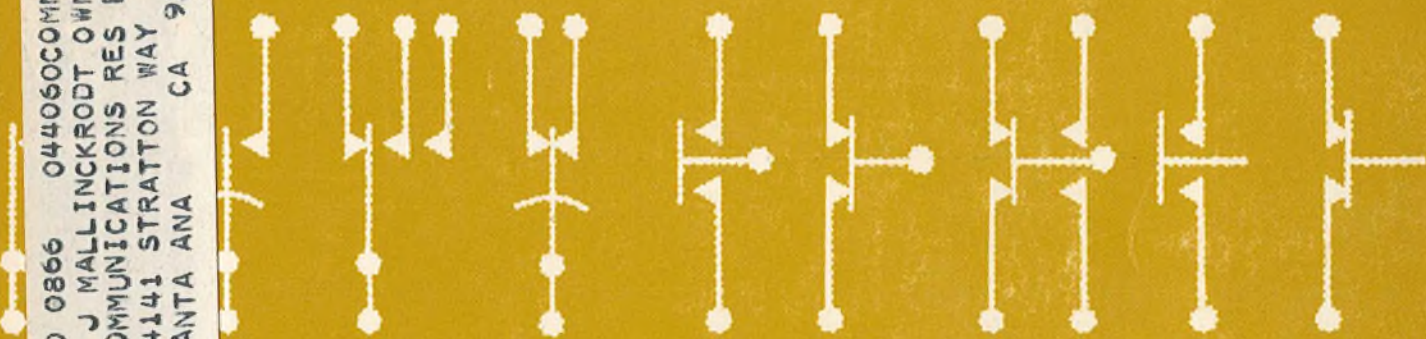
November 29, 1965

Concepts and Ideas Essential to Design Action

ELECTRONIC DESIGN

Relays vs. semiconductors * Relay application notes

Who-makes-what chart * Specifying information



RELAY APPLICATIONS

In ceramic or glass...

VAC high voltage relays mean

R ELIABILITY!

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ct mass, contacts free of oxides and pitting and minimum contact
e. These long-life reliability features are made possible only
se of operation in a high vacuum dielectric. Vacuum technology
nade high reliability, long life high voltage switching practical,
considerable savings in space and weight. Developed for high
ge, high peak current applications, Hyvac relays are well suited
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c's broad line and "Quick Reaction Time" is geared to your most
al delivery schedule. We have the high vacuum experience, design
roduction capability to provide special modifications of our stand-
ff-the-shelf designs in unbelievably short order. Hyvac, a company
enough to be responsive, large enough to be responsible. Check
rief specifications of our "H" series:

HYVAC TYPE	HC-1	H-8	H-9	H-11	H-12	H-16	H-17	H-18	H-19	H-20
t Arrangement	SPDT	SPDT	SPST	SPST	SPDT	DPDT	SPDT	DPDT	DPDT	SPST
perating (kv dc)	25	20	20	12-air 18-oil	8-air 12-oil	12-air 18-oil	25	10	20	28
ous current, (amps-rms)	14	15	15	15	15	15	25	10	20	75
ing time, max (ms)	6	15	15	18	18	20	25	15	40	25
ltage, nominal (vdc)	26.5	26.5	26.5	26.5	26.5	26.5	26.5	26.5	120	26.5
. price (1-9 pcs)	$59	$98	$98	$105	$110	$128	$128	$135	$135	$150

only

For complete technical information, contact your nearest
sales engineering representative, or write directly to us.

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207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399
700	710	720	730	740	750	760	770	780	790	800	810	820	830	840	850	860	870	880	890
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702	712	722	732	742	752	762	772	782	792	802	812	822	832	842	852	862	872	882	892
703	713	723	733	743	753	763	773	783	793	803	813	823	833	843	853	863	873	883	893
704	714	724	734	744	754	764	774	784	794	804	814	824	834	844	854	864	874	884	894
705	715	725	735	745	755	765	775	785	795	805	815	825	835	845	855	865	875	885	895
706	716	726	736	746	756	766	776	786	796	806	816	826	836	846	856	866	876	886	896
707	717	727	737	747	757	767	777	787	797	807	817	827	837	847	857	867	877	887	897
708	718	728	738	748	758	768	778	788	798	808	818	828	838	848	858	868	878	888	898
709	719	729	739	749	759	769	779	789	799	809	819	829	839	849	859	869	879	889	899

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☐ I do design engineering work.

☐ I supervise design engineering work.

☐ I set standards for design components and materials.

☐ I do no design engineering work.

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Air Mail Direct to Manufacturer

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I would like information immediately on the product listed below. I may possibly have an application for this item in the near future.

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ELECTRONIC DESIGN'S RELAY DIRECTORY 1965

Mark B. Leeds
Technical Editor

For the first time, a comprehensive, applications-oriented guide to relays is at your fingertips. Chances are that one year (or more) from now, you will still be using this reference issue.

Devoted to design, selection and specification needs, it contains virtually all you need to know about relays.

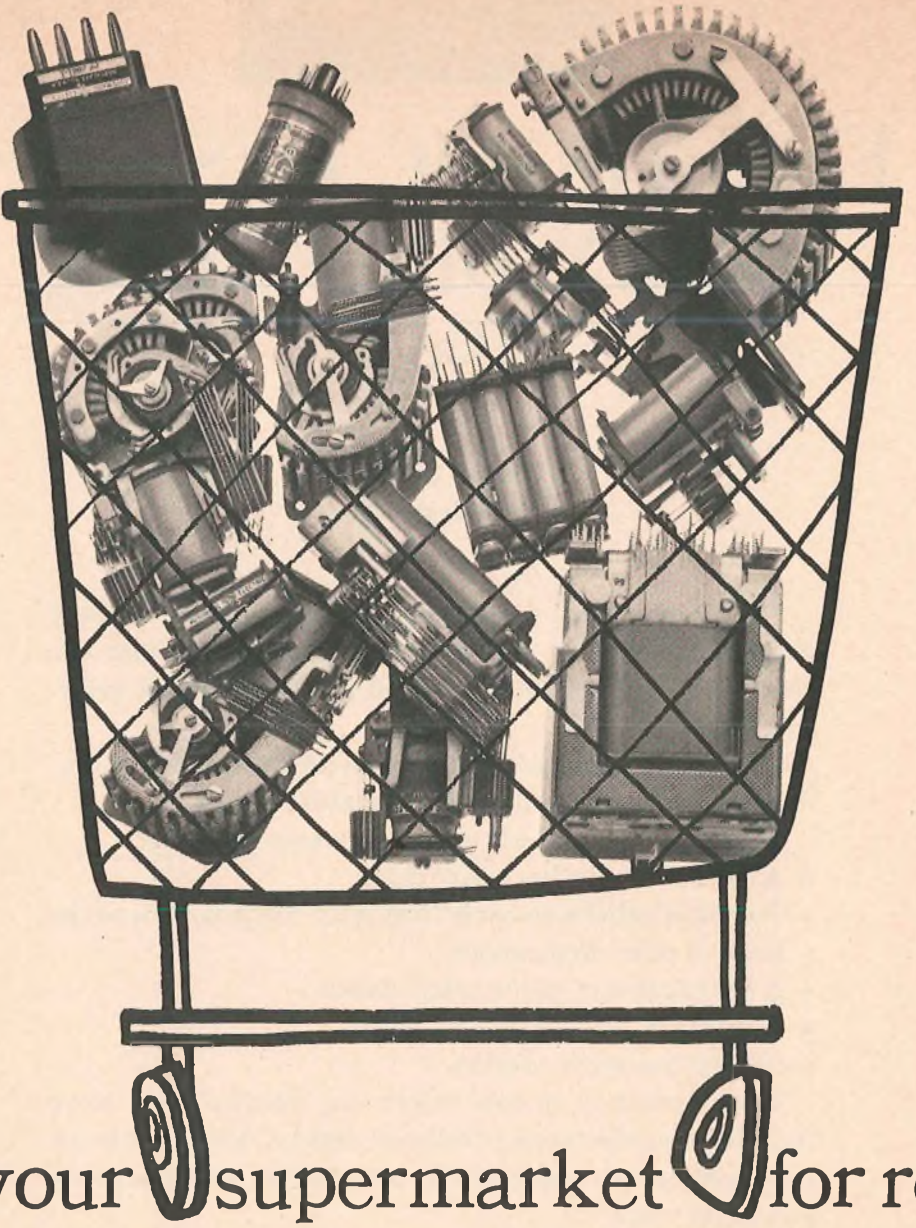
Included in the contents of this reference issue are:

- A handy "who makes what" chart.
- Technical articles ranging from relay fundamentals to the latest in relay applications.
- A compilation of useful relay circuits.
- A listing of MIL and NASA specs.
- A relay-literature offering.

The information in this report was solicited from more than 400 manufacturers. Technical articles were written by industrial experts representing both leading manufacturers and major users.

ELECTRONIC DESIGN wishes to acknowledge its appreciation for the expert assistance and guidance offered by the National Association of Relay Manufacturers (NARM) in particular. Three of the technical articles were written by members of the NARM Board of Editors. They represent condensed versions of material extracted from the forthcoming NARM Engineers Relay Handbook (to be published by Hayden Publishing Co. next Spring).

Be sure to bring your relay data up-to-date by obtaining catalogs, specification sheets and other information. Just circle the numbers from the manufacturers' literature offering (p 6) on the Reader-Service Card. Also, consult the New Products section (p 82) to secure the latest in relay products.



AE is your supermarket for relays and switches. Over 200 types... for off-the-shelf delivery within 7 days!

Get 'em fast—direct from us—at no extra charge. That's the AE Stock Program.

Under this growing program, we keep about 205 types of relays, switches and accessories on hand at all times. In quantities large enough to fill your ordinary requirements within one week.

You get this fast delivery on many of the most popular types from AE's broad line: EIN (integral socket) relays with power contacts; mercury-wetted contact relays; PC Correeds*; rotary stepping switches with Gold Levels for dry circuits; ERM (magnetic latching) relays; Class E relays with four different terminal designs, and many more.

Send for your free copy of Circular 1053, "AE Relays and Switches in Stock." It's the latest listing of items available for quick delivery. Just write to the Director, Relay Control Equipment Sales, Automatic Electric, Northlake, Ill. 60164.

*U.S. Patent Pending

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ON READER-SERVICE CARD CIRCLE 3

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List of manufacturers and their literature offerings 6

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Commutated relay spearheads new switching technique 18

Don't dismiss the relay for data processing systems 24

Designing with relays is more subtle than you think 30

Curing interference in relay systems: Look to the source, then suppress 37

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Pinpoint your relay needs by writing complete specifications 52

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ELECTRONIC DESIGN is published bi-weekly by Hayden Publishing Company, Inc., 850 Third Avenue, New York, N. Y. 10022. T. Richard Gascoigne, Chairman of the Board; James S. Mulholland, Jr., President. Printed at Poole Bros., Inc., Chicago, Ill. Controlled circulation postage paid at Chicago, Ill., and New York, N. Y. 62,108 copies this issue. Special reference issue $5 a copy.

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CONTROL INNOVATION

easy to mount easy to wire

NEW GENERAL ELECTRIC CR120 TYPE H RELAYS GIVE YOU 9 MOUNTING METHODS–4 PLUG-IN, 2 TRACK-MOUNTED FORMS

General Electric's new CR120 Type H general purpose relay line incorporates mounting and wiring innovations which give you the ideal relay for many electronic and electrical applications such as machine tools, air conditioners, photoelectric switches, office machines and packaging machines.

MOUNTING FLEXIBILITY

You can choose from a variety of mounting arrangements — stud or screw-mounted open relays, front- or back-mounted relays with dust covers or plug-in relays.

Back-mounted relays with dust covers are offered with plastic mounting channel for easy snap-in installation.*

Two types of plug-in arrangements are offered. A unique General Electric front-wired socket gives you the smallest, lowest cost relay-socket combination yet manufactured that meets UL creepages and clearances for 150 volts. And these sockets give you the added flexibility of push-mounting in a special G-E mounting channel.* Wiring is simplified by .110" terminals for either flag-type push-on terminals or solder connection. The front-wired socket will accept 5- or 10-amp double-pole, double-throw relays.

Back-wired sockets provide .205" terminals. These sockets meet UL creepages and clearances for 150 volts and will accept 5- or 10-amp relays with up to three-pole, double-throw contacts. Tube-type plug-in relays (octal or 11-pin) are also offered.

All relays have molded-in terminals, solid one-piece armature assembly and reinforced construction. Five-amp forms have .110" and 10-amp forms .205" terminals.

EXTRA CONVENIENCE

Now you can order relays with two terminals on each side of the coil and two on the common side of each double-throw contact. This simplifies wiring by eliminating the need to put two wires on one terminal. It is particularly helpful when you are wiring the relays in series.

Manual operators and neon indicating lights are available for your special applications. An exclusive manual operator for all relays with dust covers, except back-mounted forms, permits manual relay operation during check out and testing.* Indicating lights give you quick visual indication of coil circuit condition. Sensitive 3-amp relays and latched forms are also available.

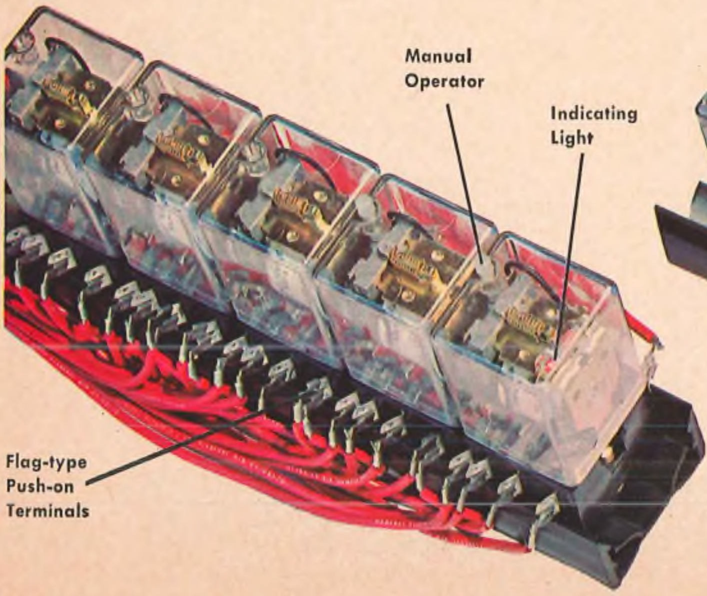
For more information, contact your G-E Sales Engineer or Distributor. Or write for publication GEA-7882 to Section 811-58, General Electric Co., Schenectady, N. Y.

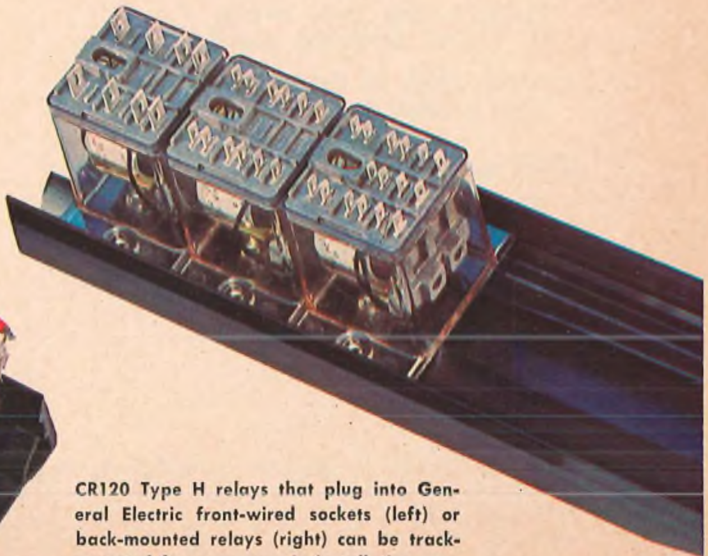
CONSTRUCTION INDUSTRIES DIVISION

* Features not offered by any other manufacturer of general purpose relays.

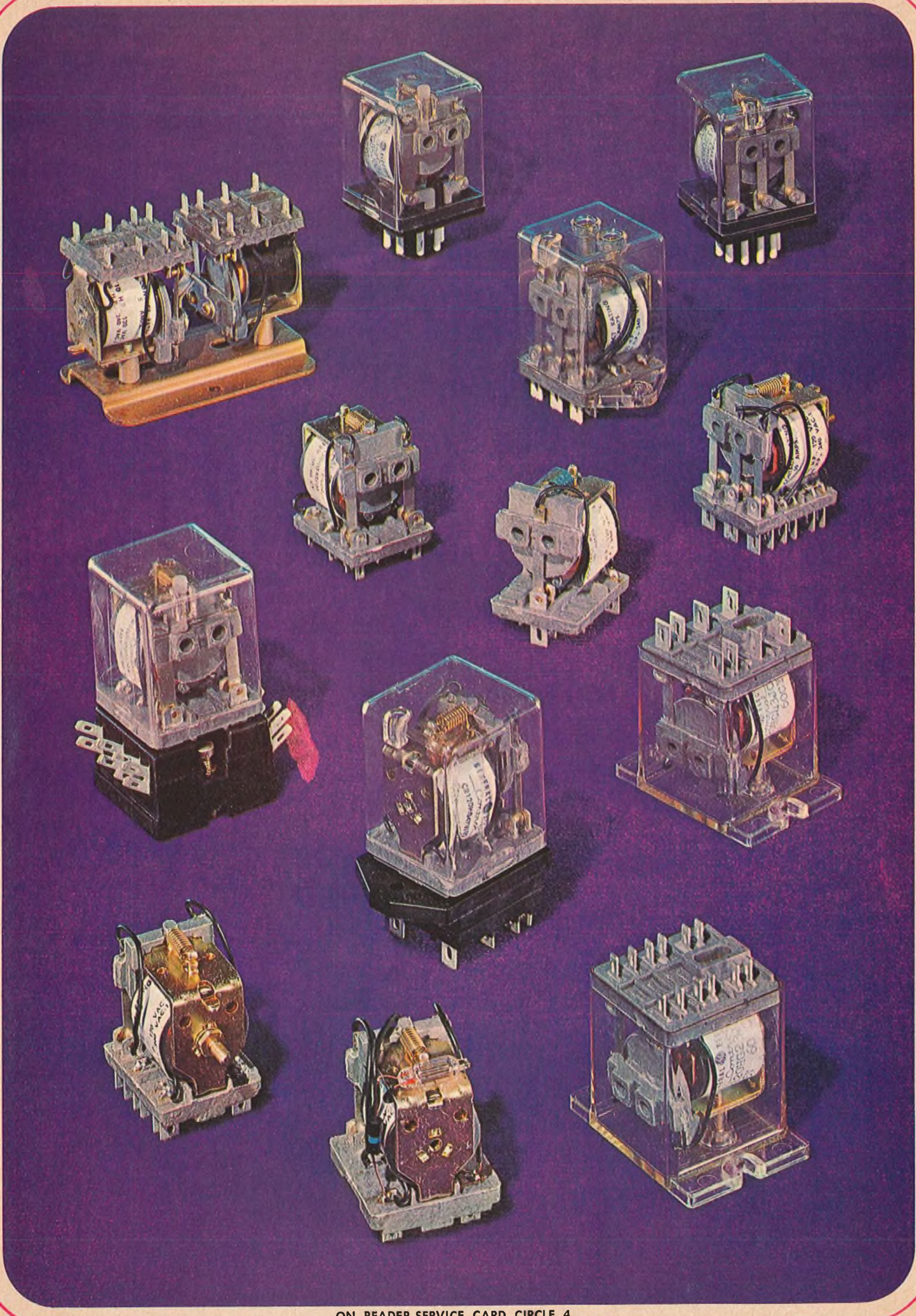
Progress Is Our Most Important Product

GENERAL ELECTRIC





CR120 Type H relays that plug into General Electric front-wired sockets (left) or back-mounted relays (right) can be track-mounted for easy snap-in installation.



List of manufacturers and available literature

Bring your relay data file up to date. Use the Reader-Service card to obtain the literature offered. Dot chart, page 64, shows who makes what.

Manufacturer	Literature Offered	Reader Service Number
Acromag, Inc. 15360 Telegraph Detroit, Mich.	Data sheets, application notes	250
Adams & Westlake Co. 1025 N. Michigan St. Elkhart, Ind.	Catalogs, data sheets, article reprints	251
Ad-Yu Electronics 249 Terhune Ave. Passaic, N.J.	Data sheets	252
Agastat Timing Instruments 1027 Newark Ave. Elizabeth, N.J.	Application notes, catalogs	253
Airborne Accessories Corp. 1414 Chestnut Ave. Hillside, N.J.	Data sheets, application notes, catalogs, article reprints, customer service	761
Airpax Electronics, Inc. P.O. Box 8488 Fort Lauderdale, Fla.	Data sheets, catalogs, application notes	254
Allen-Bradley Co. 1201 S. Second St. Milwaukee, Wis. 53204	Catalogs	255
Allied Control Co. 2 East End Ave. New York, N.Y. 10021	Data sheets, catalogs,	256
Amphenol RF Division 33 E. Franklin St. Danbury, Conn. 06813	Data sheets, catalogs, design aids	257
Amtron, Inc. 14631 S. Waverly Midlothian, Ill.	Data sheets, catalogs, application notes	258
API Instruments Co. 7100 Wilson Mills Rd. Chesterland, Ohio 44026	Catalogs, data sheets	259
Artisan Electronics 5 Eastmans Rd. Parsippany, N.J.	Data sheets, catalogs	260
ATR Electronics, Inc. 300 E. Fourth St. St. Paul, Minn. 55101	Data sheets, catalogs	261

Manufacturer	Literature Offered	Reader Service Number
Automatic Electric Co. 400 N. Wolf Northlake, Ill.	Data sheets, design aids, application notes, catalogs, article reprints, drawing templates	262
Automatic Metal Products Corp. 323 Berry St. Brooklyn, N.Y. 11211	Data sheets, catalogs	263
Automatic Switch Co. Hanover Ave. Florham Park, N.J. 07932	Data sheets, catalogs	264
Automatic Timing & Controls, Inc. King of Prussia, Pa. 19406	Catalogs	265
Avtron Manufacturing, Inc. 10409 Meech Ave. Cleveland, Ohio 44105	Data sheets, design aids, application notes	266
Babcock Relays **Div. of Babcock Electronics Corp.** 3501 Harbor Blvd. Costa Mesa, Calif.	Data sheets, application notes, catalogs, article reprints	267
Barber-Colman Co. 1300 Rock St. Rockford, Ill. 61101	Data sheets, application notes, catalogs	268
Blonder-Tongue Labs., Inc. 9 Alling St. Newark, N.J. 27102	Data sheets	269
Bourns, Inc. 1200 Columbia Ave. Riverside, Calif.	Catalogs	270
Bramco Controls **Div. of Ledex Inc.** College & South Streets Piqua, Ohio 45356	Data sheets, application notes, article reprints	271
Branson Corp. P.O. Box 845 Denville, N.J.	Catalogs, data sheets	272
The Bristol Co. Box 1790 Waterbury, Conn. 06720	Data sheets, catalogs, design aids	273
Butler Roberts Assoc., Inc. 202 E. 44th St. New York, N.Y. 10022	Data sheets, catalogs	274

Manufacturer	Literature Offered	Reader Service Number
Cardinal Control Co. Kensington Rd. Kensington, Conn.	Data sheets, catalogs	275
C. P. Clare & Co. 3101 Pratt Blvd. Chicago, Ill. 60645	Data sheets, catalogs	276
Comar Electric Co. 3349 W. Addison St. Chicago, Ill. 60618	Data sheets, catalogs	277
Computer Components, Inc. 88-06 Van Wyck Expwy. Jamaica, N.Y.	Data sheets, application notes, catalogs	278
Control Systems Div. of Control Data Corp. 4455 Miramar Rd. La Jolla, Calif. 92037	Data sheets, application notes	279
Cook Electric Co. 2700 N. Southport Ave. Chicago, Ill. 60614	Data sheets	280
Cornell-Dubilier Electronics 50 Peris St. Newark, N.J.	Data sheets, catalogs, cross reference	281
Cornell-Dubilier Electronics Div. of Federal Pacific Electric Co. 118 E. Jones St. Fuquay-Varina, N.C. 27526	Data sheets, catalogs,	282
Corona Engineering Service 94-52 Corona Ave. Elmhurst, N.Y.	Data sheets, catalogs	283
Coto-Coil Co., Inc. 65 Pavillion Providence, R.I. 02905	Catalogs	284
Couch Ordnance, Inc. 3 Arlington St. No. Quincy, Mass. 02171	Data sheets, catalogs	285
James Cunningham, Son & Co., Inc. Honeoye Falls, N.Y.	Data sheets, design aids, application notes, catalogs, article reprints, operational theory	286
Cutler-Hammer, Inc., Specialty Products Div. 315 North 12th St. Milwaukee, Wis.	Data sheets, design aids, application notes, catalogs	287
Davis Electric Co. Box 38 Cape Girardeau, Mo. 63701	Data sheets, catalogs	288
Donner Electronics, Inc. 200 Ingalls Ct. Melrose, Mass.	Data sheets, catalogs	289
Dormeyer Industries 3418 N. Milwaukee Ave. Chicago, Ill. 60641	Data sheets, catalogs	290
Douglas Randall, Inc. 6 Pawcatuck Ave. Westerly, R.I.	Data sheets, catalogs	291
Dow-Key Co. S.E. Highway 59 Thief River Falls, Minn.	Data sheets, catalogs	292
Eagle Signal Div. of E.W. Bliss 736 Federal St. Davenport, Iowa	Data sheets, catalogs	293
Ebert Electronics Corp. 130 Jericho Turnpike Floral Park, N.Y.	Data sheets, catalogs, article reprints	294
Elec-Trol, Inc. 18828 Bryant St. Northridge, Calif.	Data sheets, catalogs	295
Electronic Applications Co. 10916 Vasye St. El Monte, Calif.	Data sheets, article reprints, samples	296
Electronic Controls, Inc. Wilton, Conn. 06897	Data sheets, application notes, catalogs, article reprints	297

