboratories, is "Innovative Metrology – Key to Progress."

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The Editor is indebted for most of the material contained in this article to P. H. Goebel, R. E. Anderson, and R. F. DeBoalt. Financing details were verified and expanded upon by W. D. Hill.

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## "The old order changeth . . ."

As companies grow, old patterns tend to change. Our International Division is currently growing at a rapid pace; we are progressively assuming a more and more direct role in our sales abroad, and old marketing relationships are dissolving.

In Europe we are establishing our own sales subsidiaries, and we have taken over from old and valued friends the job of selling and servicing GR products. Thus, in 1964, we established General Radio Company (U.K.), Limited and said good-bye to Claude Lyons, Limited after 27 years. As of the middle of 1969 we purchased the GR segment of Etablissements Radiophon, our French outlet for over 33 years, and rechristened it General Radio France, with Paul Fabricant temporarily staying on as President to ease the transition.

In setting up our new subsidiary, General Radio Italia S.p.A., and bidding farewell to Ing. S. and Dr. Guido Belotti S.r.l., we again bring to a conclusion a long and fruitful collaboration. Dr. Belotti, and his father before him, represented us in Italy for 37 years and will continue to manufacture, under GR license, Variac® autotransformers.

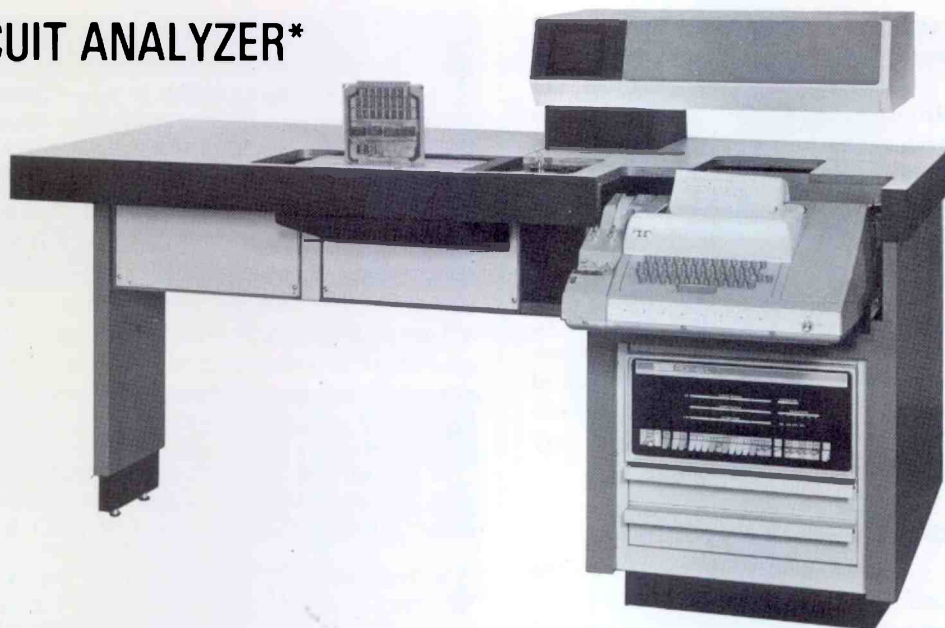
We have expanded the coverage of our German subsidiary, General Radio GmbH, to the northern part of Germany as well as the southern. This brought to a close a shorter association with Dr.-Ing. G. Nüsslein but one that has helped significantly to expand GR's market in Germany.

In Latin America we have worked for 29 years through the export house of Ad. Auriema, Inc. In furthering our objective of establishing as direct contact as possible with our customers, we are now moving one step closer to them by replacing this channel by a network of representatives directly responsible to GR. To Carlos Auriema, who, with his father before him, has been our colleague and friend, we must now say goodbye.

These gentlemen – Claude Lyons, Paul Fabricant, Dr. Guido Belotti, Dr. Günter Nüsslein, and Carlos Auriema – have all been good friends, as well as business associates, of GR. We wish them well in their continuing pursuits and thank them for their contributions to General Radio's successes.

– D.B. Sinclair

# GR 1790 LOGIC-CIRCUIT ANALYZER\*



## GR 1790 DEFINED

The GR 1790 Logic-Circuit Analyzer is a computer-controlled functional GO/NO-GO and diagnostic test system for logic devices ranging from basic 14-pin integrated circuits to assemblies with as many as 96 inputs and 144 outputs. The system performs up to 4000 tests per second and yields a GO/NO-GO indication and a typewritten or scope-displayed error message.

Purchase justification is easy.\*\* Savings are stressed in the process of programming and in the ready adaptability of test fixtures. Test programs are written by technician-level personnel in much less time than it takes to write manual test procedures, and costly tooling is eliminated by the simple and flexible device adaptor between the tester and the tested. Testing costs are low because of the speed of computer-directed tests, and troubleshooting costs can be sharply reduced by the inclusion of operator diagnostic instructions in the test program.

The simplified test language developed by General Radio can be learned in just a few hours. The entire test operation is characterized by speed and efficiency:

1. The operator writes a test program consisting of simple statements of the

input and output conditions of the circuit to be tested.

2. The test program is converted to punched tape on the teletypewriter and then is automatically translated into a more compact form; programming errors are detected during the translation.

3. The test program is entered into the computer via the high-speed tape reader.

4. The test circuit is connected to the system by a device adaptor corresponding to the input/output configuration of the circuit.

5. The operator presses the START button on the control panel.

All testing then proceeds automatically. Should a fault occur, the operator can troubleshoot immediately or continue to test the remainder of the devices, saving the repair work for later.

The five steps above apply only when a new test program is required. If the test operator receives a new manufacturing run of a previously tested device only steps 3, 4, and 5 will be needed, thereby enhancing the speed and savings features of the GR 1790.

## THE PHYSICAL ORDER

The standard system components of the GR 1790 are:

- Computer with 4,096 12-bit words of 1.6- $\mu$ s-cycle core memory.
- Interface system.
- Control panel.

- Power supplies.
- Teletypewriter with keyboard, tape reader, and tape punch.
- Photoelectric tape reader.
- Alpha-numeric display oscilloscope.
- Logic probe.
- Device adaptor kits. †

Options include a rack version, additional memory, and programmable logic levels.

In both desk console and rack versions, all controls are within easy reach and monitoring indicators are readily visible (Figure 1). The GR 1790 does not

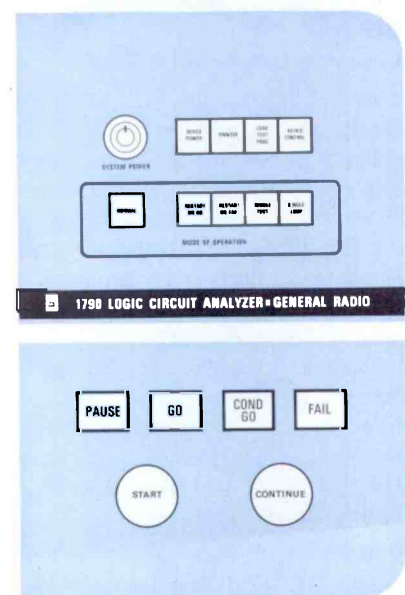


Figure 1. Control panel layout.

\*Abstracted from special brochure available upon request.

\*\*See page 3.