Manufacturer	Literature Offered	Reader Service Number
Electronic Specialty Co. 4561 Colorado Blvd. Los Angeles, Calif. 90039	Data sheets, design aids, application notes, catalogs	298
Electro-Tec Corp. Box 667 Ormond Beach, Fla.	Data sheets, design aids, catalogs	299
E-T-A Products Co. of America 6284 N. Cicero Ave. Chicago, Ill. 60646	Data sheets, catalogs, customer service	350
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Filtors, Inc. 65 Daly E. Northport, N.Y.	Catalogs, data sheets	352
Fisher-Akin Co. Box 342 Manhattan Beach, Calif.	Data sheets, application notes	353
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GE Construction Industries Div. Rt. 66 Bloomington, Ill.	Data sheets	766
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General Reed Co. 174 Charles St. Metuchen, N.J. 08840	Data sheets, catalogs	357
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A. W. Haydon Co. 232 N. Elm St. Waterbury, Conn.	Data sheets	366
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Larson Instrument Co. Greenbush Rd. Orangeburg, N.Y.	Data sheets, catalogs, article reprints	382
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Milwaukee Relays, Inc. 606 E. Pioneer Rd. Cedarburg, Wis. 53012	Data sheets, catalogs	398
Mobil Electronics, Inc. P.O. Box 1132 Anderson, Ind. 46015	Data sheets, application notes, catalogs	399
Monitor Controller Co. 99 Grove St. Rockland, Mass. 02370	Catalogs	700
Mossman-Elliot Corp. 204 S. Larkin Ave. Joliet, Ill.	Catalogs	701
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New Product Engineering, Inc. **Subsidiary of Wabash Magnetics** 1st & Webster St. Wabash, Ind.	Data sheets, design aids, application notes, catalogs, article reprints, application kit	703
Ohmite Manufacturing Co. 3601 Howard St. Skokie, Ill.	Catalogs	704
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Payne Engineering Co. 603 Morris St. Charleston, W. Va. 25301	Data sheets, catalogs	707
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Phipps Precision Products 7749 Densmore Ave. Unit 7 Van Nuys, Calif. 91406	Data sheets, catalogs, article reprints, detail drawings, product briefs	710
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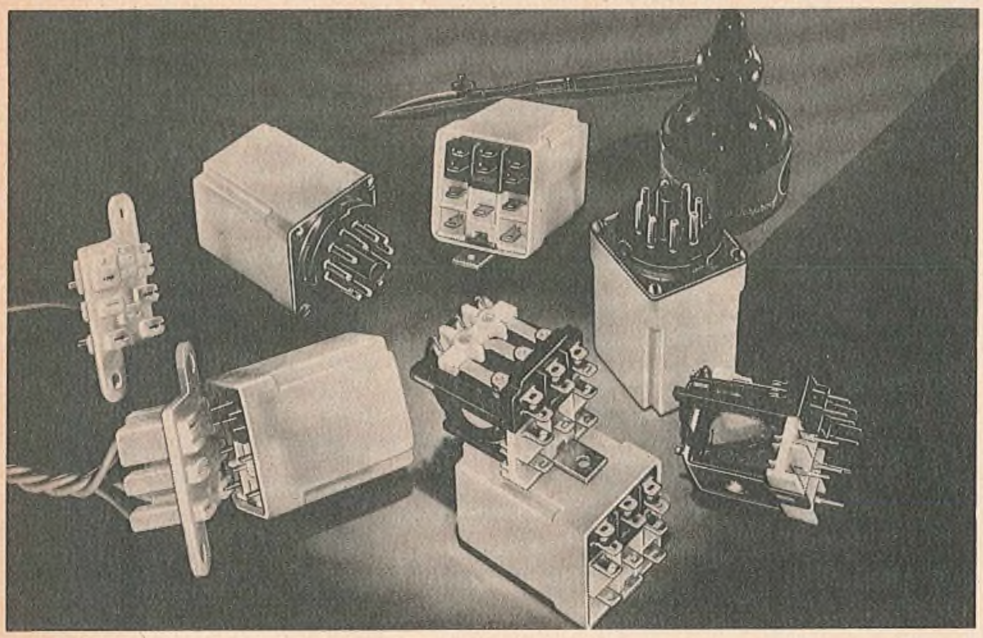
Potter & Brumfield, Div. of AMF 1200 E. Broadway Princeton, Ind.	Data sheets, design aids, catalogs	712
Precision Thermometer & Instrument Co. Southampton Industrial Park Southampton, Pa. 18966	Catalogs	713
Price Electric Corp. E. Church & Second St. Frederick, Md.	Data sheets, application notes, catalogs	714
Printact Relay Div., Executone Inc. 47-37 Austrell Pl. Long Island City, N.Y.	Data sheets, catalogs	767
Quantatron **Div. of Teledyne, Inc.** 1631 Tenth St. Santa Monica, Calif. 90404	Data sheets	715

ON READER-SERVICE CARD CIRCLE 212 ➤

RBM CONTROLS NEWS

Serving Major Markets Since 1921

RELAY EDITION: 93



New 3PDT Switching Relays are Most "Versatile" and "Real Cost Savers"!

AC AND DC MINIATURE RELAY users have been presented with new cost-saving opportunities with the introduction of the RBM CONTROLS line of 3 pole double-throw switching relays.

The new Type 93 line includes both open and enclosed types, and is characterized by their rugged construction features, conservative ratings, versatility, and, above all, by several important cost-reducing features.

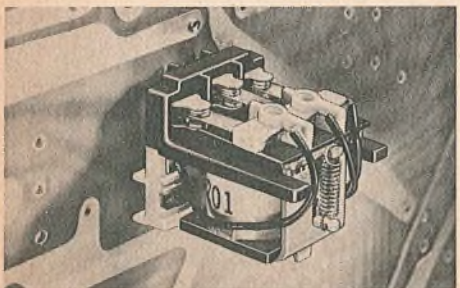
FRONT WIRING—All terminals, both coil and contacts, are out the front of the terminal block surface. This "everything out the front" construction makes it easier to wire, with resulting reductions in assembly costs.

Another cost-reducing feature is the one-screw, single-hole front mounting standard, which cuts both mounting and assembly time.

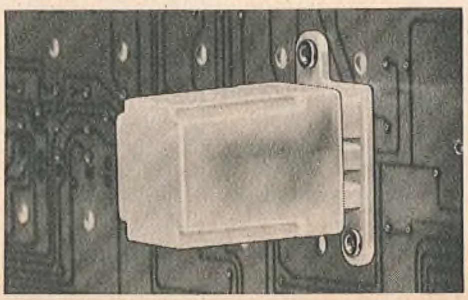
CONTACT FLEXIBILITY—Both open and enclosed types are available in three terminations — **3/16" quick connects, solder type, or printed circuit.** Continuing with the versatility of the new line, RBM CONTROLS has also provided contact flexibility. Button type power contacts can be provided on the relays with highest quality crossbar heavy duty contacts for reliable circuit operation on multiple switching operations.

MOUNTINGS—Numerous types of mountings are available. For the open type relay they include: (1) 6-32 Stud With Lug, (2) Single Hole With Lug, (3) Front Mounting, (4) Printed Circuit. The enclosed type relay includes: (1) Printed Circuit, (2) 8 & 11 Pin Octal Plug-In, (3) Quick Connect Plug-In, (4) Solder Terminal—Front Mounting, (5) Quick Connect—Front Mounting.

Open and Enclosed Printed Circuit Relays



Open type relays are available with printed circuit terminals for easy, low cost assembly to printed circuit board.

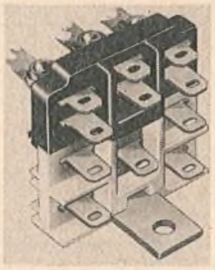


Enclosed type relay plugs into receptacle that is mounted directly to printed circuit board.

Special Construction Offers Many Advantages

MOLDED PLUG

For 3/16" quick connect plug-in enclosed relay provides protection in handling and servicing.

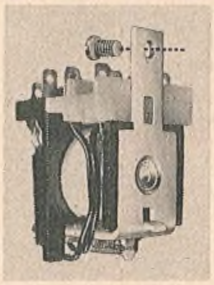


WIRING FLEXIBILITY

Both coil and contact terminals are out front for ease of wiring and low cost assembly.

CONTACT FLEXIBILITY

Button type (a) and crossbar (b) power contacts available on same relay for multiple switching operations.



LOW COST MOUNTING

One screw, single hole standard **front** mounting reduces assembly time.

General Specifications

CONTACTS—To 3PDT, Button—power, Crossbar—low energy loads.

COIL—DC to 110 Volts, AC to 240 Volts.

LIFE—Mechanical—10,000,000 Minimum; Electrical—10,000,000 Dry Circuit.

UL & CSA—Recognized under U/L Component Recognition Program and CSA with variety of contact ratings, coil voltages, and terminations.

Standard controls available from your authorized distributor.

For complete technical data, please write to RBM CONTROLS, Division Essex Wire Corporation, Department 93; Logansport, Indiana.

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Raytheon Co. 141 Spring Lexington, Mass.	Data sheets, application notes	716
RBM Controls Div. of Essex Wire Corp. 131 Godfrey Logansport, Ind.	Data sheets, catalogs, application notes, article reprints	717
Regent Controls, Inc. Harvard Ave. Stamford, Conn.	Data sheets, application notes, catalogs	718
Relaymatic, Inc. Madison St. Sag Harbor, N.Y.	Catalogs	719
Relay Sales Fort Myers, Fla.	Catalogs	720
Rixon Electronics, Inc. 2121 Industrial Parkway Silver Springs, Md.	Data sheets, engineering bulletin	721
Ro Associates, Inc. 917 Terminal Way San Carlos, Calif.	Data sheets	763
Rochester Instrument Systems, Inc. 275 N. Union St. Rochester, N.Y.	Data sheets, application notes, catalogs	722
Rowan Controller Co. P.O. Box 306 Westminster, Md. 21157	Data sheets, catalogs, design aids, application notes	723
Schrack Electrical Sales Corp. 1140 Broadway New York, N.Y. 10001	Data sheets, catalogs	724
Sealectro Corp. 139 Hoyt St. Mamaroneck, N.Y.	Data sheets, design aids, catalogs	725
Sensitak Instrument Corp. 531 Front St. Manchester, N.H.	Data sheets, application notes, article reprints	726
Sigma Instruments, Inc. 170 Pearl St. S. Braintree, Mass. 02185	Data sheets, application notes, catalogs	727
Solenoid Devices, Inc. 2500 Compton Blvd. Redondo Beach, Calif. 90278	Data sheets, catalogs	728
Solid State Electronics Corp. 15321 Rayen St. Sepulveda, Calif.	Data sheets, catalogs	729
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Stearns-Lyman Electronic Corp. 12 Cass St. Springfield, Mass.	Data sheets, application notes, catalogs, article reprints	731
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Suttle Equipment Corp. 135 S. LaSalles Chicago, Ill. 60603	Data sheets, catalogs, customer service	734
Systems Matrix, Inc. 960 E. State St. Trenton, N.J.	Data sheets	735
Teledyne Precision, Inc. 3155 W. El Segundo Blvd. Hawthorne, Calif.	Data sheets, application notes, catalogs, article reprints, test reports	736
Telex/Aemco Div. of Telex Corp. 10 State St. Mankato, Minn.	Data sheets, application notes, catalogs	737
Teltronics, Inc. 23-27 Main St. Nashua, N.H. 03060	Data sheets, application notes, catalogs	738

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Texas Instruments Inc. 34 Forest St. Attleboro, Mass.	Fact file	740
Thermal Controls, Inc. 75 Rutgers St. Belleville, N.J.	Data sheets, catalogs	741
Thermosen, Inc. 375 Fairfield Ave. Stamford, Conn.	Data sheets, application notes, catalogs, article reprints	742
Tia Electric Co. Subsidiary of Heinemann Electric Co. 178 Alexander St. Princeton, N.J.	Data sheets, application notes, article reprints, customer service	743
Torotel, Inc. 5512 E. 110th St. Kansas City, Mo.	Data sheets	744
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Tung-Sol Electric, Inc. One Summer Ave. Newark 4, N.J.	Data sheets	764
Union Switch & Signal Div. of Westinghouse 1789 Braddock Ave. Pittsburgh, Pa. 15218	Catalogs	749
Vanguard Relay Corp. 225 Cortland St. Lindenhurst, N.Y. 11757	Data sheets, application notes, catalogs	750
Vapor Corp. 6420 W. Howard St. Chicago, Ill.	Catalogs	751
Wacline, Inc. 35 South St. Clair Dayton, Ohio	Data sheets	752
Warco Industries, Inc. 569 Melville St. Louis, Mo. 63130	Data sheets, catalogs, customer service	765
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Westinghouse Electric Corp. 95 Orange St. Newark, N.J.	Data sheets, application notes, catalogs, article reprints, textbook	754
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Wheelock Signal, Inc. 273 Branchport Ave. Long Branch, N.J.	Data sheets, catalogs, article reprints, test reports	756
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For complete details on how Wheelock can help solve problems involving space, weight and environmental limitations, write for the NEW Wheelock Reed Relay Catalog. It features the latest test data on reed relay life and reliability, dynamic characteristics and static characteristics.

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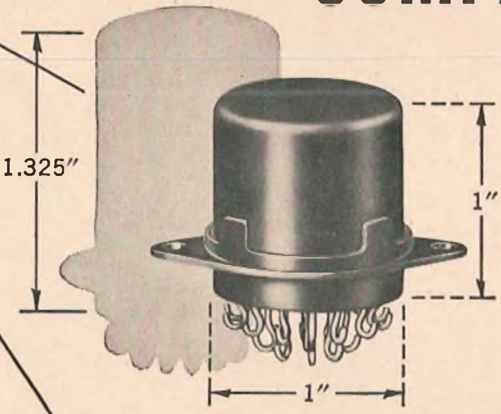
ON READER-SERVICE CARD CIRCLE 5

NEW FROM ALLIED

SMALLEST 6PDT RELAY

COMPARE



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* S-SERIES

√WKJ-SERIES

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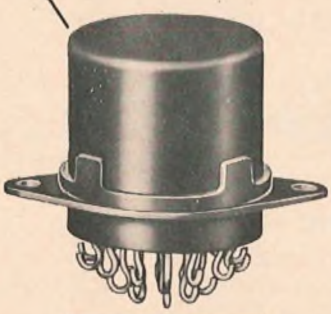
WMR SERIES



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The WMR Series represents a unique combination of advanced design technology and miniaturization. It is suitable for upgrading existing equipment, and particularly recommended for dependable centralized switching in new systems.

PATENT PENDING

Compact	1″ dia. X 1″ high
Welded Construction ..	No solder flux
Reliable	Bifurcated, gold plated contacts
Versatile	Low level to 3 amperes, to 6PDT
Rugged	30G, 2000 CPS vibration; 100G Shock
Stable	Low friction, ball bearing armature
Interchangeable	Conforms to MIL-R-5757/1 and /7

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ALLIED CONTROL COMPANY, INC.

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AL-284

ON READER-SERVICE CARD CIRCLE 6

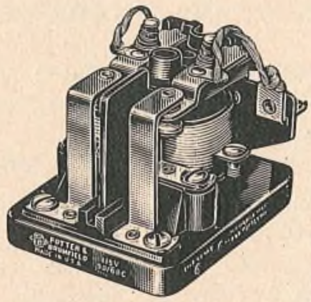
These P&B relays are immediately available at factory prices from your electronic parts distributor

CD-38

SOLID STATE TIME DELAY—You get excellent timing characteristics in these knob-adjustable solid state relays. Timing range: 0.6 to 60 seconds. AC or DC models. Internal DPDT relay rated at 10 amperes, 115V AC resistive. For continuous duty over temperature range of −40°C to +55°C.

KHP

COMPACT FOUR-POLE RELAY—Small, rugged 4PDT relay designed to meet exacting requirements of data processing, computer and process control applications. Rated at 3 amperes at 30V DC or 115V AC resistive. Solder terminals. Special sockets have printed circuit or solder lug terminals. Also available hermetically sealed.



PR

POPULAR 25 AMPERE POWER RELAY—Compact, heavy-duty power relay listed by U/L and CSA. Screw terminals and rugged construction suitable for industrial application requiring reliability and long life. AC or DC models.

GM

VERSATILE IMPULSE/SEQUENCING RELAY—Unusual single-coil relay can be used to latch, step, count and switch in sequence. Switching occurs during drop-out for greater reliability. AC or DC models. Contacts rated for 3 amperes. Can also be furnished with uni-directional printed circuit boards having 10 or 12 switch positions.

KR3-H

SMALL RELAY SWITCHES 20 AMPERES—Three KR3-H relays will fit in space required for most other 20-ampere relays. Mechanical life exceeds one million operations and twin contacts are rated at 20 amperes at 115V AC, 60 cycles resistive or 28V DC, 1 HP 115/230V 60 cycles. Contact terminals will accept ¼″ quick-connects or solder connections.
Contact arrangement: SPST-NO-DB.

...and there are 60 other types to choose from!

Chances are, you'll save both time and money when you order standard P&B relays from an authorized distributor. You'll get speedy service at factory prices. Your P&B distributor has available more than 60 basic relay types totalling 627 coil voltages and contact arrangements. All are shown in our new Stock Catalog 100 . . . free from your electronic parts distributor. Ask for a personal copy today.

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ON READER-SERVICE CARD CIRCLE 7

Have semiconductors relegated relays to a second-class status?

"No!" says author Murray, for the relay still possesses characteristics not obtainable in solid-state devices. To prove the point, he compares their attributes.

DESPITE THE FACT that many traditional relay functions have been taken over by semiconductors, relays are not on the way out. They still offer superiority over solid-state devices in several competitive areas. Also, there are many applications that semiconductors are not yet capable of fulfilling. These are usually marked by very high steady-state currents or extremely high isolation requirements.

Unfortunately many design engineers do not have a firm grasp of all of the factors affecting the relay-versus-semiconductor choice. Some are unduly influenced by either the simplicity of the relay or the "in" status of the semiconductor. Judicious selection requires a point-by-point comparison of relative merits and shortcomings (see table).

Semiconductors have longer life-span

Solid-state devices do not have known wear-out modes. When operated within specified limits, their life is indeterminate—far in excess of their auxiliary circuitry. Some types—the zener diode, to cite one—are now offered with "lifetime guarantees." In addition semiconductor longevity is not influenced by cycling.

On the other hand, relays have a finite contact life that is largely dependent upon the material used, the nature of the load placed across the contact terminals, and the environment of the application (temperature, humidity, etc.). The lifespan is affected by the relay's cycling capability; degradation occurs less rapidly when the relay is not subjected to repetitive cycling. Contact life typically varies between 20,000 and a few million cycles, depending, of course, on the type of relay involved and the load.

Relay switching speeds slower

With very few exceptions, the switching speed of relays is limited to a millisecond or slower. In addition this function is accompanied by a transient period (for contact bounce) that is several times longer than the corresponding switching transient time of semiconductors. Moreover the speed of operation is affected by the presence of low impedances in shunt with the coil. For example, a diode placed across the coil will extend the relay's release, or dropout, time.

Solid-state devices exhibit typical switching times in the microsecond and nanosecond regions. A few microwave types—such as the varactor diode—achieve a switching speed faster than 1 nsec. The durations of transient signals are usually negligible in comparison with those of relays.

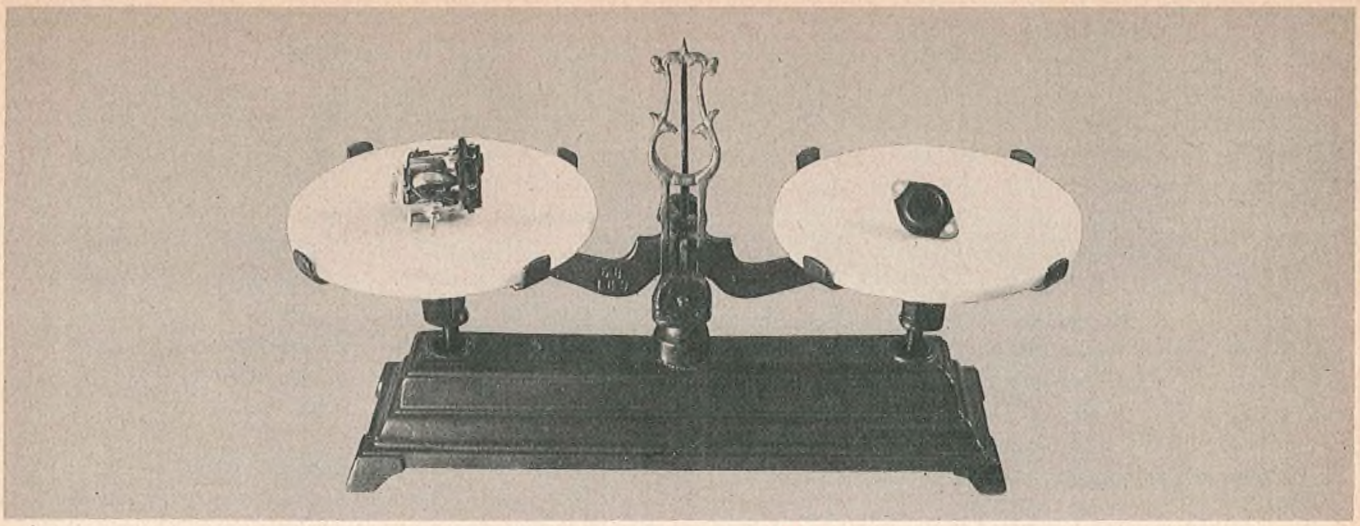
The power capabilities of relays generally exceed those of semiconductors in most electrical (as differentiated from electronic) applications. Thus, a figure of merit may be established whereby the product of switching speed and output power is used to make the judgment.

Relays bear less g's

Semiconductor parameters are not appreciably affected by either vibration or shock. They typically withstand vibrations of 100 g's and shocks in excess of 250 g's. An acceleration test of 10,000 to 20,000 g's is commonly used in screening programs to eliminate parts with weak bonds or other mechanical defects.

Relays are able to withstand vibration levels of 20 to 30 g's and shock levels of 50 to

William A. Murray Research Engineer
Boeing Co., Aerospace Div., Seattle, Wash.



Device comparison

Circuit requirement	Relays	Semiconductors
1. Life	Finite cyclic life.	Insensitive to cycling.
2. Switching speed	Relatively slow (low audio).	Ranges from slow to very fast (beyond 1.0 nsec).
3. Vibration and shock environment	20 to 30 g vibration limit.	100 g vibration limit or greater.
4. Circuit transients	Relatively insensitive.	Very sensitive to voltage peaks.
5. Input signal	Coil operates with wide range of ac or dc, relatively imprecise.	Requires dc power source, tolerates narrower variation of input signals, very precise and highly sensitive.
6. Circuit isolation	Excellent isolation.	Lower isolation.
7. Radiation environment	Less sensitive than semiconductors.	Sensitive—increased leakage and loss of gain occur.
8. Output current	Greater maximum capacity, contact bounce present, contact resistance varies.	SCR types have high capacity but turn-off is difficult.
9. System voltage	Handles ac and dc, high values easily accommodated.	Switches ac and high levels only with increased circuit complexity.
10. Amplification	Not an amplifier, per se, although small signals can control large ones.	Sensitive—can handle low inputs, excellent amplification.
11. Temperature	Good performance at high temperature, poor at low temperature.	Excellent low temperature capabilities, upper limit generally much lower.
12. Weight and size	Heavy & bulky.	Smaller & lighter, although more auxiliary components are present.
13. Cost	Cost of auxiliary components is low.	Low-cost devices available.
14. Reliability	Dependent upon circuit complexity, electrical and environmental factors.	Excellent reliability.
15. Design data	Sometimes not complete.	Readily available.

150 g's without any accompanying opening or closing of contacts. They will survive considerably higher levels of vibration and shock when the contacts are not loaded or when contact transfer is acceptable. Vibration in excess of specified limits may cause contact chatter, thereby shortening life (as the contacts make and break the load).

When low currents are switched by a relay subjected to moderate vibration, signal modulation may occur. The contact resistance at these low signal levels can vary from 1 to 1000 ohms. If the impedance of the contact load is not considerably higher, the changes in contact resistance result in signal modulation at the resonant frequency of the contact, and as a consequence, malfunction.

Relays more tolerant of transients

Semiconductor circuits usually require protection against externally generated transients. In particular, their voltage ratings cannot be exceeded for even short periods without the danger of misoperation, damage or destruction. The inverse-voltage ratings are especially susceptible.

Relays are relatively immune to transients of a shorter duration than their operating times. In virtually all relay applications, wider transients do not occur. In addition the switching of inductive loads with relays is less hazardous than with semiconductors, because the induced transient voltages are more easily accommodated by the relay.[1]

Input signal accommodation a toss-up

Relays may be operated by a wide variety of dc and ac voltages. Their parameters are fairly stable with time and life. Operate and release times, however, vary considerably with voltage and temperature. Moreover, although a wide range of trigger signals is accommodated (a 50% tolerance on the low side of rated input is not uncommon), the lack of precision of the input leaves something to be desired. The relay is basically a go-no-go device that is not particularly input selective or sensitive.

Input signals may vary between wide limits without ill effects in semiconductor circuitry. In addition semiconductors are more sensitive than relays, and they also require less drive power. However, additional power supplies and circuit components are often required when the proper input voltages are not available. Further restrictions are imposed by the dictates of reverse ratings, overdrive and the inter-junction relationships which must be maintained.

Isolation: relay lead narrowed

Relays will isolate inputs from outputs and unconnected output circuits from each other with a minimum specified insulation resistance of 1000 megohms. Except for the field-effect class of devices, semiconductor types require increased circuit complexity to even approach this degree of isolation. Moreover, semiconductor leakage currents increase with time, which further impairs their isolation capability. Solid-state devices cannot tolerate high ac voltages as well as relays.

Semiconductors less radiation-resistant

Relays are less sensitive to radiation than semiconductors. A comparison of the maximum fast neutron (integrated) exposure that each can withstand and still remain useful shows 10^{15} neutrons/cm^2 for relays and 10^{13} neutrons/cm^2 for semiconductors.[2] However, recent advances in solid-state technology—particularly the field-effect types—have narrowed this gap. An exposure to high radiation results in a reduction of transistor gain by a factor of 10 to 20. Germanium devices are less affected than silicon types.

Relay pick-up and dropout voltages, on the other hand, increase by 5-10% when exposed to the same amount of radiation. Radiation increases the leakage current levels in relays. The insulation ability of the relay also diminishes when it is subjected to radiation.

Output current: Relays take high road

Relays have a very wide range of current handling capabilities. Their upper limit figure exceeds that of the semiconductor. Solid-state devices are presently limited to just under 1000 ampers. SCRs, which have the highest capabilities of semiconductor devices, are more difficult to turn off than turn on. Thus, for the switching of high currents, the relay is the simpler, more versatile unit.

With low-level currents, the semiconductor has two advantages: It is able to amplify the input signal, and it is not subject to cycle-to-cycle variations in voltage drop across the device. Relays can't achieve either of these advantages. The output of semiconductor circuits, however, drifts with time and temperature, thereby necessitating compensation techniques. The relay's output circuit is, by comparison, less temperature-sensitive.

The voltage drop across the device is lower in relays that in solid-state devices. But the relay contact drop will vary from cycle to cycle. Misses can also occur with relays (a miss being a high contact resistance that occurs on one cycle and that disappears on

VERSATILITY and RELIABILITY make

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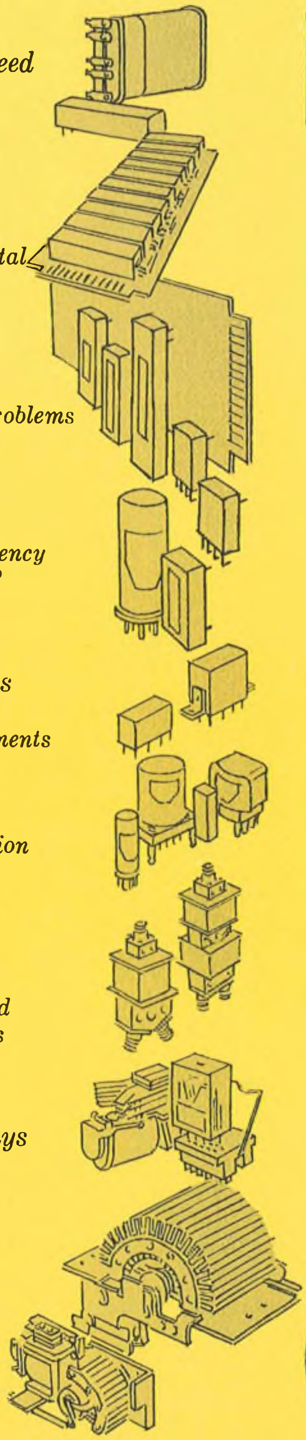

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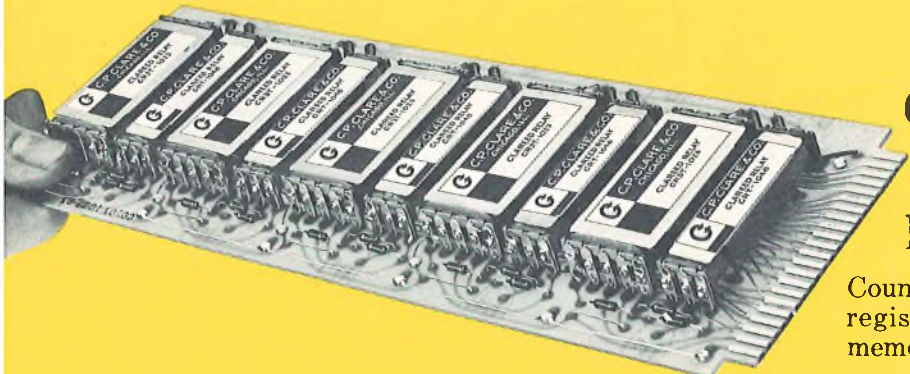

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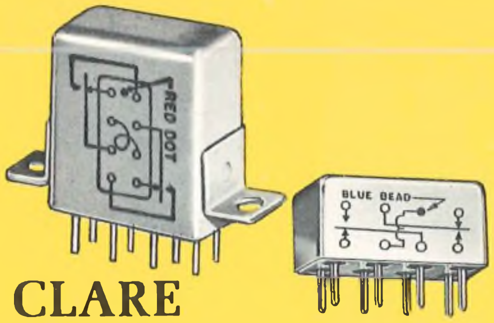

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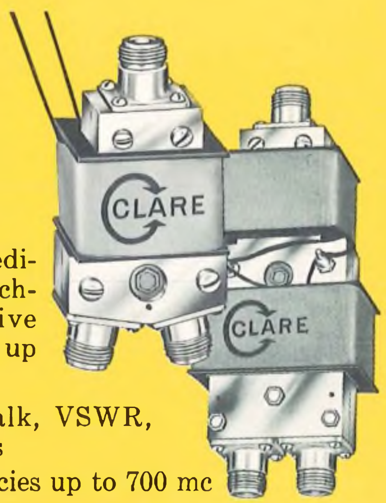

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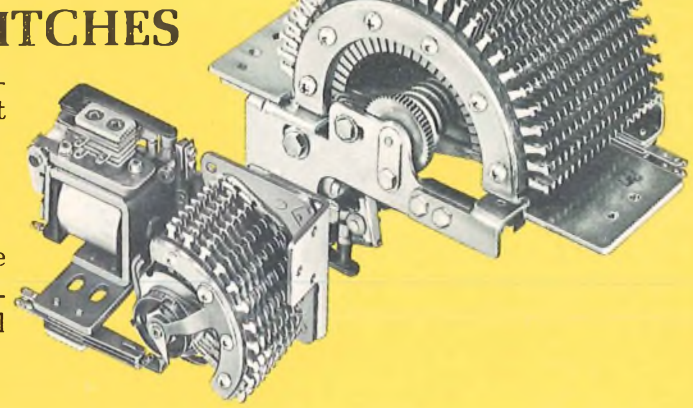

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relays and control components

subsequent cycles). Unlike semiconductors, though, the relay output is less affected by the nature of the load—that is, neither matching nor buffering is required.

Output voltage: relays get the nod

Relay contacts can handle ac, dc, RF—virtually any type of voltage. Their output voltage range is from millivolts to thousands of volts. The switching of ac voltages with semiconductors entails the use of complex circuitry. Moreover, for high voltages, several solid-state units must be used.

Amplification: semiconductors a natural

The relay is not generally considered an amplifier *per se*—yet it will efficiently turn a very high current on and off with a small signal. The greatest power amplification from a relay can be achieved when one relay is used to switch several circuits carrying high currents. This property of amplification is limited to the low audio range because of slow relay switching speeds.

It is well known that solid-state devices are superior to relays for amplification, particularly at low-signal levels and for higher-speed waveforms. Although this amplifying property is a natural one, it often isn't put to use in switching applications. Moreover even though the input signal may be faithfully reproduced (something relays cannot achieve), some distortion is introduced into the output, even when it isn't wanted, as a result of this property.

Weight, size favor semiconductors

When simple functions involving power or several control circuits are involved, relay circuitry is usually far less complex than its semiconductor equivalent. For example, considerable solid-state circuitry is required to replace a six pole, double-throw relay switching four amperes. Thus, size may favor the relay on these occasions.

However, the weight of the relay is usually much greater than the combined weight of the semiconductor and its associated components. Low-level switching applications generally favor semiconductors, because of savings in both weight and size. This is particularly true since the advent of microelectronics.

Cost: no clearcut victor

Generally speaking, applications incorporating relay circuitry are less complex, requiring fewer components, than their semiconductor equivalents. From the standpoint of cost, this would appear to favor the relay. However, the price of semiconductor components—particularly the plastic-encapsulated types—has continued to drop. Solid-state devices are available today in the same cost range as passive components (resistors, capacitors, etc). Prices must be checked to determine which of the two is cheaper.

Temperature: relays a close second

Both devices are normally rated to operate over the same temperature range. The gain and other key semiconductor parameters vary with temperature. But so do relay operating voltages and switching times.

Relays have a potential for operation at higher temperatures (200°C or more) than semiconductors. However, the low-temperature capabilities of solid-state devices exceed those of relays. Moreover, although compensation methods are available for both, the techniques for semiconductors are more precise and offer greater over-all thermal stability—for example, when matched transistors are used.

Reliability: circuitry is the key

Assuming that cyclic and environmental considerations are not too severe for relays, circuit complexity will be the chief determinant in comparing reliability. Increases in the complexity of power supplies or other auxiliary equipment should be considered. The sum of the failure rates of all parts should be obtained for the circuit employing relays and the circuit employing semiconductors. The designer is referred to MIL Handbook 217 for a guide to relative part failure rates.[3]

Semiconductors: design data abounds

Relay manufacturers have not been as prolific as their semiconductor counterparts in supplying information for design. Needed, for example, are more data to permit realistic prediction of failure rates; coil-life data; information on pickup voltage and coil resistance variations with temperature; contact bounce figures, and others.

Semiconductor manufacturers on the other hand typically bombard potential users with analogous information. The net result may be a tendency on the part of designers to lean towards the solid-state devices. ■ ■

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2. Technical Memorandum No. 18, Battelle Memorial Institute (1960).

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Commutated relay spearheads new switching technique

By combining the long-life and non-arcing properties of semiconductors with the transient and high-current accommodation of relays, more reliable switching is achieved.

A HYBRID relay-semiconductor circuit fills a long-standing control systems need. It removes the inherent weaknesses of each switching element and possesses the desirable virtues of both.

Unlike the conventional relay-semiconductor combination, the commutated relay uses a solid-state switch as a full-load carrying element, but only for short periods. The semiconductor can thus carry loads far in excess of its rating because the load-carrying intervals only occur when the relay is opening or closing.

In the conventional system, the semiconductor's role is confined to buffering, suppressing, or such auxiliary functions as providing time-delays.

The relay's coil is also used in a different way in the commutated relay. It serves as a control mechanism in which the contacts are used both to gate the semiconductor and to carry the full load current for most of the operating cycle.

The commutated relay can thus switch motors and other power systems without the usual arcing or high noise. It is more reliable, has a high-power capability, longer operating life, and easily accommodates the transients generated. In one case this hybrid approach resulted in extending the operating life of the relay used from 50,000 cycles to over three million cycles.

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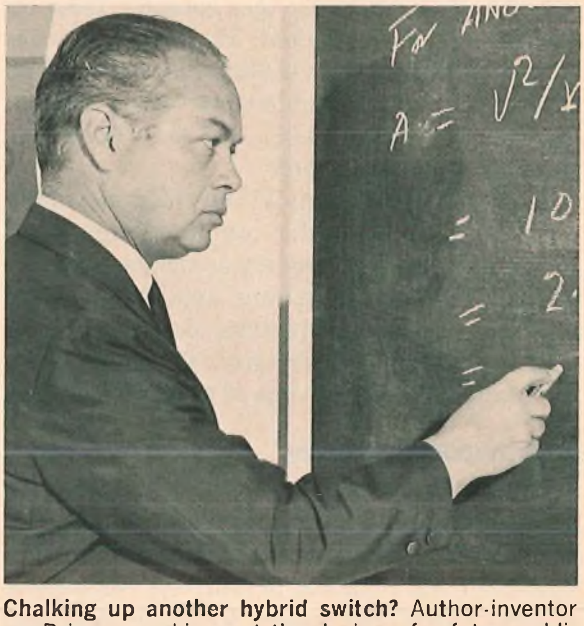
President
vB Research and Development
Las Vegas, Nev.

*This article is an expanded version of a paper given by Mr. vonBrimer at the 13th Annual National Relay Conference, Oklahoma State University, Stillwater, Okla., April 27-29, 1965.

Weaknesses of the usual approach

What's wrong with the conventional approaches to relay or semiconductor switching? Both the relay and the semiconductor



Chalking up another hybrid switch? Author-inventor vonBrimer, working out the design of a future addition to the commutated relay device family.

possess certain shortcomings as switching devices. Their limitations result in high cost due to short life and low reliability.

The relay has the following weaknesses:

- Generation of mechanically induced noise into the system.
- Short life under high-current loads.
- Shortened life and limited reliability due to contact-arcing.
- Relatively slow switching speeds.
- Lengthened delay before reaching steady-state because of contact bounce.

Relay advantages for general switching applications are:

- Ability to withstand very high voltage and current transients.
- Very high steady-state load ratings.
- Circuit simplicity.

On the other hand, semiconductor limitations are:

- Comparatively low current ratings.
- Vulnerability to current and voltage transients.
- Relative circuit complexity.

It does possess the following desirable traits:

- Rapid switching speeds.
- Long (virtually infinite) life.
- Relatively quiet operation.
- Toleration of high magnitude, short-duration signals well beyond steady-state ratings.

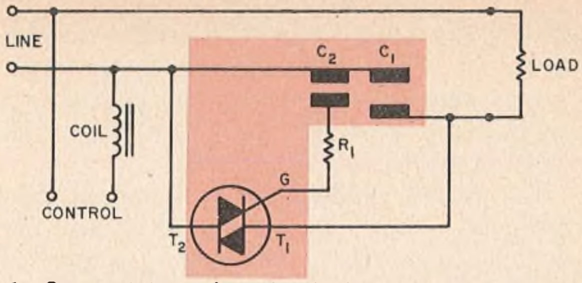
A description of commutated relay operation shows how the respective weaknesses are nullified and the strong points combined.

Operation of the commutated relay

The commutated relay (Fig. 1) functioning is keyed to the triode ac semiconductor switch (a five-layer diode also known as a Triac) and its arrangement with the delay contacts.

The Triac can be turned on by a signal of either polarity and will conduct in both directions.[1] The "gate" signal is supplied from the line voltage through dropping resistor R_1. In switching currents of 50 amps (at 125 vac), the controlling gate current is 50 ma at 3 volts, or, 0.15 watts. Thus, the dropping resistor R_1 need only have a 0.5 watt rating.

A single-pole, single-throw relay with auxiliary contact C_2 is used. The contacts have been pre-adjusted so as to achieve a sequential order of switching. The load contact C_1 has a wider gap than the auxiliary contact C_2. Thus, when the relay coil is energized, C_1 will close after C_2 has closed. Similarly, when the coil is de-energized, C_1 will open before C_2 does.



1. Commutator relay circuit features Triac switch and unique contact arrangement to achieve more reliable switching. This approach combines the desirable attributes of its semiconductor and relay components and overcomes the inherent limitations of each.

Operating sequence is as follows: As the coil circuit is energized, contact C_2 closes and turns on the Triac. This supplies current to the load through terminals T_1 and T_2. A very short interval later, load contact C_1 closes, and, by its shunt connection of low resistance, removes the load current from the Triac for the duration of the ON cycle.

When the coil circuit is de-energized, contact C_1 opens (while the Triac is still energized) and the load current transfers to terminals $T_1 - T_2$ without any arcing. A very short interval later, contact C_2 opens, turning off the Triac. Typically, the time interval between the operation of the contacts C_1 and C_2 would be 2 msec for a relay with a total operation time of 5 msec.

In the commutated relay, a Triac with a continuous rating of six amperes will easily switch short-time transients of 1000% overload.[2] Note that the I^2t rating of the Triac is the governing design point. This means that switching may occur later in the cycle, so long as the higher magnitude current (borne by the Triac) has a proportionally reduced duration. Thus the control circuitry must be time-regulated to accommodate this limitation. The relay contacts will also conduct transient currents of this magnitude as long as the semiconductor performs the main switching function. For over-voltage transients, the Triac is only exposed for 2 msec per second of operation. Expressed as a ratio of OFF-time to ON-time, the duration of exposure to overvoltage or overcurrent is reduced by a factor of 500.

Commutated relay has high reliability

Reliability is usually the most important attribute to be considered. The major factors contributing to relay failure are contact arcing (on interruption) and contact bounce (on making contact). These negative factors are eliminated in the commutated relay.

Major factors in the failure of solid-state switches are either high current levels or short-time, high-voltage transients during operation. Since the relay contacts short-circuit the semiconductor for all but an infinitesimal part of the operating cycle, these problems are eliminated.

The bounce characteristics found in conventional relays are also reduced by the commutation system. The contact bounce of the gate-switching circuit (C_2) is electrically eliminated, as the initial contact gates the Triac switch on. The switching time consumes 20 μsec. The Triac will remain on without any further gate signal until a polarity reversal occurs at the half-cycle crossing of the load current. This reduces the current below the holding value for the Triac. For this reason, the load does not see any contact bounce at C_1 or C_2, even if it does occur.

The operating speed is also improved by the commutated relay. Moreover, there is much less variation in the switching times with load. In conventional relays, the bounce will vary with individual relays, adjustments and the nature of the load. With commutation, this variation, as well as the usual relay change in pull-in, drop-out, contact resistance, etc., (due to mechanical erosion and wear) are reduced.

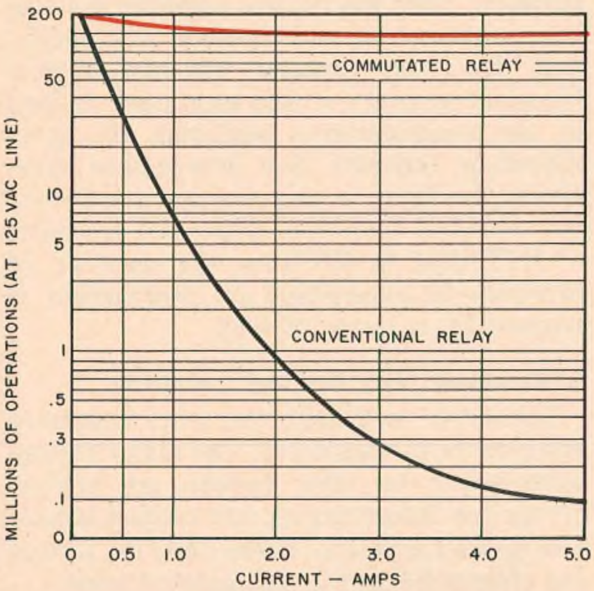
Low-level current flow and dry operation are both achieved with the desirable minimum contact drop of a relay. However, because of the switching function of the semiconductor, the failure tendency due to oxidized contact surfaces (a common occurrence with conventional relays) is decreased. Commutated relays are relatively free from unwanted switching due to voltage spikes or circuit transients. This is because the mechanical reaction-time of the relay is usually longer than the duration of the spike or transient. The Triac is isolated from these transients because the relay will not close on them; this adds greatly to the overall reliability of the unit.

In many applications, the commutated relay should be considered as a simple redundant system with the relay effectively paralleled by a solid-state switch. With this premise, it is evident that the relay's reliability and life are increased several hundred times by the elimination of arc damage to the contacts. The semiconductor has its reliability and life increased because of its isolation from circuit transients and its confined use (short duty-cycle). Together, the life and reliability of a commutated relay is thus much greater than that of a simple relay or solid-state switch when either is used independently (see Fig. 2).

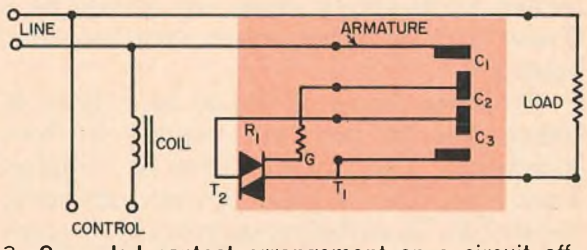
Extending the commutation principle

In some industrial applications, the line transients of overvoltage or high frequency (dv/dt effects) may cause some spurious switching with the circuit of Fig. 1. A slow-down RC filter placed across terminals $T_1 - T_2$ will alleviate this problem. Overvoltage protection devices (such as suppressors) can also be used to eliminate this spurious switching effect.

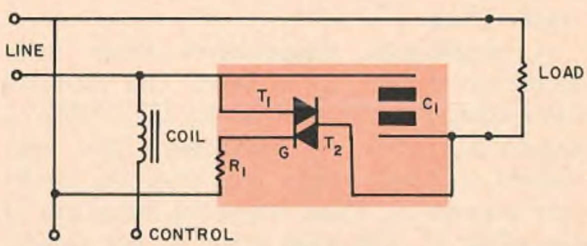
A cascaded contact arrangement can be used to isolate the semiconductor from the line transients (Fig. 3). The operating



2. **Increased lifetime is just one** of the benefits reaped by the commutated relay principle.



3. **Cascaded contact arrangement** on a circuit offshoot of the commutated relay isolates the semiconductor from line transients.



4. **Faster turn-on of the switching circuit** is provided when the Triac gate circuit is parallel to the relay coil. Current reaches the load in just 15 μsec.

sequence is similar to that of Fig. 1, the major difference being the isolation provided by the extra contact (note that complete isolation of the switch component is provided until contact C_2 is closed).

When the coil is first energized, contact C_2 gates the Triac switch ON to provide load current flow until contact C_3 closes and shorts out the Triac. On the release of the relay (de-energization) contact C_3 transfers the load to the Triac. Contact C_2 "de-gates" the Triac to OFF, thus opening the load current path. Contact C_2 is the last to open and it isolates the switching system. It is arranged to open slowly in order to give the Triac time to effect complete interruption of the load current. The purpose of contact C_1 is to always open or close under zero current conditions in the circuit.

For the faster turn-on of more substantial loads, a semiconductor switch can be gated on by the control circuit at the same time the relay coil is energized (see Fig. 4). Operation of the system is as follows: The Triac is turned on by its gate circuit at the same time the relay coil is energized. This permits current flow through the load in just 15 μsec. The relay contacts close about 5 msec later (333 times slower), and remove the load from the Triac by their parallel (short-circuit) resistance. For the duration of the ON time, the Triac does not see any load. The contacts, being closed, have a very high-current capability.

As the control switch is opened, the relay contacts open, but the Triac stays on until a current zero-point is reached. As this point is passed, the relay contacts have already established a small gap, thereby preventing the starting of an arc. Note that the Triac does not (in the absence of gate signal) remain ON past the zero current point.

Although this discussion was limited to an ac circuit using a Triac for relay commutation, this does not imply that the technique is limited exclusively to that combination. SCRs, transistors and many other solid-state devices may be similarly fitted into multiple-throw switches, deck switches, stepping relays, and many other electro-mechanical components to achieve commutated switching. The commutated relay may thus be viewed as the forerunner of many a novel, hybrid-type approach to control systems design. ■ ■

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1. E. K. Howell, "Triac Control for AC Power." General Electric Application Note 200.35, May, 1964.
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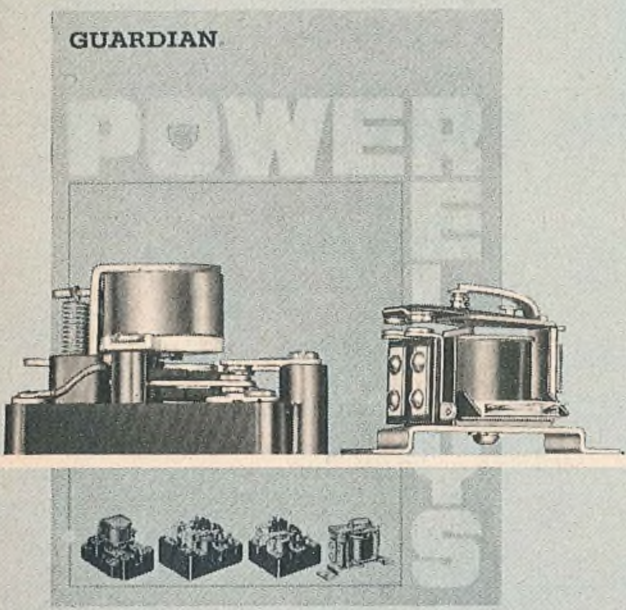

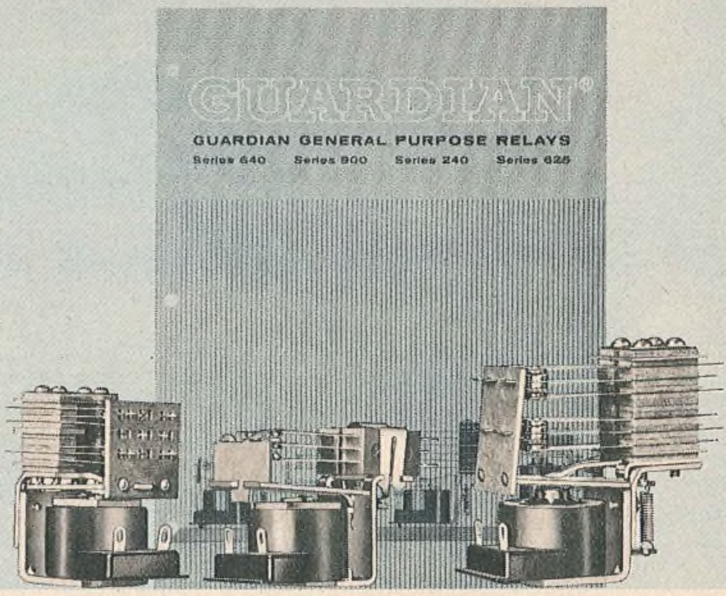

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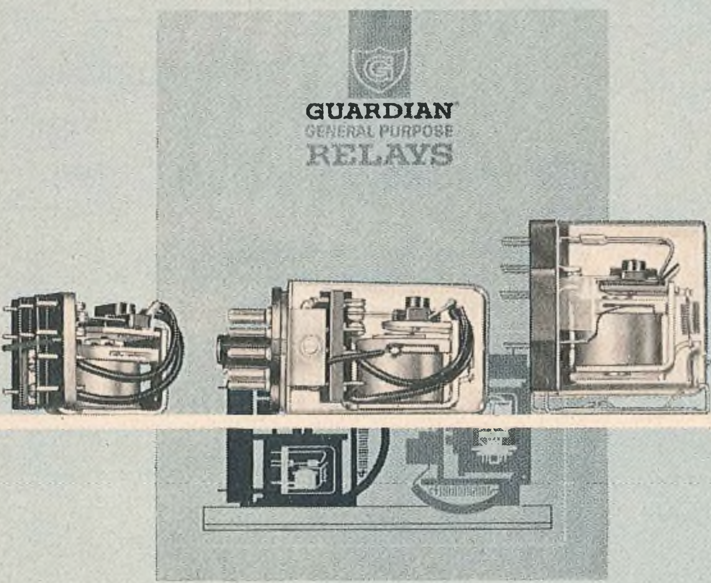

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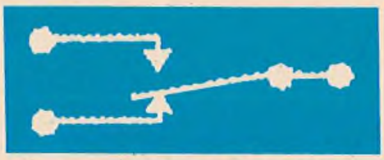

Don't dismiss the relay for data-processing systems

For slow-speed instrumentation, the relay offers distinct advantages over its semiconductor counterpart. It offers simplicity of design, low cost and higher efficiency.

THE TRANSMISSION of electrical signals without distortion or loss of level is essential in data processing. When the rate of data transmission is confined to the low-frequency (audio) range, the relay offers certain advantages. Unlike solid-state devices, it requires neither elaborate auxiliary circuitry nor well-regulated power supplies. In addition it can provide more efficient load carrying and more faithful signal reproduction than its semiconductor counterpart.

In a variety of instrumentation problems, the end products are printed digital records, punched tapes or magnetic recordings. In data processing for psychological testing particularly, the data change slow enough that relay circuitry is preferred. Many automatic analysis applications, such as heart-rate analysis or industrial batch monitoring systems, fall into this category. An elementary data processor for such applications appears in Fig. 1.

The basic system includes a counter and its associated control circuitry for accumulating data on either time between events or events themselves. A relay-operated sequence controller is used for controlling the entry of data onto the record, entry and reset of the auxiliary memory, and start and stop of the counter. The auxiliary memory element stores such pertinent information as batch number, dates or experiment number. The system is completed with a recording device.

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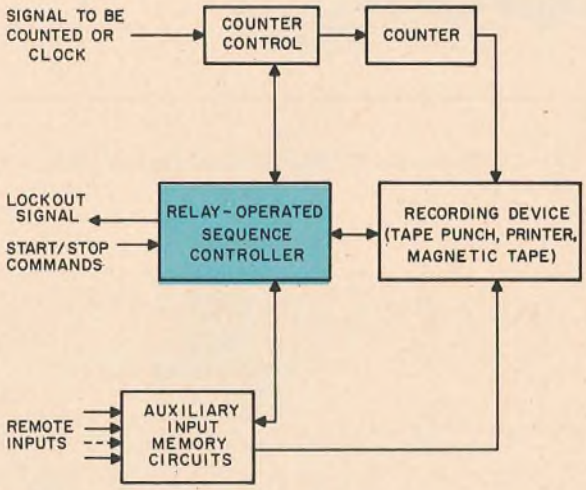
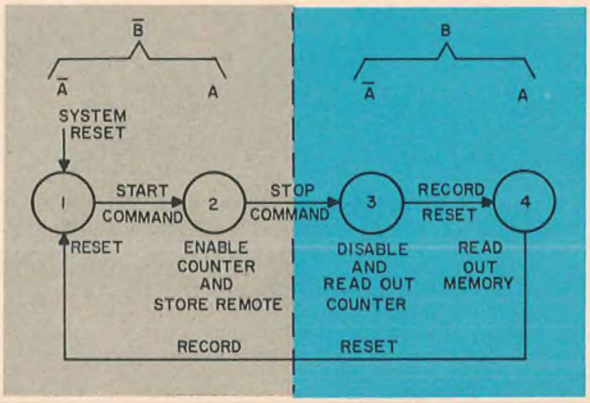


1. **Basic data-processing system** uses a relay-operated sequence controller as the key element in the programing sequence.



2. **Phase-state relationships** of a basic data-processing system indicate the sequence of operations.

Relay operates sequence controller

The heart of the "wired program" machine is the sequence controller. The design of this device determines the essential characteristics of the data processor. Consider the functional role of the data processing system (as represented in Fig. 2). Here the circles represent the state spaces of the machine, and the arrows represent the sequence of operations. Superimposed on these arrows are the conditions to permit the machine to pass from one state to the next. Since four states are indicated, two bistable circuits are required.

The letters above the state spaces refer to the condition of the two bistable circuits. Thus State 1 (Reset) will be the condition $\overline{AB}$ (Not A and not B). State 2 (which readies the counter and samples and stores the remote data) is decoded as $A\overline{B}$ (A and not B). State 3 stops the counter and reads out the number stored in it. Finally the memory is read.out during State 4 (AB).

Initially some manual reset is provided, which forces the relay flip-flops into State $\overline{AB}$. When the machine receives a command to start from the process it is monitoring (it might be the onset of the first heart beat, the first element in the batch, or the stimulus in the psychological experiment), it sets the first flip-flop. This flip-flop, having been in State $\overline{A}$, is now in State A, and the total machine is in State $A\overline{B}$. The stop command (from the second heart beat, the n^{th} element of the batch, or the proper subject response in the psychological experiment) simultaneously resets A to $\overline{A}$ and sets $\overline{B}$ to B. The machine is now in State $\overline{A}B$, which permits the output to pass to the recorder.

The author, Gordon Silverman, checks the performance of his relay electronic dash-processing system. The relay memory stages use fewer components than their semiconductor equivalents and do not introduce signal distortion.

When the recording device has completed its program, it will normally provide a reset signal, which is used to advance the sequencer to its next state. Here the memory bank outputs are recorded. When the recording device has completed its read-out, it again supplies a reset signal. This signal is used to return the sequencer to its reset state (State 1), where it awaits a new start command.

Relay vs semiconductor criteria

The phase state relationships are:

$$\text{Reset} = \overline{AB} \qquad (1)$$

$$\text{Enable Counter} = A\overline{B} \qquad (2)$$

$$\text{Record Counter} = \overline{A}B \qquad (3)$$

$$\text{Record Memory Output} = AB \qquad (4)$$

These equations are used for the setting or resetting of a particular flip-flop. Consider the dotted line in Fig. 2. All states to the left of the line are $\overline{B}$ (in addition to either A or $\overline{A}$), and all states to the right are B. Any arrow (or transition) crossing this line from left to right would be a condition for setting the second flip-flop (going to State B). Any arrow crossing this line from right to left would be a condition for resetting this flip-flop to State $\overline{B}$. Thus,

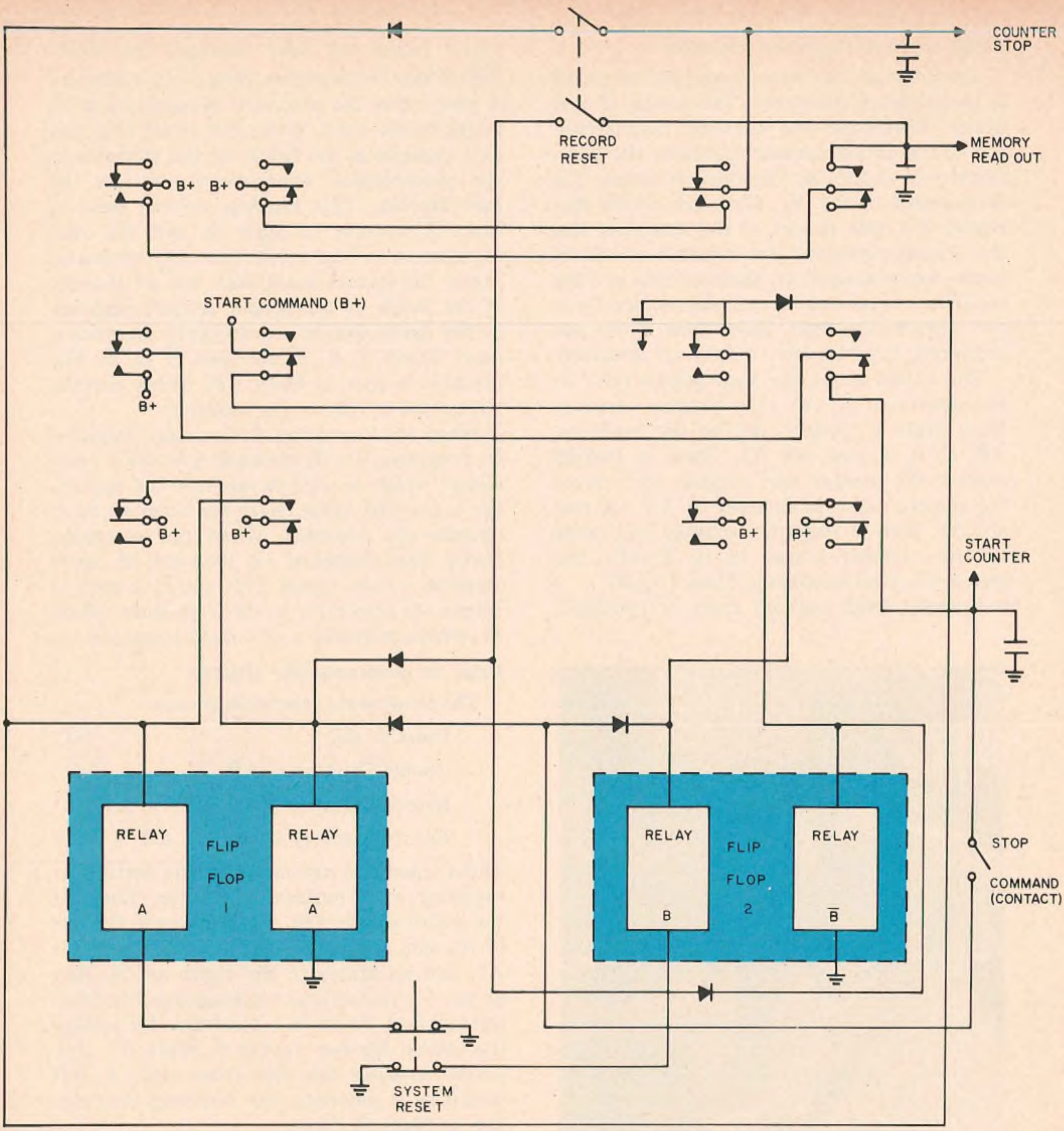
$$B = \text{(State 2) and (Stop Command)} \qquad (5)$$

$$\overline{B} = \text{(State 4) (Record Reset) + (System Reset)} \qquad (6)$$

$$A = \text{(Reset) (Start Command) + (State 3) (Record Reset)} \qquad (7)$$

$$\overline{A} = \text{(System Reset) + (State 2) (Stop Command)} \qquad (8)$$

The actual design of the sequencer is thus reduced to a logical arrangement of the phase state diagram and the writing of appropriate equations from it. To contrast the two device approaches (relay and semiconductor) in data-processing systems, a relay-implemented processor and a semiconductorized proces-

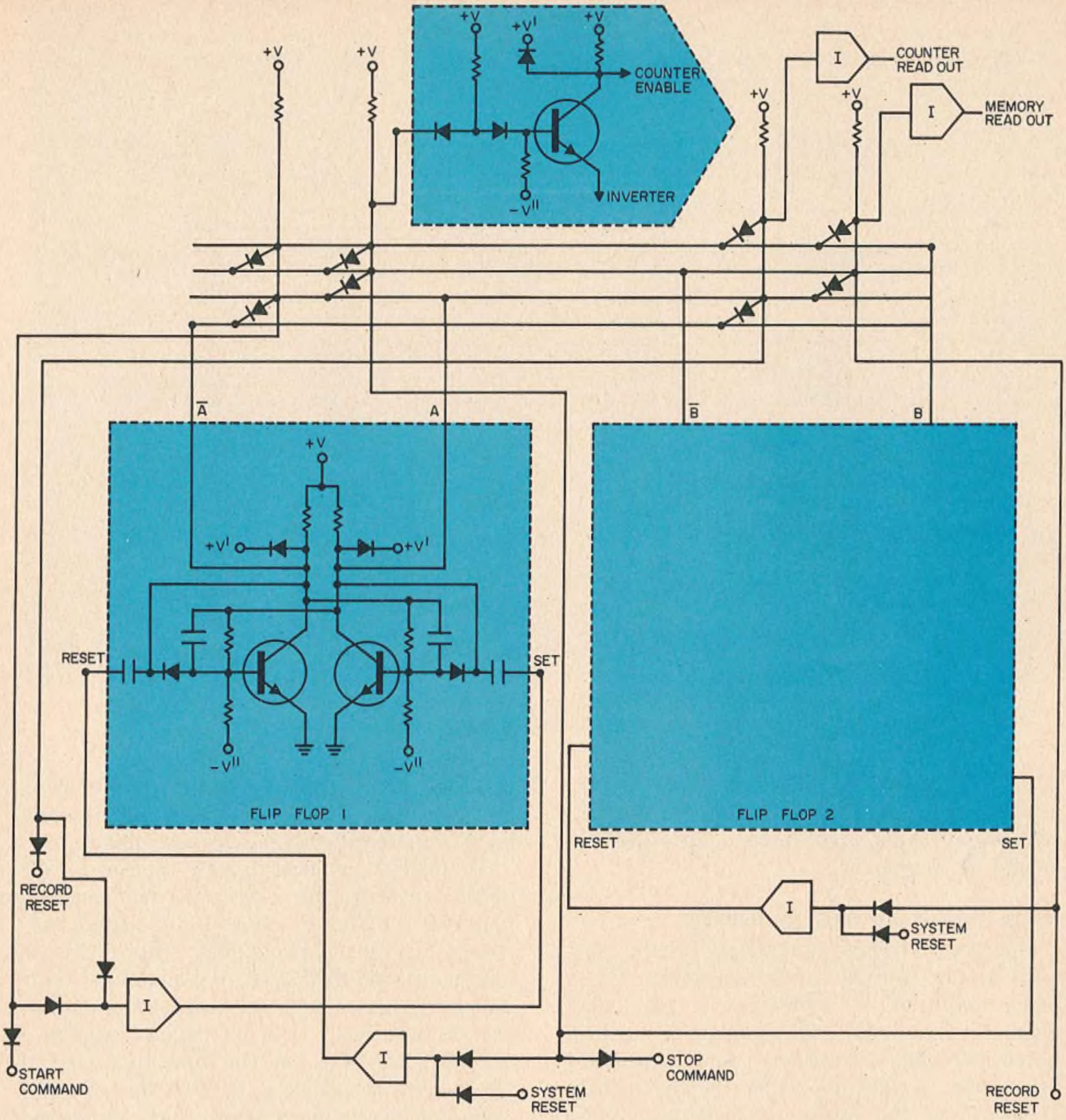


3. **Relay-operated data-processing sequencer** features less complex circuitry than an equivalent semiconductorized system (compare with Fig. 4). The phase-state diagram (Fig. 2) forms the basis for the design of the sequencer, shown in the reset state.

sor are presented (Fig. 3 and Fig. 4, respectively). The relative complexities of these two approaches are readily apparent. Obviously the transistorized approach includes a greater number of components, with added costs of manufacturing.

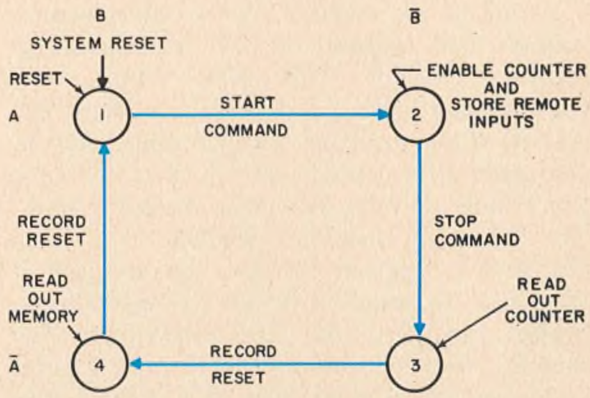
The diagrams reveal critical "race" conditions. Consider, for example, the transition from State 2 to State 3. Notice that flip-flop *1* must go from State A to State $\overline{A}$ and flip-flop *2* from State $\overline{B}$ to State B. If this transition were to occur non-simultaneously, either one of the states AB or $\overline{AB}$ could occur during the transition. If the machine enters either of these states during its transition from State 2 to State 3, it could stop. This is because the only external transition signal present at the time is the stop command. A data block would have thereby been missed. This is one kind of "critical race."

A similar situation exists for the transition from State 4 to State 1. For relay-operated sequencers, multiple relay transitions are to be avoided for this reason. An im-

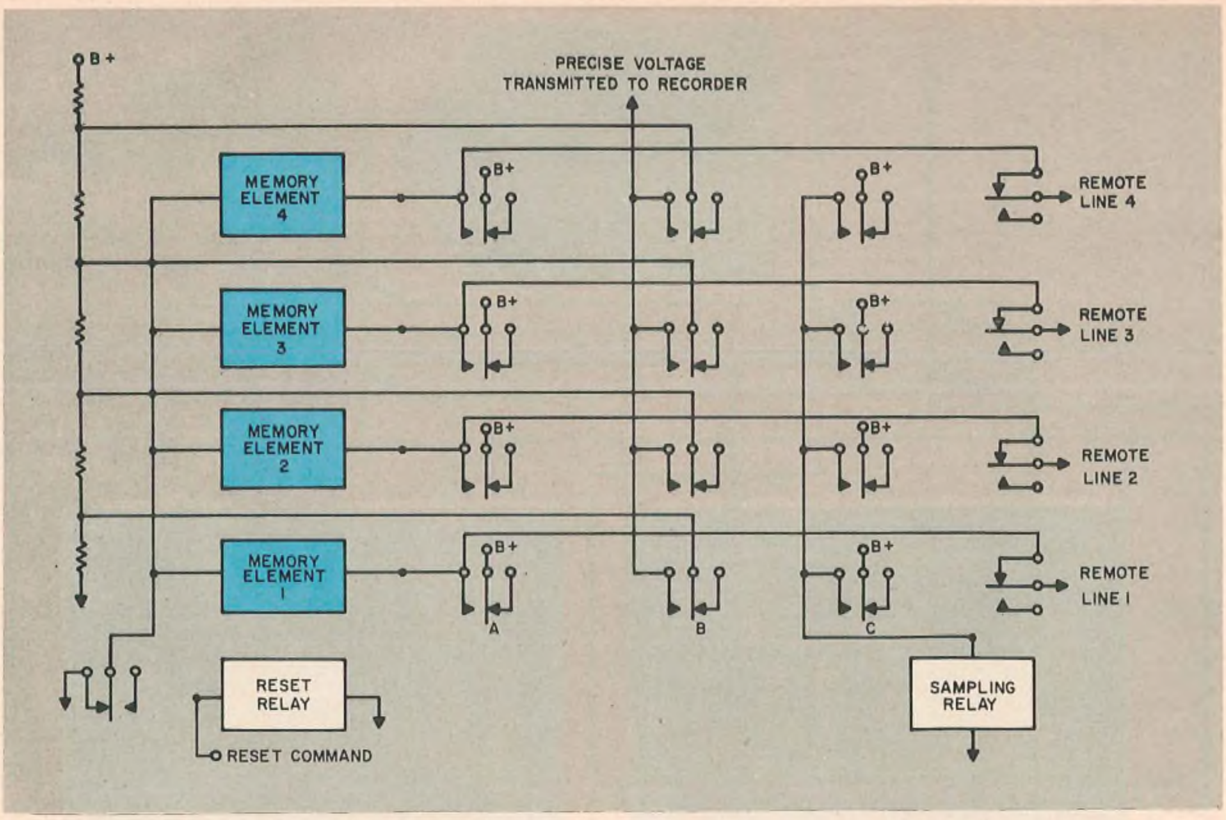


4. **Solid-state sequencer** (the functional equivalent of Fig. 3) is more costly and complex than its relay-based counterpart. This type is more suitable for fast-rate (above audio frequency) data processing.

proved sequencer would employ a "unit-distance" arrangement. In this case only one relay is operated when going from one state to another. A phase-state diagram for this improved sequencer (unit distance) is shown in Fig. 5. Note that in going from any state to the next, only one relay changes state (AB, $A\bar{B}$, $\bar{A}\bar{B}$, $\bar{A}B$, AB, etc). Transition states are occasionally added to achieve a unit-distance phase state diagram. These serve the purpose of assuring that multiple transitions do not occur. For example, a sequencer with two relays (4 binary states) cannot be traversed from a given point back to that point in three steps without a multi-



5. **Modified sequencer phase-state relationships** use a unit-distance separation of functions to insure that multiple transitions do not occur.



6. **Relay memory circuit** features fewer components than semiconductor counterpart and does not distort signal being processed.

ple relay transition. However, the fourth, unused, state could be used as a dummy transition, thus providing a unit-distance design arrangement.

Relay suitable for memory function

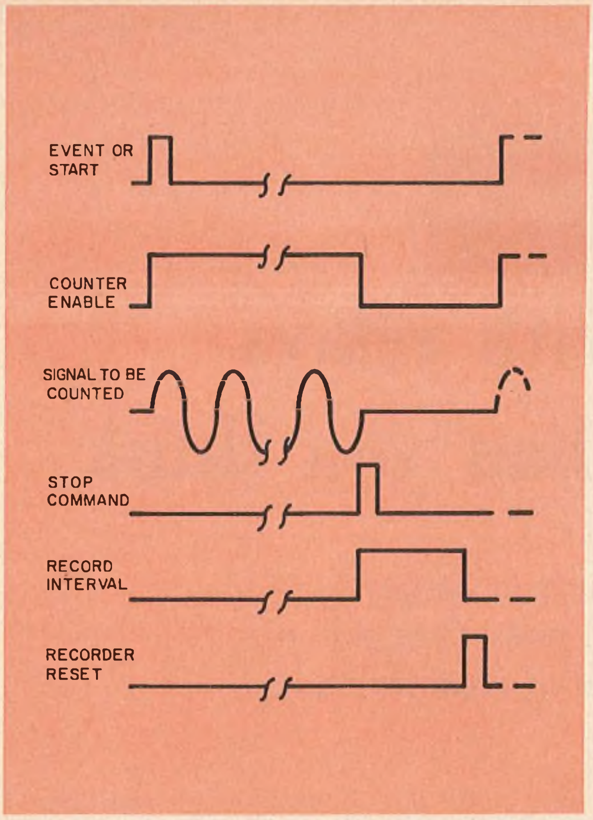
The use of relays in data-processing systems is not limited to the sequencer. It is often required to memorize a particular element of an array (the record number in a batch-recording situation) for subsequent recording. In addition it may be required to transmit to the digital recorder a precise voltage representing this number. These requirements are satisfied by a representative 4-line relay memory (Fig. 6).

If one of the remote lines is energized, a voltage will appear on its corresponding memory element. This relay closes, and consequently locks itself in (via contact set *A*). At the same time the sampling relay is energized (via contact set *C*), disconnecting the remote sources from the memory bank. The selected memory element will then transmit a precise voltage (on the set *B* contacts) to another device (conceivably a digital recorder) for later recording. The memory element remains closed until a reset command is received. The reset relay opens the common ground line, thus unlocking the previously selected memory element. When this system is compared with an equivalent memory bank that uses semiconductors, the latter's increased complexity is evident.

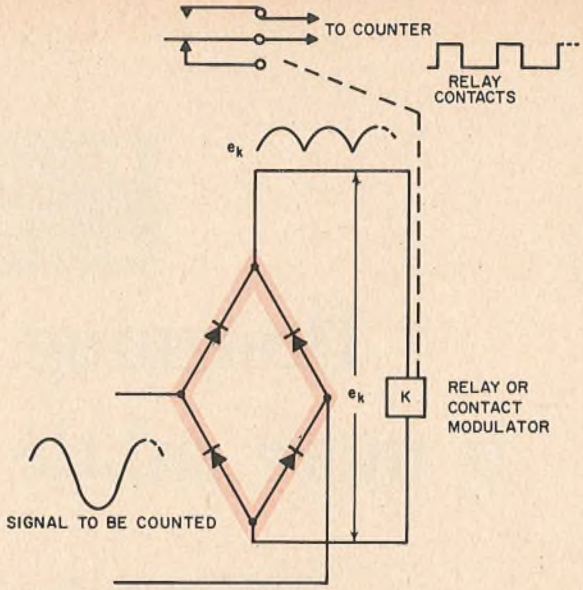
To provide an undistorted voltage to the digital recorder, an electronic transmission gate with matched elements is usually required in the semiconductor case. This is because if the diodes are not matched, their offset voltages (potential drop at the operating current level) will not cancel, causing a voltage other than the true input to appear at the output. In addition, to turn the gate ON and OFF at the appropriate times requires a gate driver. The driver applies the proper bias voltages to the control diodes, so as either to back-bias the signal diodes (thus cutting off the transmission gate) or to back-bias the control diodes (allowing the output voltages to be controlled by the input signal and thereby turning the transmission gate on). These elements significantly add to the cost of such a memory. Additional supply voltages are also required. The equivalent relay system avoids these additional elements.

Limitations of relay EDP

Data-processing systems of the type considered thus far are asynchronous. The commands from the external system are not dependent on any internal data-processor clock. As such, the maximum data rate is



7. **Timing sequence of a relay processor.** Relay transition times limit the data-processing rate.



8. **Diode-bridge and relay** arrangement for improving the resolution times of the counter element in the relay EDP system.

limited by the time necessary to process the data. A timing chart for the processor appears in Fig. 7.

Two limitations must be considered when employing relay data-processing circuits. The first is the error in the timing (or measure of the event) introduced. This error arises because of the finite time required for the counter to be activated after the receipt of a start signal (shown as simultaneous in the illustration). This reduces to the time required to change the state of a relay flip-flop. The time for this is twice the transition time of a single relay (since one relay must be energized and the second de-energized). A representative time is 60 msec for ordinary (long life) elements.

Special-purpose, high-speed (and higher cost) elements can reduce this time to 5 msec, not including reed relays, which will operate faster but have fewer numbers of contacts. In some situations it may be possible to eliminate this error by anticipating the actual start of the event.

If, in addition to the above error, the signal being counted is asynchronous with the control signals (as would be the case if line frequency were being counted), the error introduced by the counter must be included. If the signal is introduced just after the counter has passed the trip level, the counter will run the first cycle and then have to wait a complete cycle before detecting the first count pulse.

This error, called resolution error, can be cut in half by increasing the resolution. A circuit that will increase the counter resolution is shown in Fig. 8. The relay or contact modulator contacts close twice for each cycle. If the counter now misses the first cycle, it has to wait only a half cycle before the next count pulse.

The second limitation of this data processing system rests in its method of resolving sequential stimuli. After the receipt of a stop command, the recording process begins. When the records are in the form of a printed tape (a digital recorder), the time required to print is typically 30 msec. During this interval, it is necessary to hold the contents of the counter, or memory, fixed, thus making it unavailable for any new, incoming event. The fastest data rates here are about 16 events per second (two words being required for each data block).

Two methods can be suggested to increase these data rates. With a punched paper tape record, the recording can be improved. Representative machines can process a word in 8 msec. Thus, to record a 3-digit (word) counter output and a memory word (a total of 4 words) on 8-level tape, approximately 16 msec are required. The second approach entails a register that stores the counter output while it is being recorded. This frees the counter to accept a new event. The effective data rate is thus doubled, at the expense of an additional register. ■ ■

Designing with relays is more subtle than you think

Little-known fine points of design show that the relay involves more than power-driving an isolated set of ideal switches

RELAY OPERATING LIFE and performance often fall below par when the designer stresses only one or two of the relay's features in specification or circuit design. Unknowingly, he may be sacrificing some other desirable characteristic.

This situation most often occurs when the design is limited to merely applying rated coil power and considering the contacts to be perfect switches independent of the load, which they're not.

Instead, the designer must dig into the fine points of relay design and weigh the performance tradeoffs. His attention must be addressed to such matters as:

- The factors that affect switching times.
- How temperature influences performance, life and parameter margins.
- Interference: its causes and suppression.
- Contact loading and relay selection.

When given sufficient consideration, these design criteria may mean the difference between optimum and adequate performance or between one million and ten thousand operations. Some apply directly to the relay as a whole; others focus on the relationships between the various elements that compose the relay (Fig. 1).

Contacts not near-ideal switches

The speed of switching is sometimes a paramount design consideration. There is a tendency on the part of many design engineers to dismiss contact circuitry design from their efforts because of its seeming simplicity. The contacts cannot be thought of as near-perfect switches, despite their very low ON resistance and very high OFF (isolation) impedance. The switching of contacts involves the type of relay being used, the loading of the contacts and the nature of the coil signal.

Most relays are abruptly switched ON or OFF. In many practical applications, it is satisfactory to use a multiple contact relay with a slowly changing signal, even if the contacts do not snap and/or complete their switching simultaneously. However, when this occurs at full load ratings, shortening of contact life may result. If severe vibration is also present, contact chatter may result. (See article covering switching times and chatter on p 45.) It should be noted that some relay types that always snap when slowly energized might still experience contact bounce if slow energizing is combined with high-vibration amplitude.

Small-size ac relays are inherently slower to release than dc relays (of the same size), because they must contain a delaying device to prevent their following the ac input signal. At 60 cps, the release time must be about 10 msec or longer to prevent contact release at each polarity reversal. On the other hand, the ac-type turns on faster, because it has higher in-rush currents.

Single-pole relays are generally faster than multipole types of the same contact

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rating because of smaller inertia. If several poles must be switched, but only one needs to be switched quickly, this can be done using a separate, fast relay for the one pole.

Operate (pickup) and release (dropout) times of some relays may be affected by a factor of 10 or more according to the type of circuit in which they are used. Here are some common circuit features to be considered that affect the switching times:

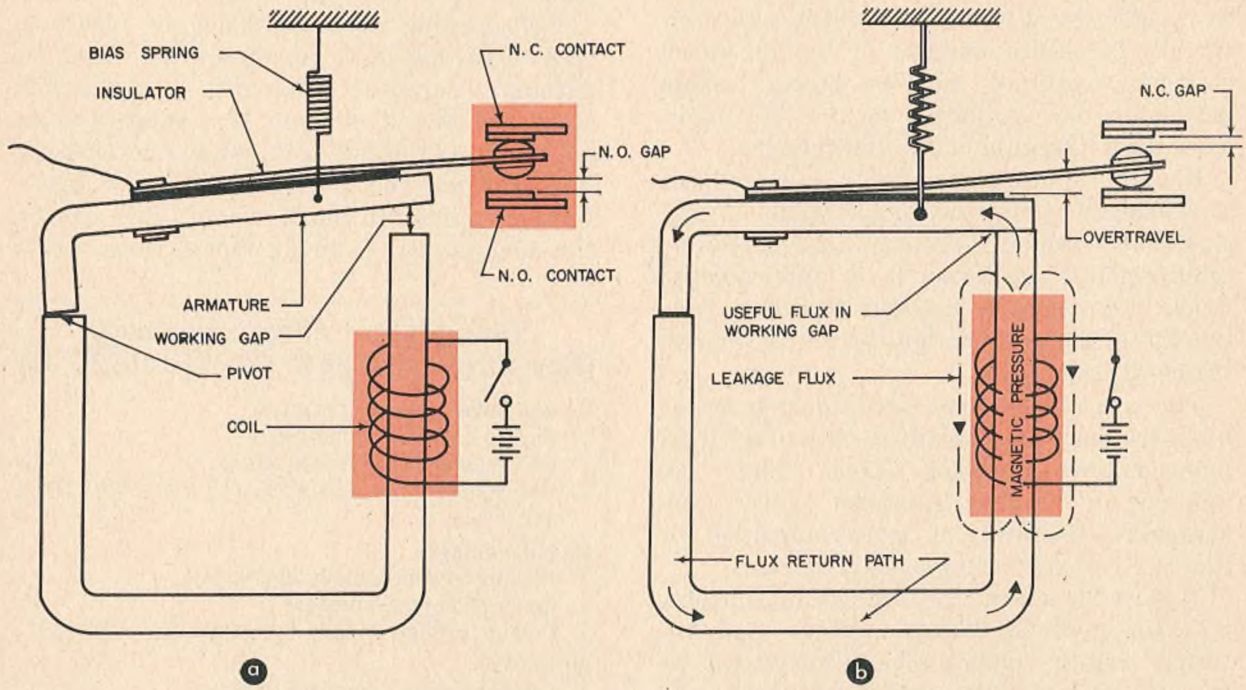
- Arc suppressors in the coil circuit cause the largest release delays.
- Coil shunts (such as indicator lamps) delay the release time.
- Inductance of the power supply, power cables or of elements in series with the coil will retard the coil current rise and, therefore, the operating speed. Energy storage due to current flow through such inductances also prolongs the release.
- Increasing the coil-circuit power beyond the normal energizing level increases the operating speed, although not proportionally.
- Pre-energizing a relay almost to the point of causing it to operate will enable it to operate faster when full voltage is applied. Likewise, pre-energizing with reverse polarity will delay the operation of the relay. Pre-energizing makes most relays (except the polar types) more sensitive to shock, vibration and constant acceleration. Pre-energizing polar relays in the reverse direction affects them favorably.
- Two relay coils in parallel can interact to affect the release times of each. If the time constant, L/R, of the two relays is equal, the release times remain unaffected. If the time constants are unequal, the current will continue to flow in the direction of the relay having the longest time constant. The net effect of unequal time constants is an increase in the release time of the relay with the larger time constant and a slight decrease in the release time of the relay with the smaller time constant.

Thermal change impairs sensitivity

As in other devices, the effects of temperature variations markedly influence performance, most importantly the sensitivity (of the coil pickup) and efficiency.

By definition, relays rated for a given voltage have effective sensitivities that are inversely proportional to the coil resistance. Thus, a 2000-ohm relay is twice as sensitive (drawing half as much power) as a 1000-ohm relay, if both are rated for the same supply voltage. When temperature changes occur, the relay with the larger resistance coil will exhibit wider variations in switching margins (tolerance of pickup and dropout levels). Thus, increased sensitivity is accompanied by a sacrifice in thermal stability.

The typical temperature effects on various basic relay types for an increase of 100°C appear in the table. For smaller changes of temperature, the effects may be assumed to be proportionately smaller. In each case, the mechanism is the same. The coil impedance is



1. **Basic single-pole relay** shows both normally open and normally closed contacts. Unenergized coil state (a) and energized coil state (b) demonstrate relay action.

temperature dependent. Thus the coil current, which determines the flux, varies with temperature. Since the flux establishes the magnetic forces, pickup and dropout are affected by the temperature change.

In the non-polarized dc type, the circuit's magnetic reluctance remains constant. However, polarized-type dc relays feature permanent magnets which are temperature-sensitive. This causes a decrease in pickup current requirements which largely offsets the increase in pickup voltage due to temperature rises. With ac relays, the portion of coil impedance that is resistive is small, and the effect on pickup voltage is negligible.

Compensation achieved by compromise

A number of temperature-compensation schemes are available. Of these, the most common involve Jeliff wire, thermistors, bimetals and external circuit techniques.

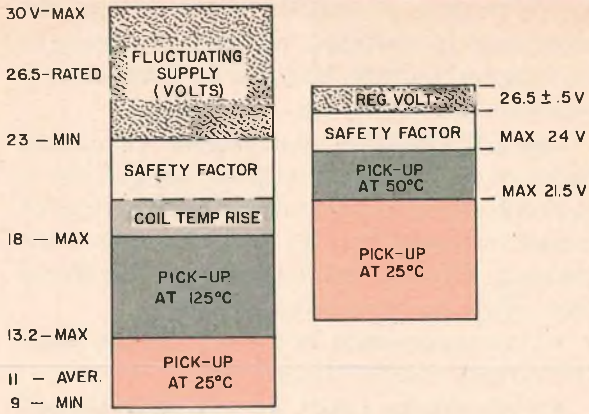
Jeliff wire is often used on the coil winding. It has a lower temperature coefficient than copper and is therefore less susceptible to temperature variations. However, its resistance is considerably higher (nearly 30 times), resulting in a much greater coil-power demand. It has given way to thermistors.

Thermistors are used in series with the coil. Occasionally, a resistor is placed in shunt with the thermistor to confine the compensating range to that which is needed (and which cannot be directly met by the thermistor itself). The negative temperature coefficient of the thermistor offsets the positive coefficient of the coil. However, more coil current is needed because of the increased network resistance, and the pickup-voltage parameter now exhibits a smaller, but nonlinear, drift (because of the thermistor).

Bimetal spring compensation also produces a net smaller temperature coefficient. A mechanical technique, it does not alter the power requirements. However, it is applicable to either the pickup or dropout function. Thus the difference between these levels varies with temperature change.

The use of external circuit-compensation methods, such as regulators, ovens and thermal-sensitive feedback loops, may not appreciably involve increased power consumption. However, it is accompanied by increased circuit complexity and cost.

Figure 2a shows the typical relationship between nominal pickup voltage and the actual supply voltage for military-type relays. Maximum pickup voltage at room temperature must not be greater than about one-half the nominal voltage. Thus, for a nominal



2. **Coil-voltage criteria** show how temperature and safety factors are accounted for (a). Power savings result when the relay's pickup voltage approaches the nominal supply voltage (b).

supply of 26.5 volts, room temperature (25°C) pickup should be about 13.0 volts max. At 125°C the increase of coil resistance causes the pickup to be about 18.0 volts.

The difference is an allowance for coil-temperature rise, for fluctuations in line voltage and to provide a factor of safety. When the voltage is well regulated and the ambient temperature is lower, one may select a relay having a pickup voltage much closer to the nominal supply voltage. A relay with this higher rated pickup voltage will typically have a higher resistance. It will then draw less power at the nominal voltage. In the case shown in Fig. 2b, the power saving is 62%.

Suppressing arcs, surges, noise

Fast-opening contacts suddenly insert a very high electrical resistance and tend to develop a surge of 1000 volts or more that stops the flow of current. If a suppressor is not used and the full peak voltage develops, a flashover may occur at any of these high-voltage points. In small relays, this causes the contact gap to break down, thus short-

Temperature effects on relays (Results of a change to 125°C from 25°C)

Dc non-polar (general purpose)

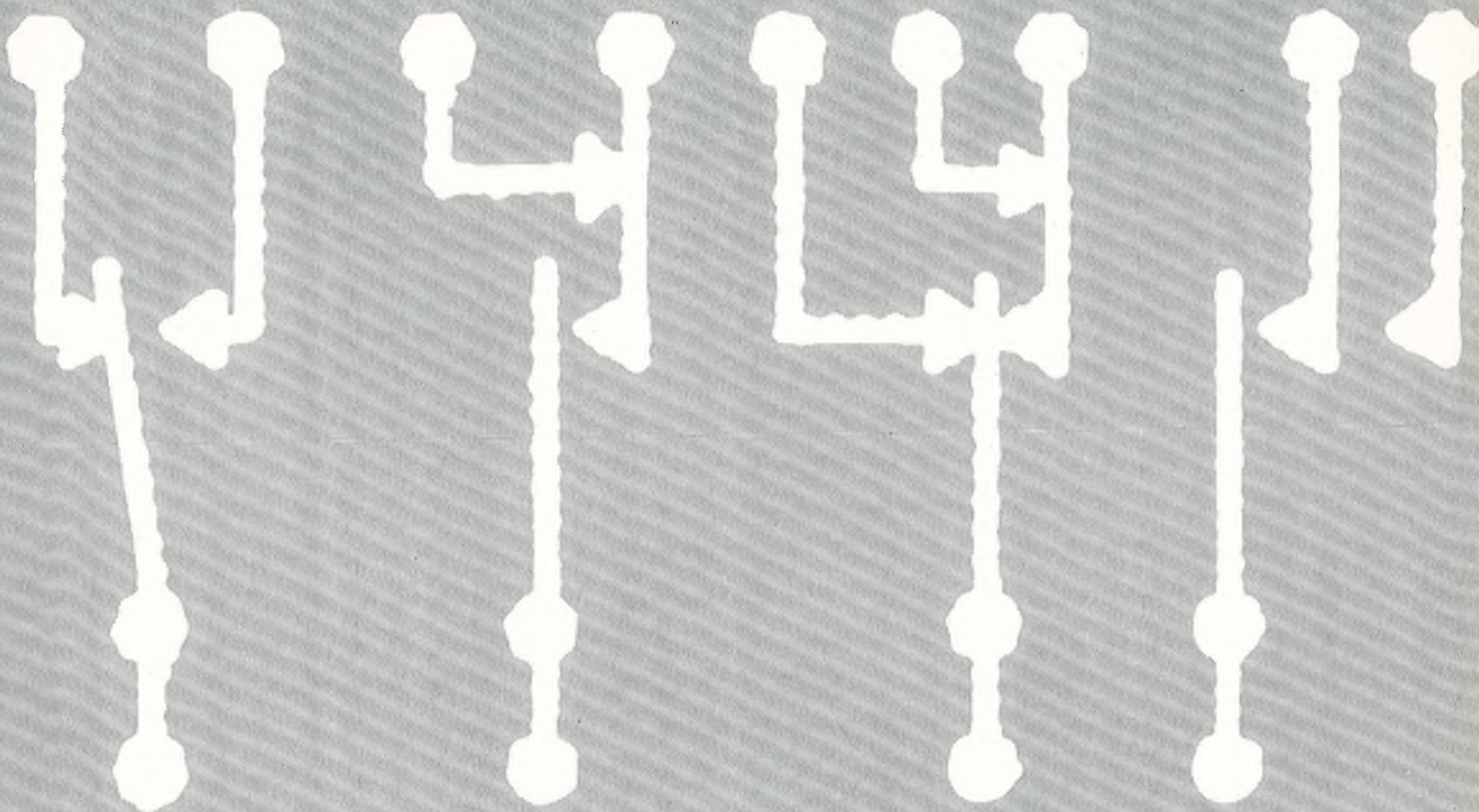
1. Pickup current unchanged.
2. Coil resistance increases 40%.
3. Coil voltage increases 40% (13 v at 25°C; 18 v at125°C).

Dc polar relays

1. Pickup current usually decreases.
2. Coil resistance increases.
3. Pickup voltage usually increases ($\Delta v < 40\%$).

Ac relays

1. Coil resistance increases 40%.
2. Coil inductance does not change.
3. Coil impedance increases about 10%.



Sigma Relays & Relay Applications

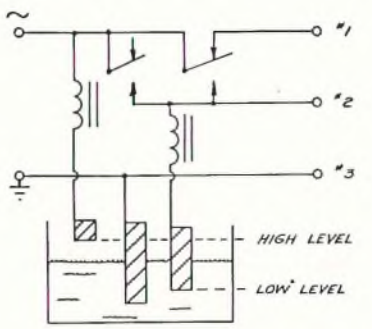
Whenever a control signal must open or close electrical contacts, more than likely there is a specific standard Sigma relay available to do the job reliably and economically. For there are more than 100,000 standard types in the Sigma line including latching and non-latching, electromagnetic and solid-state relays. They are in use in thousands of applications—industrial, commercial, consumer and military—and have been for over 25 years.

The relays and applications described on the following pages represent only a small number of these types and uses. If you need additional data for your particular circuit write to us. We'll be glad to send you more information.

SIGMA DIVISION SIGMA INSTRUMENTS INC

Assured Reliability With Advanced Design / Braintree, Mass. 02185

A simple, economical way to control liquid levels within prescribed limits.



POWER FOR FILL TERMINALS 1&3

POWER FOR DRAIN TERMINALS 2&3

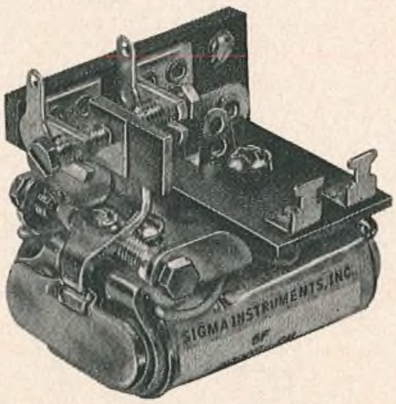
The circuit shown, utilizing a Sigma Series 5 relay, represents one of the simplest ways to control liquid levels in applications such as water treatment, chemical processing and the protection of immersion pumps in artesian wells.

As can be seen, the liquid level is sensed by immersion electrodes, a convenient and economical method when the liquid is sufficiently conductive. These electrodes can be arranged to give independently controlled high and low limits, and to operate for either filling or draining.

Depending on the size and spacing of the electrodes, the purity of the water, or the type of solution, the equivalent resistance between the electrodes can vary from 100 to 100,000 ohms. In the circuit shown, the Sigma Series 5 relay would be suitable for almost any anticipated resistance. A refinement of the circuit would permit control of solution strength of soap, caustic or acid, between prescribed values.

If you have a relay idea, or can improve this one, we'd like to hear from you. Your idea could be the next one we publish.

Versatile SPDT Series 5 relay responds precisely to signals as small as 1 mw.



The Sigma Series 5 relay is one of the most versatile relays on the market today. Its 10,000 variations are performing in applications ranging from air navigation systems and liquid level controls, as shown on the left-hand page, to burglar alarms and meter protection equipment. It is particularly useful as an overload or underload device that reacts without amplification to minute changes or differences from normal values.

With the Sigma Series 5, adjustments to 1 mw are standard. Yet, its design enables it to have unusually high contact forces even at these low inputs. Some other reasons why this relay is in such widespread use are:
1. Narrow differential—Drop out to pick up ratios extending to 80% because of easily adjustable fixed contacts and spring force. 2. Accuracy—Trip values can be set readily to within ± 5%, with micrometer-type screw contacts. 3. Stability—Trip points will not vary more than ± 2% throughout life, in the absence of contact erosion, as a result of low friction needle point bearings. 4. Ruggedness—Withstands 100 G's shock without damage, and heavy coil overloads of up to 30-to-1 for voltage or current. 5. Long life—Five million operations, barring contact damage by transients.

Try the Sigma Series 5 for yourself—free of charge. Just send for the Sigma Series 5 bulletin and a free relay redemption certificate.

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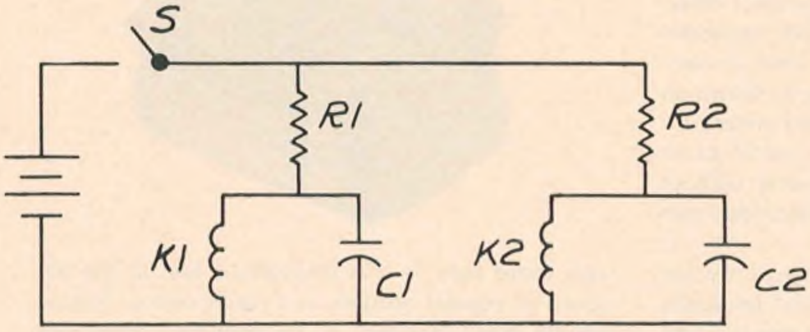
ON READER-SERVICE CARD CIRCLE 70

A dual keying circuit that switches one load only when a second load is fully energized.

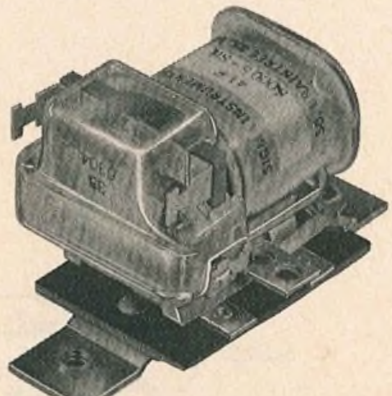


This simple dual keyer utilizing two Sigma Series 41 relays, assures connection and disconnection of one load during the interval that a second load is on. For example, in keying a transmitter, it energizes the oscillator permitting it to stabilize in frequency before the final amplifier is switched on or off.

Time constants for the circuit are chosen so that when S is closed, the contacts of relay K1 close before the contacts of relay K2; and when S is opened, the contacts of K1 open after the contacts of K2. C1 is large and R1 is small so that relay K1 has a fast pick-up and a slow drop-out. C2 is small and R2 is large, so that C2 has a slow pick-up and a fast drop-out.

If you have a relay idea or can show us how to improve this one, we'd like to hear from you. Your idea could be the next one we publish.

Built to last 30 years. Rugged industrial relay with pivotless hinge construction.



The Sigma Series 41 SPDT relay assures extra long service life in general purpose applications ranging from airport lighting systems to smoke detection controls. Its mechanical life is rated at 1 billion operations minimum. That's equivalent to 1 operation per second, 24 hours a day for over 30 years.

One reason why it can last so long is its pivotless hinge construction and extra long beryllium copper spring arm. Another is "balanced design" which includes the following characteristics and benefits: 1. High coil overload capacity: operates efficiently at control voltages 4 to 6 times rated coil input. 2. Extended contact life: heavy-duty design of stationary contacts minimizes effects of contact erosion. 3. Broad load carrying capacity: from dry circuit to as high as 10 amps. 4. Clean switching: small mass of armature contact minimizes contact bounce. 5. Versatility: wide variety of enclosures, adjustments, contact materials, coil resistances and operating characteristics to meet all kinds of industrial conditions and applications. 6. UL listed.

Test all of these "balanced design" features—free—and prove for yourself that the Sigma Series 41 will outperform any other comparable relay in your industrial applications. Just send for the Sigma Series 41 bulletin and a free relay redemption certificate.

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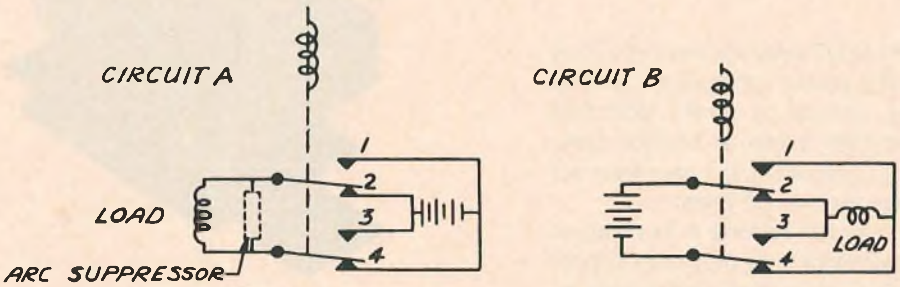
ON READER-SERVICE CARD CIRCLE 71

How to avoid short circuits when reversing polarity of inductive loads.



Circuits A and B are both commonly used for reversing polarity, but circuit A has an advantage not often recognized.

When reversing the polarity of a difficult load, such as a motor, a slight contact weld might delay the transfer of one pole while the other pole completes transfer. In circuit B this will short circuit the power supply resulting in catastrophic failure.

In circuit A a non-synchronous transfer would only short circuit the motor terminal. This is not harmful, and can be done deliberately with some relays, such as the Sigma Series 42. Short circuiting the motor, known as "slugging," stops the motor more quickly, allowing faster reversals.

Neither circuit will prevent catastrophic failure if an arc is drawn across the contact gap, because this would short circuit the power supply.

Where arcing may be a problem, arc suppressors can be used.

If you have a relay idea or can show us how to improve this one, we'd like to hear from you. Your relay idea could be the next one we publish.

DPDT relay with 100 mw sensitivity has mechanical life of 1 billion operations.

The Sigma Series 42 is designed for a wide range of general purpose applications—from alarm and control systems to demand meters and timing circuits. It combines sensitivity and long mechanical and electrical life with stability, high insulation between circuits and high coil overload capacity. Check all of its features and ratings:

Long mechanical life—1 billion operations—due to pivotless hinge construction where the motion is rolling rather than sliding, thus reducing wear.

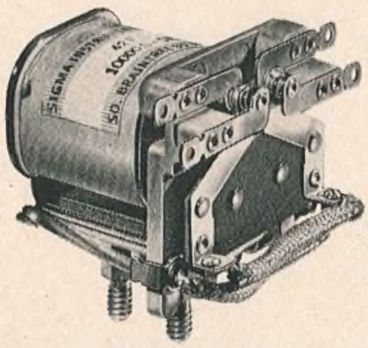
Long life under load—1,000,000 operations—due to small armature mass that reduces bounce, and controlled contact wipe that prevents circuit induced sticking.

100 mw sensitivity—minimizes coil load in circuits with limited load handling ability.

High stability—due to beryllium copper contact springs and return springs.

High circuit insulation—due to glass alkyd contact base.

High coil overload capacity—handles control voltages 4 to 6 times rated coil input.



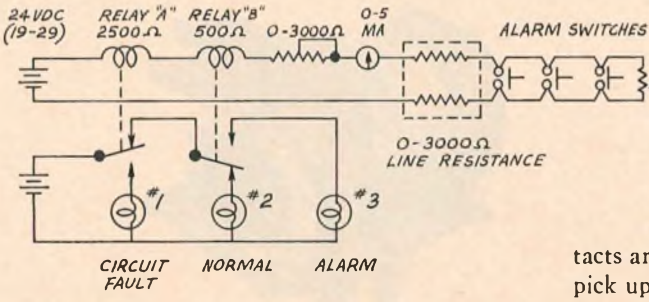
Test the U. L. listed Series 42 for yourself—free—against the type you may now be using. Just send for the Sigma Series 42 bulletin and a free relay redemption certificate.

SIGMA DIVISION SIGMA INSTRUMENTS INC

Assured Reliability With Advanced Design / Braintree, Mass. 02185

ON READER-SERVICE CARD CIRCLE 72

A self-monitoring long-distance alarm circuit that assures a state of constant readiness.



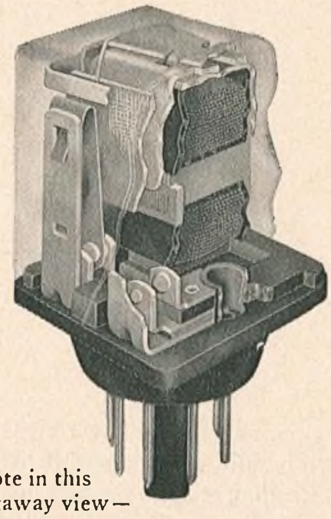
You may be able to use or adapt this relay idea. It's an alarm indicating circuit with fail-safe features that will operate over long wires from a central station. It uses two sensitive relays, such as the Sigma 4 or 26, to indicate by lights or signals, three conditions: 1. Normal condition—system functional. 2. Alarm condition—as a result of contact closure. 3. Fault condition—circuit resistance high or open.

Where the circuit is in the normal standby condition, current flow is sufficient to energize Relay A, but not Relay B. Lamp #2 is on, indicating NORMAL conditions. If any alarm contacts are closed, circuit current is high enough to pick up both relays, causing lamp #3 to indicate an ALARM. An audible signal or any automatic device such as a fire extinguishing system can also be wired for simultaneous actuation. If the circuit is accidentally opened or has been tampered with, Relay A drops out, energizing lamp #1 which indicates circuit FAULT.

Typical applications include protection against fire, intrusion, high or low water level, excess pipe line pressure, or any industrial hazard where the chances of accidental circuit opening or penalty for failure are high.

If you have a relay idea—or can show us how to improve this one, we'd like to hear from you. Your relay idea could be the next one we publish.

New 10 amp DPDT relay with no internal switch wiring. Result: Longer life.



Note in this cutaway view—
1. Complete absence of internal switch wiring. 2. Long contact blades. 3. Switch, coil and frame assemblies mounted directly on the octal plug. These features result in an extra rugged, heavy-duty general purpose relay.

The new Sigma Series 46B general-purpose relay eliminates internal switch wiring and uses heavier switch members, to provide lower circuit resistance. At 10 amperes less than ½ watt is dissipated in the switch.

Long, flexible moving contact blades reduce stress and add to the durability of the 46B. Rated life of both the AC and DC versions ranges from 500,000 operations on a 10 amp, 115 VAC resistive load, to 10 million operations with a 1 amp, 28 VDC resistive load.

46B is rugged. Switch, coil and frame assemblies are solidly fixed to the octal plug-in base, instead of the plastic dust cover. This unitized design enables it to withstand severe industrial conditions of shock and vibration.

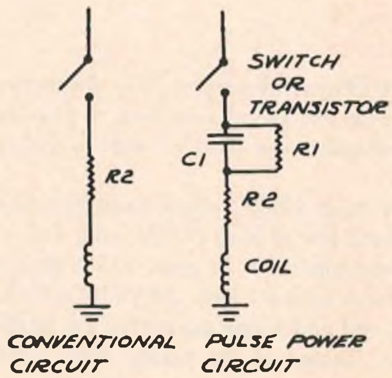
Test and compare the Sigma 46B—free of charge—against the make you are now using. Just send for the new Sigma Series 46B Bulletin and a free relay redemption certificate. Fill out the certificate upon receipt, return it to us, and we will send your free Sigma Series 46B to you.

SIGMA DIVISION SIGMA INSTRUMENTS INC

Assured Reliability With Advanced Design/Braintree 85, Mass.

ON READER-SERVICE CARD CIRCLE 73

How pulse power can be effectively used to operate non-latching relays.



Pulse power, commonly used to operate latching relays, can also be used advantageously to operate non-latching relays, both polar and non-polar.

For example, with the pulse power circuit shown, a Sigma 33VG relay can be switched in 2 milliseconds, using the required 2.5 watts of power, without damaging the relay coil or other circuit components. With a conventional circuit, the relay coil would overheat and the control transistor would be overloaded.

The pulse power circuit allows the flow of 2.5 watts only momentarily and then reduces it to a normal value by providing enough continuous current to hold the relay above drop-out. In addition, it holds the amount of inductive energy absorbed by the switch or transistor to a minimum.

Values for the coil and R2 are determined by speed requirements. C1 is large enough to momentarily pass 2.5 watts. The value of R1, based on rated operate current, is just enough to provide minimum holding current.

If you have a relay idea or can show us how to improve this one, we'd like to hear from you. Your relay idea could be the next one we publish.

Compact polarized SPDT relay with microwatt sensitivity repeats 500 pps.

The Sigma Series 72 SPDT relay is one of the most popular switching devices in the broad Sigma line. It is being used in equipment ranging from data processing systems and servo controls to differential controls and telemetering equipments. It is particularly useful in modern telegraphy applications.

A main reason for its wide use is its sensitive yet precise, distortion-free response. This is made possible by its unique design. With a very small armature mass and a very high resonant frequency, contact transfer time is at a minimum and contact bounce is virtually eliminated.

There are more benefits from the exclusive design and construction features of the Series 72:
Polar switching—safely switches plus or minus 120 volts.
Versatile mounting—unaffected by gravity, adjacent relays or socket orientation.
Long life—rated at 500 million operations.
High sensitivity—to 160 microwatts.
Easy contact replacement—doubles life expectancy.
Small size—1⁷⁄₁₆" in diameter, 2⅝" high.

The Series 72 operates for many hundreds of millions of cycles in applications involving high speed switching, telegraphy, or pulse repetition.

You are invited to try out all the advantages of the Sigma Series 72 for yourself—free of charge. Just send for the Sigma Series 72 bulletin and a free relay redemption certificate.

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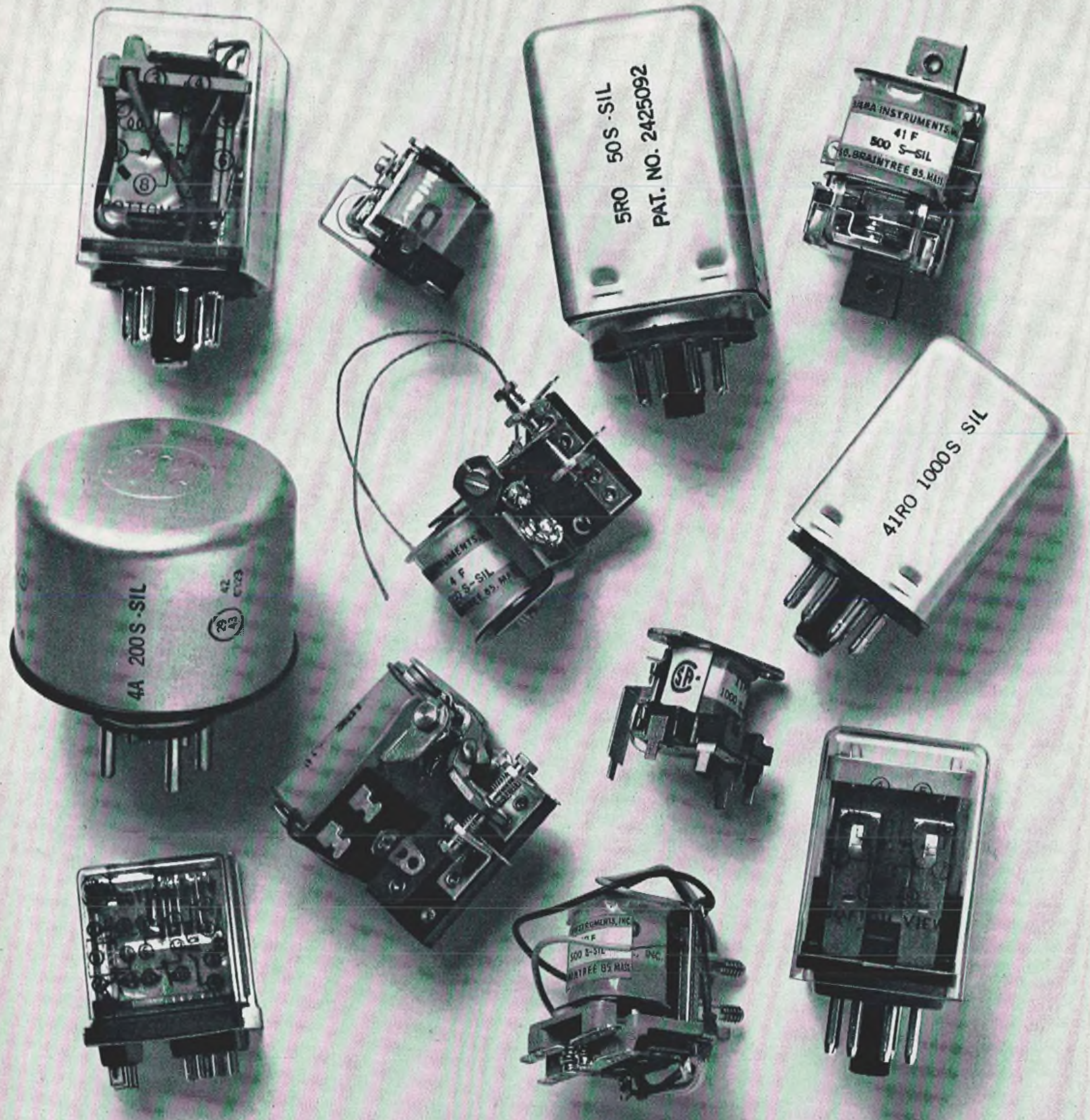
ON READER-SERVICE CARD CIRCLE 74

Sigma relays like these are in volume use throughout industry.

relays actual size



The application range for Sigma relays is as broad as industry itself. Sigma sensitive, general purpose and industrial types are at work in equipments as diverse as:

- airport lighting systems
- alarm systems
- battery chargers
- boiler salinity control systems
- burglary protection
- elevator controls
- furnace controls
- heat testing controls
- liquid level sensing circuits
- machine tool controls
- meter protection circuits
- office machinery
- photocopying equipment
- photoelectric controls
- power supplies
- radio controls
- smoke detection controls

and many, many more.

Test a Sigma relay in your application —free of charge. Just send for the Sigma 12 page easy-reference catalog and a free-relay redemption certificate.

SIGMA DIVISION SIGMA INSTRUMENTS INC

Assured Reliability With Advanced Design / Braintree, Mass. 02185 ening the life of the contact.

On the other hand, there is a voltage phenomenon that causes a transfer of material to the negative contact in the form of a spike. Such a spike has been known to grow tall enough to bridge the gap of open contacts. Thus, an arc suppressor may have to be modified or even omitted to permit a slight arcing to occur. The small amount of arcing would erode this spike and thus limit its harmful effect on bridge transfer.

RF noise is most effectively suppressed with LC-type filters, but these are too large and too heavy for most aerospace applications. Here, RC suppression is usually the best compromise. The use of a diode reduces the needle-like bridge transfer to the negative contacts, but RF noise is usually increased. This is because the diode itself is an active noise source (as contrasted with the filter elements, which are passive).

Six common types of arc suppression, along with their principal features, appear in Fig. 3. The choice depends upon which features are the most important in the given situation. The governing considerations are release-time effects, noise levels, surge and arc requirements, and ease of accommodation of relay and contact load.

RC suppressor. Good suppression with only slight release delay is provided. In terms of components, it is economical, but bulky. Low RF noise results. Select the value of C to limit the peak voltage at the contact gap. Select $R \leq R_L$ both to limit the inrush when closing the contacts and to maintain 10 volts or less across the gap at the instant of opening. Adding a diode, CR, reduces the initial peak voltage and bridge-transfer.

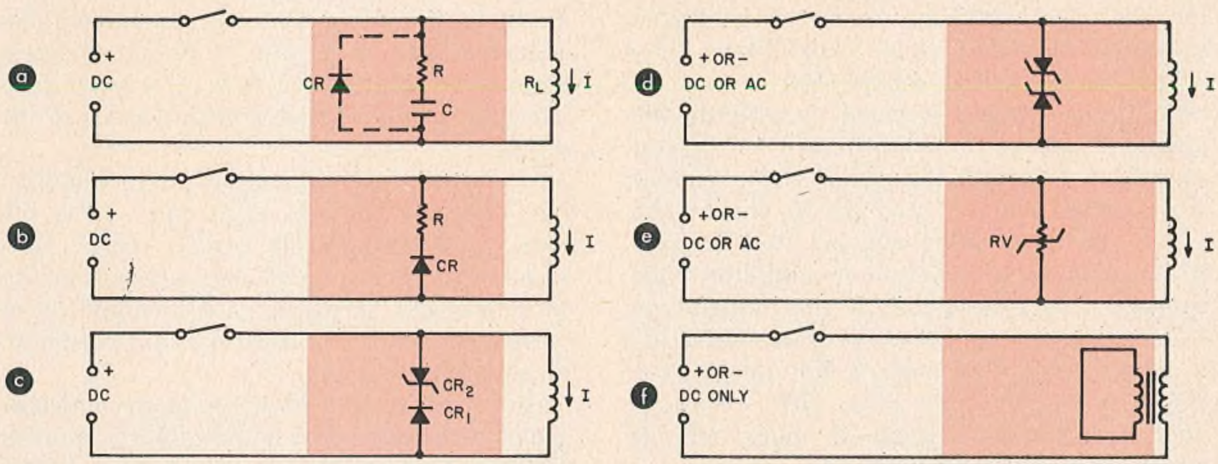
Diode-resistor suppressor. Diode CR, when used alone (no resistor), eliminates voltage surges. However, the release delay is maximized by this means of suppression. Adding a resistor, R, reduces the delay but causes an instantaneous voltage across the opening contact gap. A capacitor is sometimes used to bypass R momentarily. This keeps this IR product down until the gap is wide enough to withstand the IR voltage.

Zener and blocking-diode suppressor. This network is similar to the diode-resistor technique, except that a zener diode, CR_2, is used instead of resistor R. The high zener voltage causes faster release but a larger IR voltage drop across the opening contacts. Zeners also tend to raise the RF noise level. Neon bulbs may be substituted for the zeners for high-breakdown voltage situations.

Back-to-back zener suppressor. This technique is suitable for ac and for either dc polarity. In principle, it resembles the zener-blocking diode network. However, the zener voltage must exceed the peak line voltage. This is a restriction that is not required in the previous suppressor circuit (Fig. 3c).

Varistor shunt suppressor. Varistor RV becomes much more conductive as the voltage rises, tending to clip the voltage somewhat like a zener diode. Its nominal resistance is selected to be about 10 times larger than the load resistance to prevent high-voltage surges from damaging the circuit.

Bifilar dual-coil suppressor. By winding two coils simultaneously and shorting one of them, a bifilar arrangement is achieved. No exterior components are needed. Special coil



3. **Arc suppression techniques** have a pronounced effect on relay release time. Shown are: R-C network (a), diode-resistor leg (b), combined zener and blocking diode (c), back-to-back zeners (d), varistor shunt (e) and bifilar dual-coil (f). Types (d) and (e) are applicable to both ac and dc relays. Types a, c, d and e may shunt the switch instead of the load for less RF noise and more effective absorption of inductive energy in long lines.

construction requires twice the nominal pickup and operating power. Some delay of the operate and release functions also occurs.

Military specifications for determining release times do not usually call for an arc suppressor. Release is fastest when arc suppression is not used in the relay-coil circuit. However, this is true only if the switching contacts open fast enough and far enough to prevent an arc. The larger the relay, the more difficult it is to open the coil circuit without an arc.

An arc is a fairly good conductor, developing about 12-20 volts potential in typical small switches. This arc forms a conducting path, thereby prolonging coil current and delaying relay release. Of the various suppression methods discussed above, the RC type is usually fastest and produces results very close to rated (nonsuppressed) release. The plain-diode-in-parallel-with-the-coil approach causes the longest delays.

Note that in all cases, the amount of delay is affected by the type of relay, the sensitivity of the relay and the amount of coil overdrive. Also note that the effect of overdrive is inconsistent between relays. In other words, the best way to determine release delay is to test it.

Loading is a key to selection

In addition to its effects on the speed of switching and interference suppression, the loading on, and nature of, the contacts will exert a major influence on over-all relay performance and relay specification. For example, the actual load instead of arbitrary noninductive load ratings should be specified. Consider two relays which are equally capable of switching 5-amp noninductive loads for 100,000 operations. Based on catalogue ratings that reflect these capabilities, they would be considered equals. But it may be that the load being switched is actually the primary side of a transformer. A typical inrush of 10 times the steady-state current would cause contact sticking in one of the relays. The other relay does not stick because it may happen to have silver-cadmium oxide contacts, which do not show their advantage in noninductive load testing. Does this make a nonsticking relay better? Not necessarily. The other relay may have silver contacts with gold flash, making it more reliable under dry-circuit loading.

The load will also influence the choice of contact force. High-voltage loads and inductive loads should be switched with a relatively large gap to prevent arcing. Low-level loads are more easily accommodated by small contact gaps, because the reliability of the contact "make" is greater for smaller gaps than larger ones. The wider the gap, the greater the power required to generate the contact force. Thus, the load should be considered as part of the coil power requirement, in selecting one type of relay over a number of others.

Contact size is also linked to the magnitude of the contact load. The size should not be larger than is actually needed. The dictates of the load (arcing requirements, amplitude of currents, etc.) fix the contact size.

Engineers sometimes overspecify the contact size to "play it safe." However, the larger the contact, the greater the amount of contact bounce. Thus, the overspecified contacts, which might suggest ruggedness and long life, are slower and actually less durable!

This overspecifying of the load may take on another form. Non-simultaneous requirements should not be written in specifications as if they applied simultaneously. Suppose separate relays are to be used in two distinct applications. In one of them, the load is 10 amps and will be switched only 1000 times. Another relay is being considered for use elsewhere to switch 0.5 amps for a million operation application.

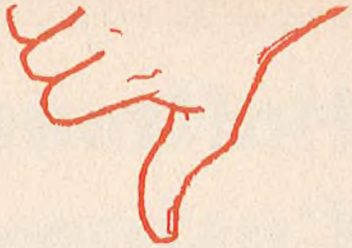
The engineer, thinking of cost-savings, may settle on one relay type (instead of two) and specify a 10-amp rating for one million operations. But these two functions will not occur simultaneously. The result is two overspecified relays and the ensuing higher cost and lower reliability.

The load environment also influences the contact selection. High-temperature ambients make the contacts' particle contaminants more active. The erosion of contacts, bearings and armature stops all increase markedly. The net result is a shorter relay life-span. Dielectric capabilities are also impaired.

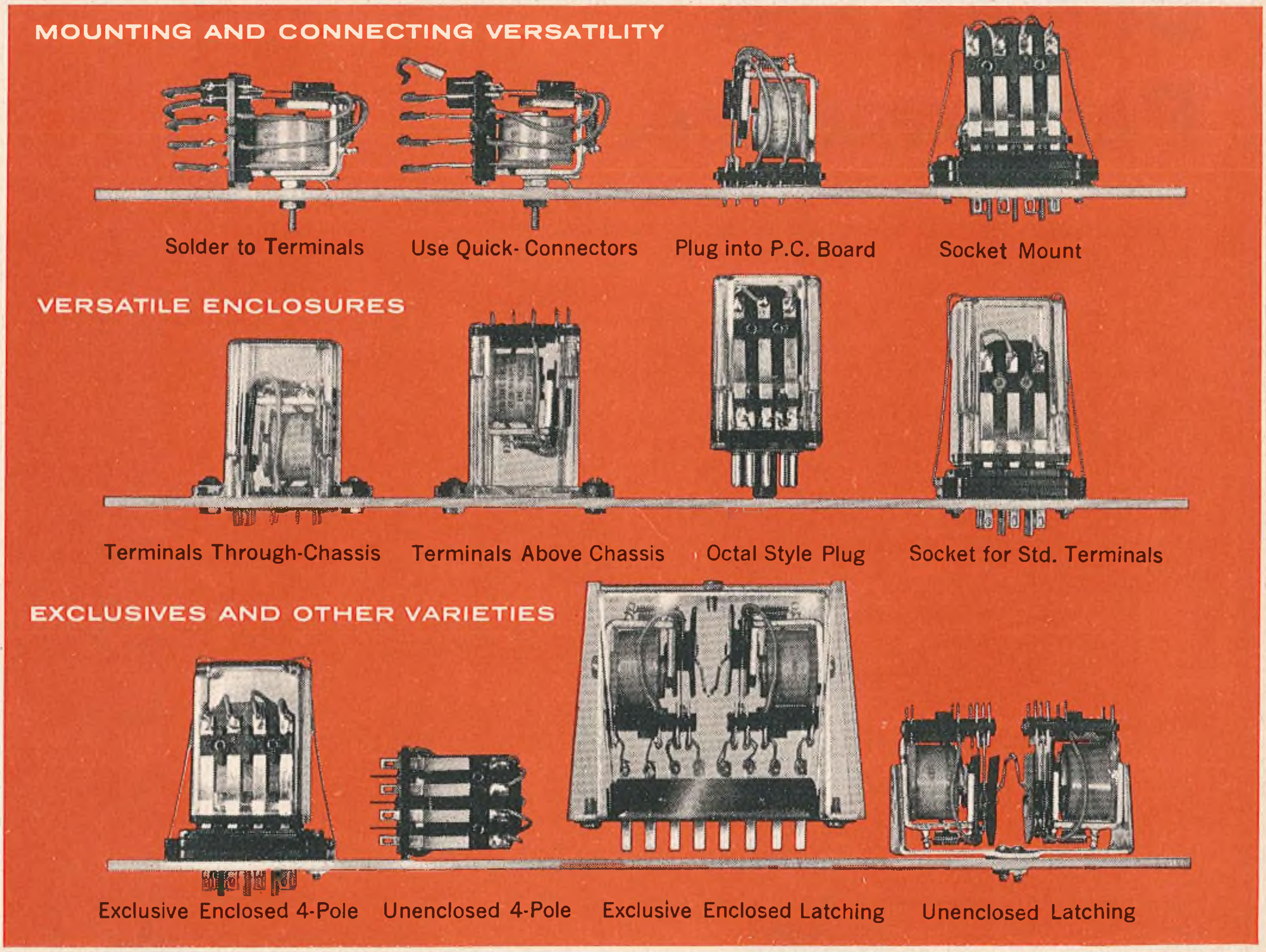
Contrary to popular belief, high humidity may greatly increase relay life. It is one reason nonhermetically sealed relays often last ten times as long as the same mechanism in a hermetic enclosure. A low-humidity environment tends to retard the lubricating action on the contacts.

Hermetic sealing excludes many undesirable environments and is mandatory for most military applications. It reduces the number of contact misses. However, relay life is usually prolonged if the same mechanism is open to reasonably clean, ordinary air. The use of a dust cover is more desirable than a hermetic enclosure for most industrial applications. ■ ■

down with "specials"!!



who needs 'em with Ohmite's big variety of *stock* GPR relays



All these and other physical variations are stocked for a variety of general purpose and specialized electrical functions such as plate circuit, thyratron, and indicator-light types. Both unenclosed and enclosed relays fit the same SOGPR socket. And don't forget, dual-purpose terminals (for soldering and quick-connectors) are standard on all unenclosed and most enclosed relays. Many models UL and CSA listed.

Contact Combinations—Up to 4PDT.

Contact Ratings—Two ratings: fine-silver contacts, gold-flashed, 5 amps resistive at 115 VAC or 32 VDC: silver-cadmium, 10 amps.

Coil Operating Voltage Range—Up to 230 VAC 60 cycles, or 110 VDC.

Coil Wattage—1.4 Watts DC: 1.6 watts (2.0 volt-amps) AC, except 2.4 watts (3.7 volt-amps) for 4-pole AC relays.

Insulation—Tested at 1500 VAC between terminals and ground.

Yours for the asking... Catalog 700 showing all Ohmite relay lines.

RHEOSTATS • POWER RESISTORS • PRECISION RESISTORS • VARIABLE TRANSFORMERS • RELAYS
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ON READER-SERVICE CARD CIRCLE 9

Hoffman Provides Customer-compatible Design and Performance.

Another Hoffman specialty is providing semiconductors of inherent reliability completely compatible with the manufacturer's needs.

An example of this is the Hoffman "N" series solar cell, an N/P, shallow diffused, photovoltaic device optimized for operation in the spectrum of space. These cells have been tested and qualified for radiation resistance in accordance with GSFC (NASA) Specification No. 63-106. An electrically conducting grid has been sintered to the active surface to reduce sheet resistance and thus increase conversion efficiency.

The following physical characteristics are manufacturing tolerances for all Hoffman Semiconductor Solar Cell Types.

1. Ohmic Contact
   A. Electrically continuous and mechanically bonded.
   B. Extends to .032 inches from the edge of the cell.
2. Grid Lines
   Total discontinuity of grid lines not to exceed .100 inches. Hoffman's photo masking technique assures mechanical tolerances.
3. Edge Chips
   .010" wide, .100" long not to exceed one such chip per top and one per bottom edge of cell.
4. Corner Chips
   .030" on the hypotenuse of the chip.
5. Weight

N120CG	.18 Gr.Avg.	N220CG	.36 Gr.Avg.
N210CG	.18 Gr.Avg.	N230CG	.54 Gr.Avg.

Typical Electrical Specifications

2 x 2^{cm} cell. . . . 430 mV @ 135 mA
1 x 2^{cm} cell. . . . 430 mV @ 65 mA

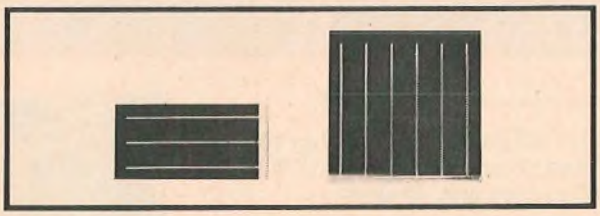
Test Temperature: 28°C ±2°C.

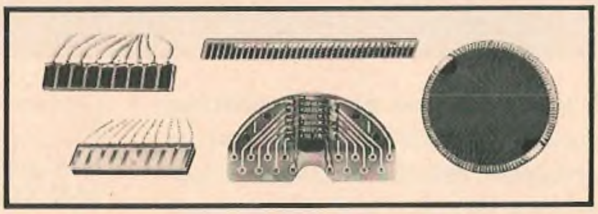
Hoffman solar cells are coated with silicon monoxide to render the active area anti-reflective to obtain maximum use of the sun's energy. These cells will withstand temperature excursions from —196°C to +200°C.

Standard environmental test: Each lot of cells is immersed in boiling DI water for periods up to one hour followed by a live steam test for a comparable period.

All of these advantages insure complete compatibility of products for Industrial uses.

Hoffman solid state photo-sensing devices are now being used for measuring, cloth cutting, sequence counting, liquid level gauging, data processing and other manufacturing functions requiring absolute accuracy.





Typical industrial compatible products: A shaft encoder is currently being produced to mechanical tolerances of ±.0005" and electrical parameters matched within 2%. Data processing readouts are being produced with an I_d of $3\mu A$ max. at 1.5 volts reverse bias. Other sensing elements are being made with active areas as small as .002" x .023" and as large as 2.5" x 1.0".

Hoffman

For further information regarding Hoffman Customer-Compatible products, write to:
HOFFMAN SEMICONDUCTOR DIVISION,
Hoffman Electronic Park, El Monte, California 91734.

SEMICONDUCTORS

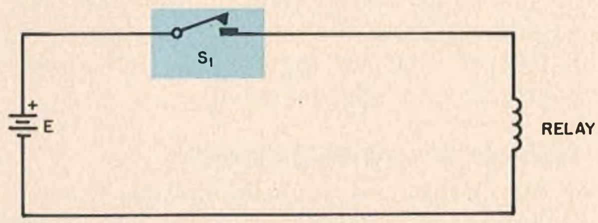
ON READER-SERVICE CARD CIRCLE 10

Curing interference in relay systems: Look to the source, then suppress

The erratic, broadband nature of switching transients and RFI makes them tough to handle. But a review of suppression methods shows that the problem is solved through design compromises.

THE PERFORMANCE of electronic systems is ever inhibited by transient and radio-frequency-interference (RFI) signals generated by switching circuits. These play havoc with the operation of the system and may even damage the components. Although many techniques are available to suppress the unwanted signals, each remedy involves a trade-off in some aspect of performance and a consideration of the size, weight and cost involved.

One type of suppression may mitigate the RFI, (which is sometimes referred to as electromagnetic interference, EMI) and do very little to retard the transients. Another suppressor may perform in the exact opposite manner. A third may reduce both RFI and transients, but with an accompanying decrease in switching speed.



1. **Simplified relay schematic,** showing a solenoid actuated by a toggle switch. The prime source of the RFI and transients is the switching of energy in the system.

Sam J. Burruano, Consultant
Burruano Associates, Inc.
Harrington Park, N. J.

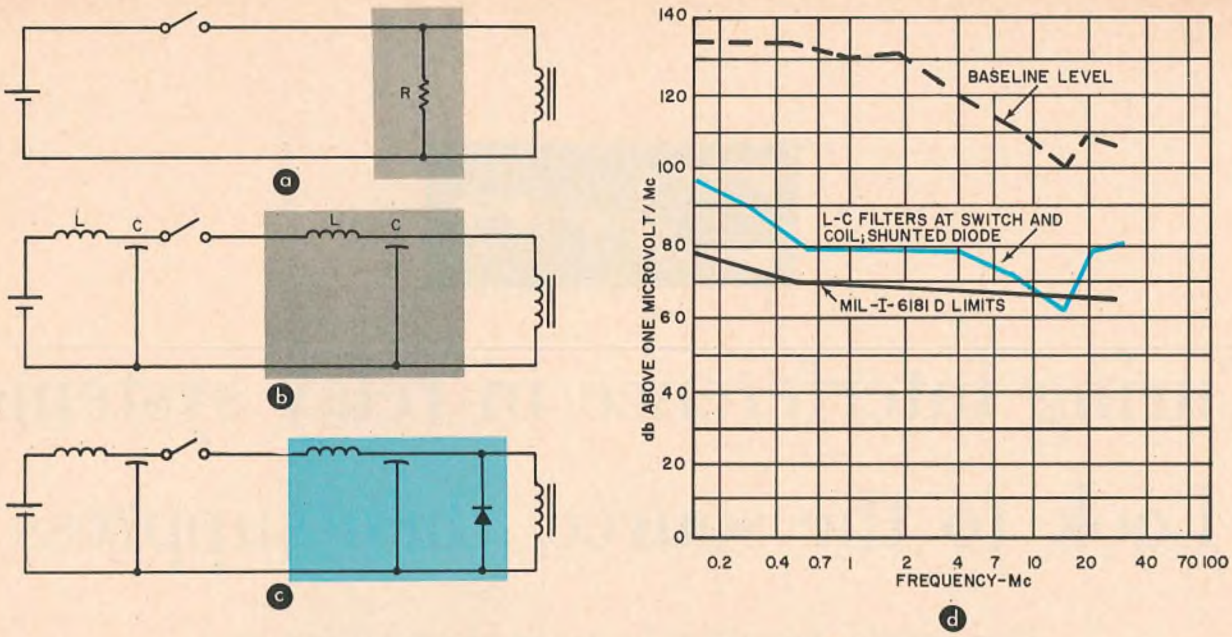
When confronted with a suppression problem then, the designer must, of necessity, choose a suppression network. His selection criteria should consider these features:

- The voltage and current levels involved.
- The suppressor's reliability.
- How well it attenuates RFI.
- How it affects noise levels.
- The suppressor's size and weight.
- How well it handles arcs and surges.
- Its influence on the switching functions, such as operate or release time.

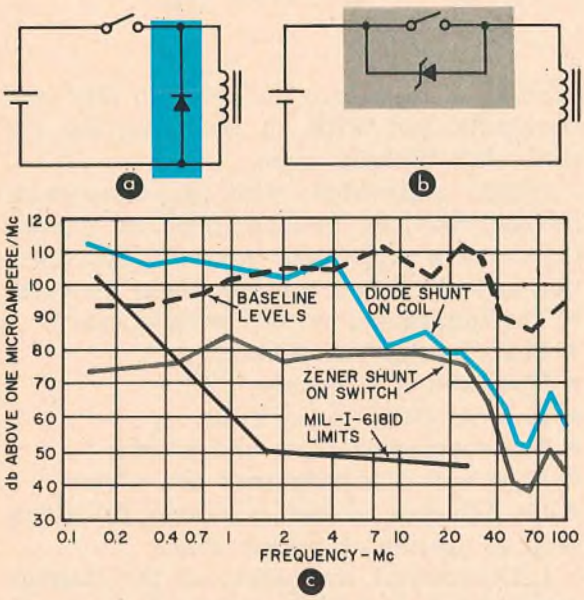
Let's examine the source of the troublesome signals and then see how they can be suppressed successfully.

Energy transfer generates RFI

The prime source of the RFI and other transients is the switching of energy in the system. A schematic of a relay solenoid actuated by a toggle switch (S) appears in Fig. 1. In closing, the switch exhibits bounce characteristics that cause the momentary de-energizing of the relay solenoid. This subsequently produces momentary oscillatory transients and switch-bounce current breaking. The latter effect is reflected as the arcing of the contacts during bounce. When S is opened, the stored energy ($1/2LI^2$) is re-



2. **Transients and switching arcs are suppressed** by the common coil-shunt resistor (a), brute-force L-section filters (b) and L-section-diode combination (c) methods. Waveforms of these methods (d) demonstrate that they fail to meet the specifications of RFI standard MIL-I-6181D.



3. **Coil transients are effectively suppressed** by a shunt diode (a), but the RFI levels remain high. A zener diode placed across the switch is more effective, as shown in the waveform of the conducted RFI levels (c).

turned to the circuit and dissipated as a loss of power in the relay core and in the switch arcing. In addition the collapsing magnetic field generates a transient or counter emf voltage expressed as

$$E = -L \frac{di}{dt} \text{ volts} \qquad (1)$$

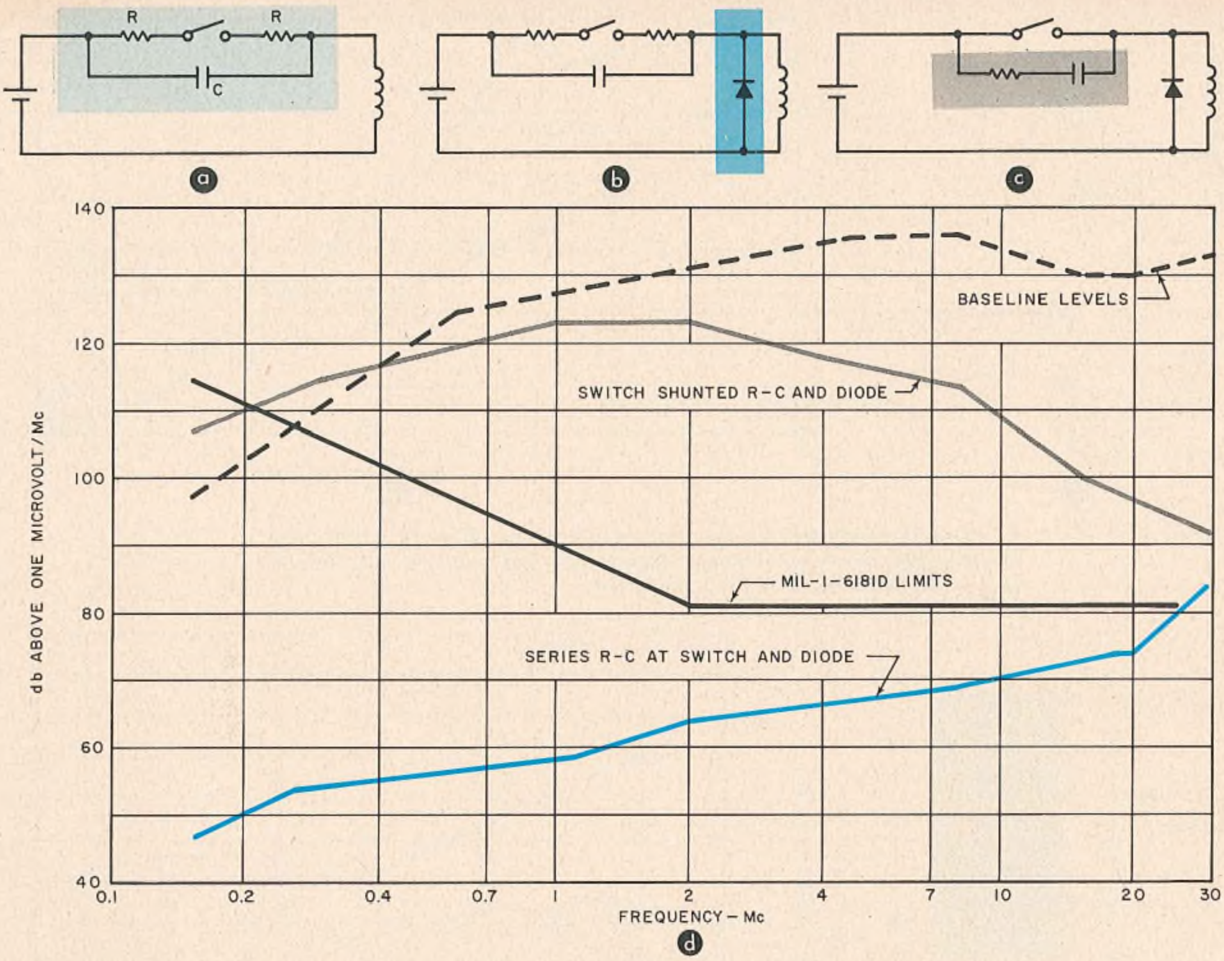
As S opens, an arc appears, due to the breaking current. This arc is quenched as the switch further opens. The arc is restruck as the relay voltage transient increases, due to the changes in coil current. The process continues until the coil current reaches zero. It may be noted in an oscilloscope trace of the coil voltage waveform that the transients do not exhibit a normal exponential rise. They take the form of a series of sawtooth waveforms and are a reflection of the switch arcing condition.

The general description of the RFI that is generated is that it is broadband in frequency and impulsive in nature. It may be conducted back into the power supply, coupled into the ac power circuits or radiated from the line, the solenoid and the switch. When the current abruptly decreases after the switch opens, the changing magnetic field resulting from the varying current is capable of inducing large impulse currents into adjacent wiring sections. The low impedance nature of this field may enable it to deeply penetrate even shielded wiring.[1]

Evolution of suppression methods

The techniques for suppressing solenoid transients and switch arcs have been developed over the years. An early RFI study showed that the coil transient could be greatly reduced by a coil shunting resistor (Fig. 2a). The magnitude of this shunt resistor is kept within four times the coil resistance

1. Techniques for measuring RFI levels may be found in military specifications such as Mil-I-6181D, Mil-I-16910C and Mil-I-11748B.



4. **RC network suppresses the RFI** but does not reduce the transients (a). Addition of diode (b) further improves the RFI suppression. Shunt-RC network combats the switch transients but does not limit the RFI (c). The effectiveness of the series-RC-network-diode combination is exhibited in the RFI level waveforms (d).

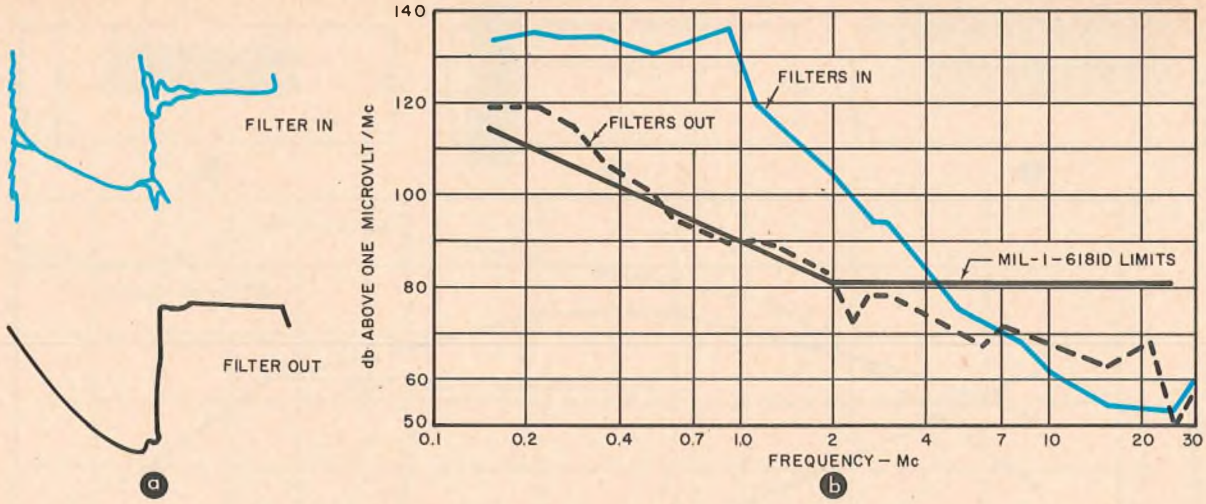
value. This method, however, has the inherent disadvantage of additional power dissipation. Moreover it is very basic and can only meet a non-stringent RFI suppression need.

The typical brute-force method of using L-section filters to suppress coil- and switch-generated RFI is shown in Fig. 2b. This network, while effectively suppressing the RFI, does not solve the problem of the coil-generated transients. It has the added disadvantage of weight and size.

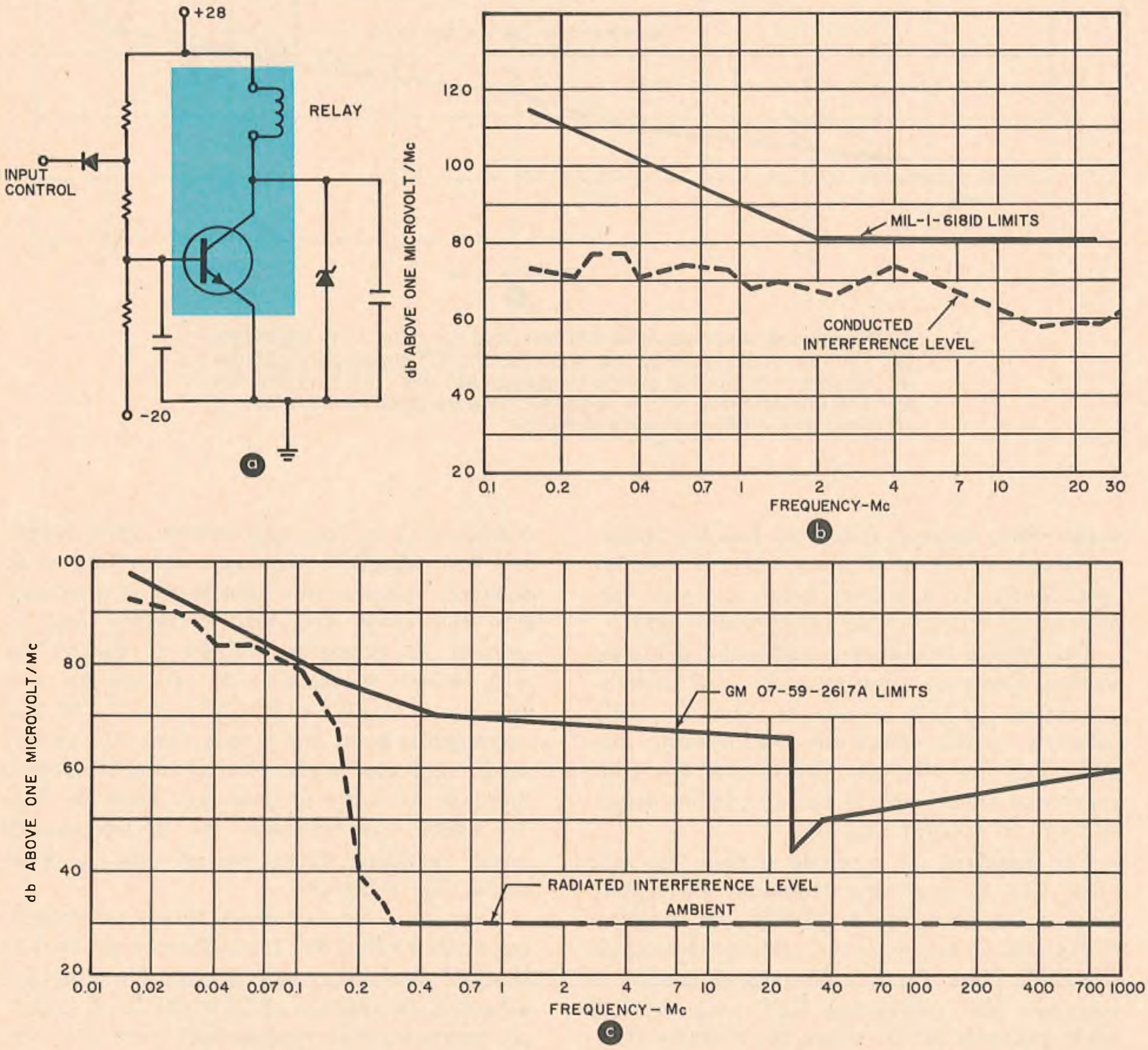
The addition of a diode across the coil (Fig. 2c), to limit the transient amplitude, reduces the transient markedly, but, because of its placement, does not sufficiently reduce the RFI. Thus, further filtering is needed to suppress the conducted RFI and shielded wiring is required to reduce the radiated RFI. Data taken (Fig. 2d) show that without shielded wiring for this network configuration, the radiated RFI levels exceed Mil-I-6181D limits.

The use of a diode alone to limit the coil transient (Fig. 3a) has become quite standard for reliability purposes. Its effect is to dissipate quickly the inductor-stored energy into the diode and load circuitry and to present no excessive voltage at the switch with which to develop or sustain an arc. However, the RFI-suppression quality of this approach is poor, and it may cause the generated, conducted and radiated interference to increase at some frequencies. Data in Fig. 3c show the increase in RFI-conducted levels resulting from use of just a diode across the relay coil.

The use of a zener diode across the actuating switch (Fig. 3b) is a superior advance to that of the diode coil shunt. This method achieved an average of 20 to 30-db of radiated magnetic-field suppression over the frequency range 0.150 Mc to 100 Mc. An additional plot of the data for the zener suppression is included in Fig. 3c. It clearly shows a more effective suppression of the conducted RFI. However, this method, while a great



5. **Current waveforms** of stepping switch-coil (a) show that transistor-driven solenoids have cleaner waveforms and reduced interference levels when filters are not employed (b).



6. **Typical transistor relay driver** (a) is logic-operated. Conducted interference level (b) at the high side of the coil shows that even without an rf filter, the RFI level is within specifications. Radiated interference level (c) was also within specs, although shielded wiring was not used.

improvement over the more conventional approaches described earlier, does not provide the total RFI suppression normally required in today's specifications.

A series-shunt RC network (Fig. 4a) that effectively suppressed the switch-generated RFI was then developed. While this network is not intended to reduce the coil transients to supply-line voltage levels, it does resolve the RFI part of the problem. In addition its use in this combination is current-limited, because of the resistor voltage drop and the power dissipation requirements. However, it is suitable only for relays drawing less than 100 ma of current. It is also attractive because the series-RC network has been reduced to an integrated circuit that approximates a postage stamp in size.

The addition of the diode across the relay coil (Fig. 4b) again improves the RFI suppression and increases circuit reliability by protecting the network capacitor from relay transient levels. The simple shunt-RC network (Fig. 4c), while helpful in combating switch transients, is ineffective in suppressing the generated, broadband RFI, even when placed in combination with the relay-shunt diode. A comparison of the shunt-RC-diode combination with the series-RC-diode combination to suppress conducted RFI appears in Fig. 4d. Note the improvement for the series network configuration—60 db at 150 Kc.

Transistors can suppress RFI

The use of transistor circuits for switching has led to a more intensive investigation of their RFI suppression possibilities when the transistors are used as solenoid drivers.[2] In 1962 the author participated in RFI suppression for Avco's SEK 17-4 R/v checkout equipment. Within the equipment, 18 solenoid-actuated stepping switches and 11 relays formed the basic broadband RFI problem. No special deviations were granted, or requested, for conducted and radiated RFI for transients over the frequency range 30 cps to 10 Gc.

In the initial design of this equipment, L-section, low-pass RF filters were used between the 28-volt supply and the stepping switch solenoid to reduce to low levels any interference conducted back to the power supply. The stepping-switch circuits used as the solenoid driver were logic-operated and employed a transistor-SCR switching combination. The predictable transients generated by these filters are noted in the comparison of the solenoid current waveforms (both with and without filters) in Fig. 5a. The difference in conducted RFI levels under the same conditions, taken at the coil high side, is shown in Fig. 5b. Note the clean current waveform and the reduced interference without the filter. In addition, radiated interference levels from this source, taken on an open breadboard basis over the frequency range 10 Kc-1000 Mc, were 20 to 50 db below specification limits over the major portion of the range.

The typical relay driver used is shown in Fig. 6a and was logic-operated. The zener diode is used to protect the transistor against the coil transients, and the capacitors are used for wave-shaping. Figures 6b and 6c show the high-side coil-conducted and radiated interference levels, respectively, for this configuration without the use of an RF filter.

Final tests for the equipment breadboard showed that radiated and conducted levels over applicable portions of the band (30 cps-1000 Mc) were well within the specification limits of GM-07-59-2617A, with one exception. At 300 Mc the radiated level was 6-db above limits. This was attributed to the ac ON toggle switch. The test results were obtained without either outside shielding or the use of a single RF filter for any dc or ac power lines.

Different suppressors often combined

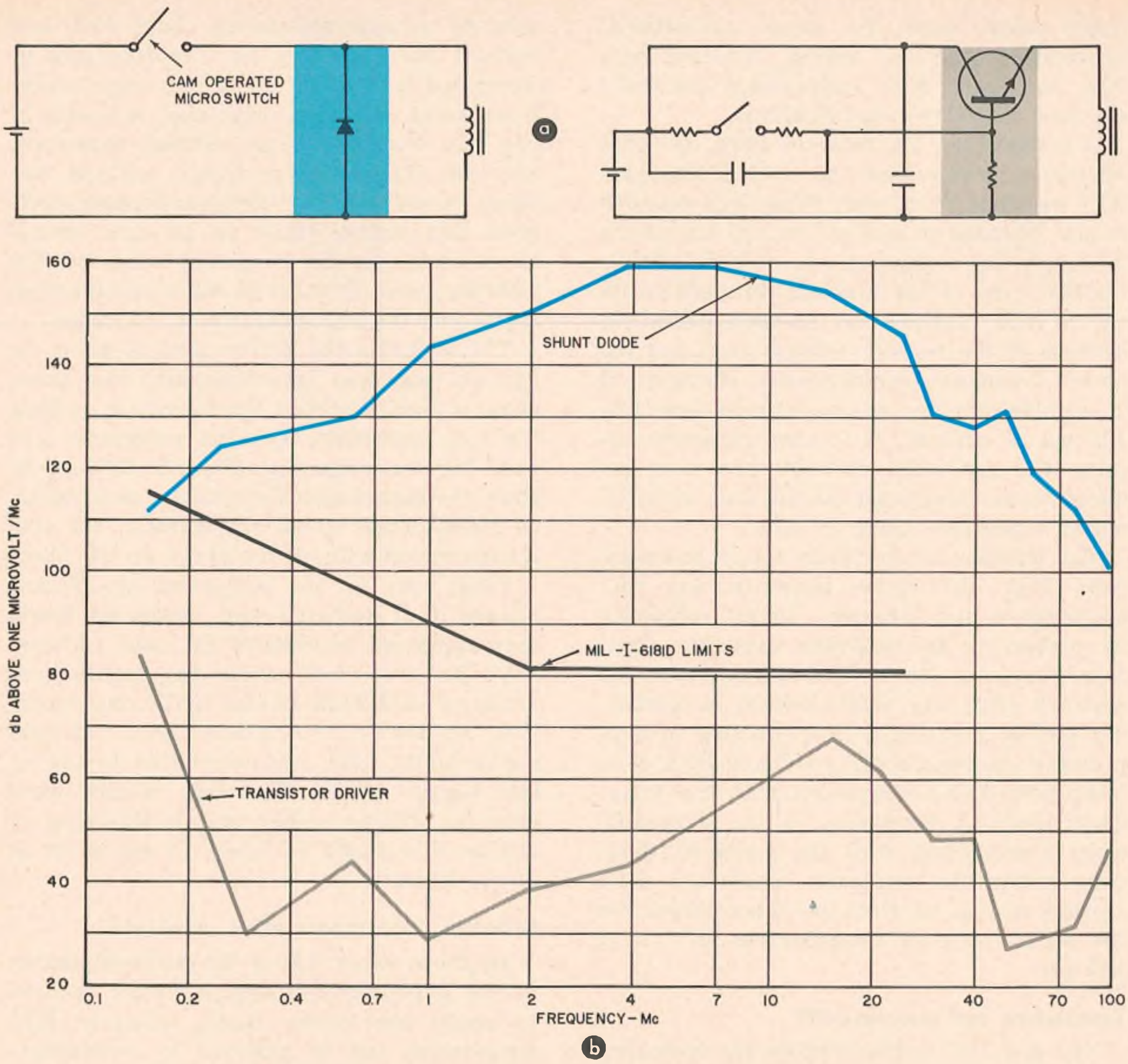
In those cases where the solenoid driver is not logic-operated and a switch is used to apply the driver input, effective RFI suppression can be achieved by a combination of methods. The series RC network (integrated circuit) can be put to use as part of the switch-driver combination to make an RFI-free circuit.[3]

The test circuits used appear in Fig. 7a. A microswitch, actuated by a cam, energizes the relay directly in one case, and a series-RC-network-suppressed switch, controlling a transistor driver, does the job in the other. The comparative results of conducted RFI for the two configurations is shown in Fig. 7b. Note the marked differences in the levels.

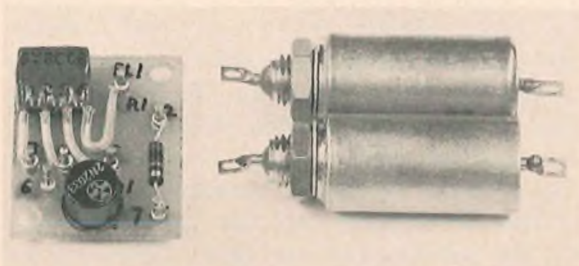
The advantages of the series-RC and driver combination are many. The current through the microswitch for the switch-relay circuit is 0.5 amp; for the switch-driver circuit, the current is only about 5.0 ma. In the case of the simple cam-operated microswitch, two low-pass RF filters (LC type) would be required to suppress the switch and relay broadband RFI. In the other networks, no filters are required, other than the RC

2. Pecota's Study at Sperry Gyroscope, IRE Convention Record, Vol. 6, Part 8, 1958.

3. As reported by Busch and Albin (surprs) at the 1965 Relay Conference, Stillwater, Okla.



7. **Shunt-diode suppressor** (top) falls far short of combination transistor driver-series-RC-network suppressor (bottom) in reducing interference in non-logic-operated solenoids (a). Test results of conducted RFI levels (b) show the marked superiority of the combination suppressor method.



Run interference into the ground . . . Transistor-driver suppressor network (left) is more effective then heavy and bulky, conventional brute-force filter suppressor (right).

network shown for the switch. This network (described earlier) consists of two 30-ohm resistors, which also provide the proper bias for transistor saturation, and a 0.47 μf capacitor element.

The other advantages of this design are size and weight. A comparison of the sizes of the filters and the switch-transistor driver makes clear the substantial improvement in the driver case. This underlines the fact that the engineer need not use bulky suppression networks for limiting interference in small solid-state systems (see photograph).

All of the methods used to suppress RFI in relays extend the release, or drop-out, time of the relays. A method for calculating relay drop-out time is given by Donohoo (see bibliography). In the transistor driver circuit approach, both zener and conventional diodes placed across the coil will reduce the drop-out time. This method is basically similar to the use of back-to-back zener diodes for relay-transient suppression (as shown by

Jordan and others). The problem with the use of the single diode is that its action continues the flow of current through the coil and prevents drop-out from occurring immediately after the circuit's supply energy has been cut off. The zener diode placed back-to-back with the ordinary diode precludes this holding action.

In virtually all of the methods to suppress interference, a key point in design is involved: The most effective suppression is obtained when the network is placed at the source of the interference, rather than at a so-called "critical" output point. This results in improved system reliability and the greatest economy in size, weight and cost. ■ ■

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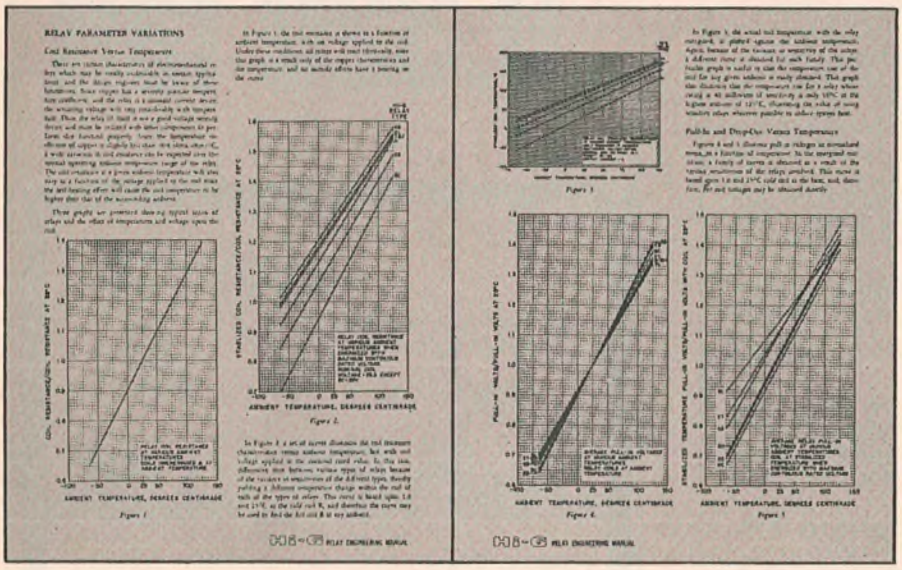

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Standardized relay terminology simplifies selection and aids usage

Plagued by the lack of uniformity in relay nomenclature? Then use these performance-oriented standards. They facilitate understanding and may even optimize design.†

AT FIRST GLANCE, no device seems basically simpler than a relay. One would expect, therefore, that standardization of terminology would be easy. But prior to relatively recent publications by NARM and ASA*—and similar groups and trade associations—little or no progress was made in developing a common language.

One reason for this is that the many and varied industries that rely on relays use different technical language. Each has over the years, by usage and practice peculiar to its own operation, established relay designations differing from those in other industries.

In comparing relays, engineers may become frustrated by the lack of uniform terminology. One catalog or specification sheet may describe a relay's attributes with such terms as pull-in, release, pickup time, and so on. Another will feature pickup, dropout and operate time as the corresponding equivalents.

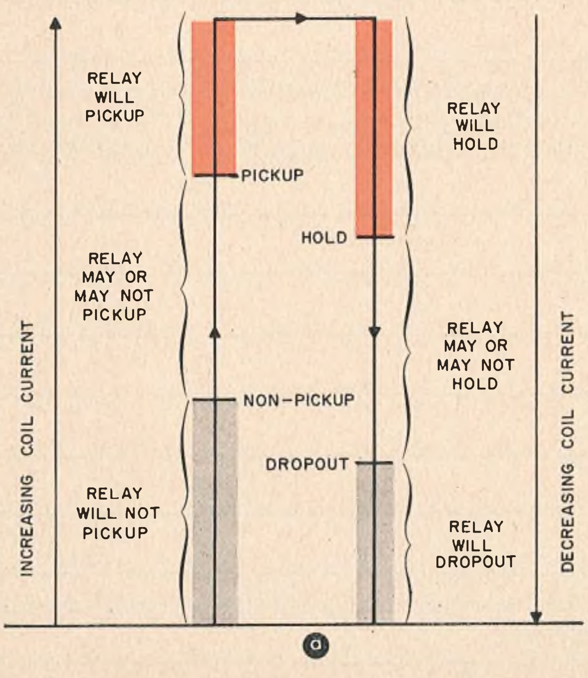
To alleviate this problem, a broad-based set of standards is being established by NARM.

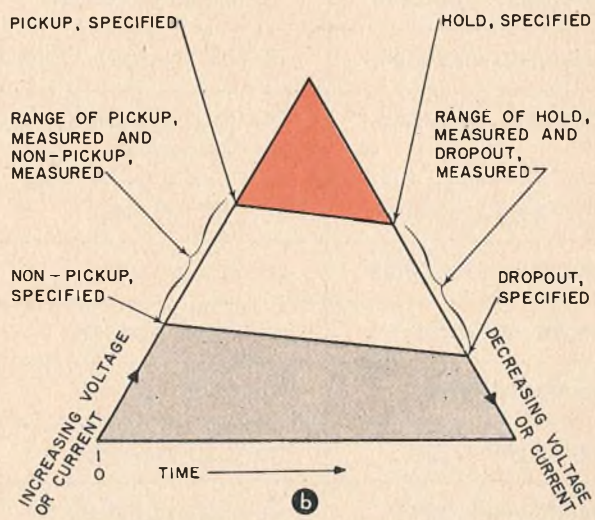
From these standards, let's consider the ones that are most important for design engineers (see Table 1). Nomenclature on the physical makeup of the relay, materials, etc., has been omitted. Similarly, let's look at the preferred terminology as it applies to applications (Table 2).

The next step is to see how the preferred terminology is used in practice. The function

* The National Association of Relay Manufacturers (NARM) in a joint effort with the American Standards Association (ASA).

†This article is a condensed version of material extracted from Sect. II of the forthcoming NARM Engineers Relay Handbook.





1. **Relay performance terminology** is based on the excitation state of the coil (a). Note that three distinct regions establish the four boundary conditions of non-pickup, pickup, hold and dropout (b).

Table 1. Definitions of relay terminology

Bridging	The normal make-before-break action of a make-break contact combination. A momentary coming-together of adjacent contacts (in stepping switches). Also, "Abnormal Bridging": The undesired closing of open contacts caused by a metallic bridge or protrusion developed by arcing.
Chatter	The undesirable vibration of the relay armature and/or contacts caused by uncompensated or inadequate ac performance, or external shock and vibration.
Contact bounce	The intermittent, internally induced opening of closed contacts or closing of open contacts caused by the vibration of parts during relay operation or release. Also may be the result of external vibration or shock.
Dropout, measured	The maximum current or voltage at which the relay restores to its unoperated position.
Dropout, specified	The specified maximum current or voltage at which the relay must restore to its unoperated position.
Functioning time	The time between energization and pickup or between de-energization and dropout.
Hold, measured	The minimum current or voltage at which the armature does not move perceptibly from its fully operated position after having been energized electrically.
Hold, specified	The current or voltage at or above which the armature is required not to move perceptibly from its fully operated position, after having been energized electrically.
Lock-up relay	A relay that is capable of remaining in the fully operated position after the energizing pulse has been terminated.
Maximum dropout	(see Hold, specified)
Maximum pickup	(see Pickup, specified)
Minimum dropout	(see Dropout, specified)
Minimum pickup	(see Non-pickup, specified)
Non-dropout, measured	(see Hold, measured)
Non-dropout, specified	(see Hold, specified)
Non-operate, measured	(see Non-pickup, measured)
Non-pickup, measured	The maximum current or voltage at which a relay does not operate any contacts or only specified contacts.
Non-pickup, specified	The current or voltage at or below which a relay is required to not operate any contacts or only certain specified contacts.
Non-release, measured	(see Hold, measured)
Non-release, specified	(see Hold, specified)
Operate, measured	(see Pickup, measured)
Operate, specified	(see Pickup, specified)
Operate value, just	(see Pickup, measured)
Operate value, must	(see Pickup, specified)
Pickup, measured	The current or voltage at or below which the armature is seated against the coil core by assuming its fully operated position or a specified position.

Pickup, specified	The specified current or voltage at which the armature must assume its fully operated position or a specified position.
Pull-in value, measured	(see Pickup, measured)
Pull-in value, specified	(see Pickup, specified)
Pull-on value, measured	(see Pickup, measured)
Pull-on value, specified	(see Pickup, specified)
Rating, short-time	The highest value of current or voltage that the relay can stand without injury for specified short intervals. For ac circuits, the rms total value, including the dc component.
Release, measured	(see Dropout, measured)
Release, specified	(see Dropout, specified)
Time, actuation	The time at which a specified contact functions.
Time, actuation, effective	The sum of the initial actuation time and the contact-bounce intervals following such actuation.
Time, actuation, initial	The time of the first closing of a previously open contact or the first opening of a previously closed contact.
Time, bunching	The time during which all three contacts of a bridging contact combination are electrically connected during the armature stroke.
Time, contact bounce	The interval from initial actuation of a contact to the end of the bounce.
Time, drop-away	(see Time, release)
Time, dropout	(see Time, release)
Time, operate	The interval from coil energization to the functioning time of the last contact to function. It does not include contact bounce time.
Time, pickup	(see Time, operate)
Time, pull-in	(see Time, operate)
Time, release	The interval from coil de-energization to the functioning time of the last contact to function. It does not include contact bounce.
Time, stagger	The interval between the actuation of any two contact sets.
Time, transfer	The interval between opening the closed contact and closing the open contact of a break-make contact set.

of the coil and the reaction of the contacts is presented in Fig. 1. Standard terms describe the correct amount of coil power to achieve the relay action.

Figs. 2 and 3 show the actions of the relay and the proper terms to use in describing its actions (functioning).

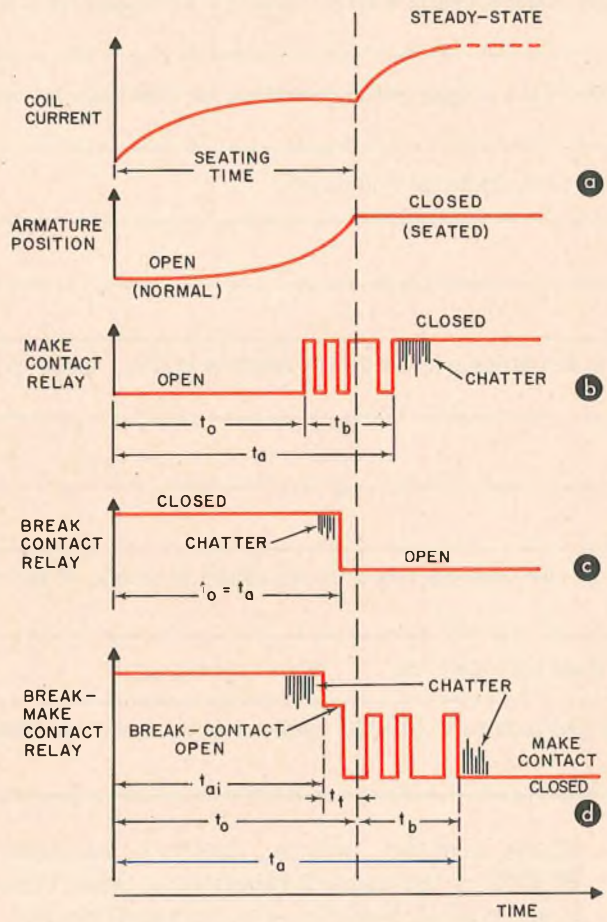
In designs where operating times are most critical, the traces on Figs. 2 and 3 can be used to establish timing requirements. Note that the portions devoted to transient effects (contact bounce, chatter)—consume 10-20% of the over-all functioning time. This is not typical, however. The transient portion may even consume as much time as the functioning period in some common relay types. The drawings themselves are simulated (near-ideal), rather than actual. This was done to facilitate the understanding of the switching action.

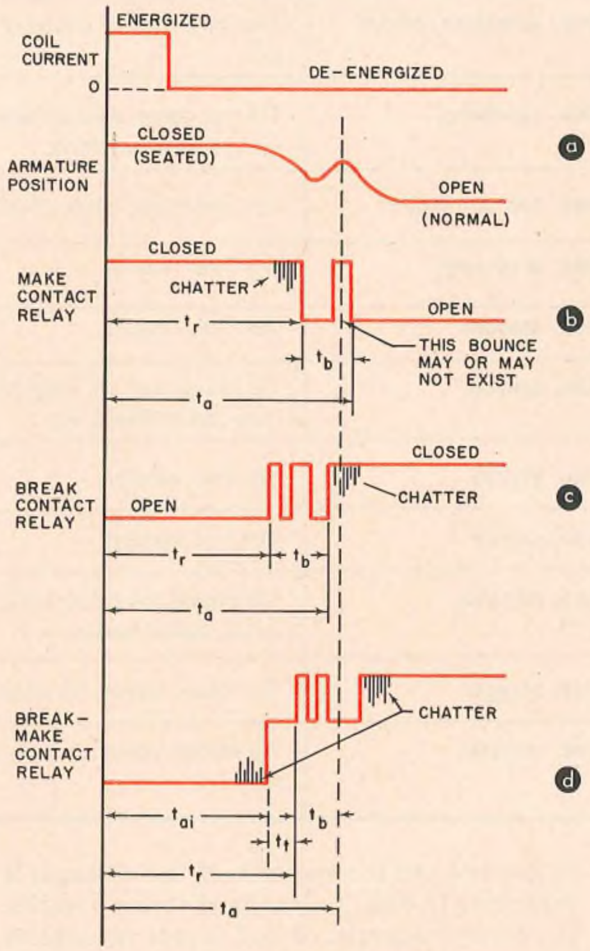
(Note also that in Fig. 2a, on energization, the coil current varies as a function of

(text copntinued on p 50)

Table 2. Relay performance terminology

Preferred	Not preferred
Dropout, measured	Release, measured
Dropout, specified	Release, specified Minimum dropout
Hold, measured	Non-dropout, measured Non-release, measured
Hold, specified	Maximum dropout Non-dropout, specified Non-release, specified
Non-pickup, measured	Non-operate, measured
Non-pickup, specified	Minimum pickup
Pickup, measured	Operate, measured Pull-In (or Pull-On) value, measured Operate value, just
Pickup, specified	Operate, specified Pull-In (or Pull-On) value, specified Operate value, must Maximum pickup
Time, operate	Time, pickup (or pull-in)
Time, release	Time, dropout (or drop away)





NOTE: 1. t_a = ACTUATION TIME
2. t_b = BOUNCE TIME
3. t_o = OPERATE TIME
4. t_r = RELEASE TIME
5. t_t = TRANSFER TIME
6. t_{ai} = INITIAL ACTUATION TIME
7. CHATTER ALSO KNOWN AS "GRASS" & "DYNAMIC RESISTANCE"

2. **Relay pickup function displayed with time as a base.** Contact change is shown as a function of coil current and armature position (a). Note that armature position as well as coil impedance determines current. Transient phenomena for MAKE (b) and BREAK (c) contacts and combination MAKE and BREAK contacts in one relay (d) are depicted.

3. **Time traces of the relay dropout function.** Coil current and armature position (a), MAKE contact (b), BREAK contact (c) and combined MAKE and BREAK contacts (d) are plotted as a function of elapsed time after the coil current has dropped to zero. Note that contact current flows as long as contacts are not open, independent of coil state.

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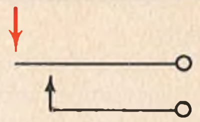
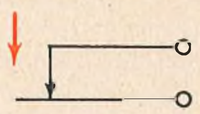
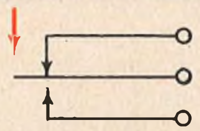
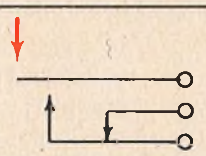
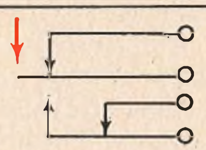
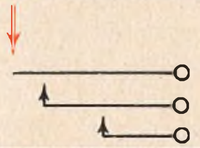
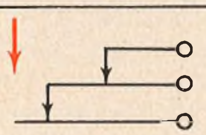
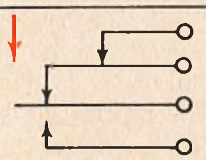
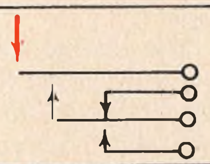
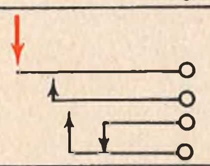
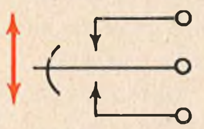
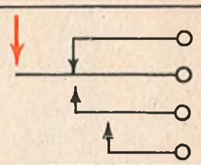
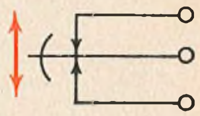
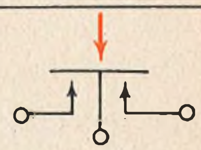
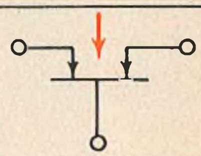
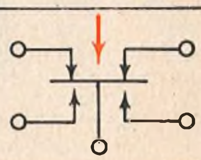
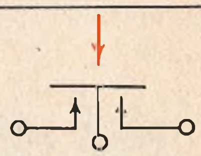
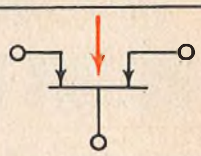
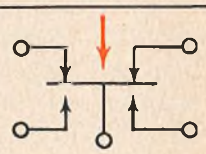
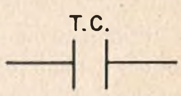
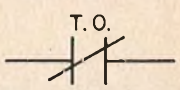
A	MAKE or SPSTNO	
B	Break or SPSTNC	
C	Break, Make, or SPDT (B-M), or transfer	
D	Make, Break or Make-Before-Break, or SPDT (M-B), or "Continuity transfer"	
E	Break, Make, Break, or Break-Make-Before-Break, or SPDT (B-M-B)	
F	Make, Make SPST (M-M)	
G	Break, Break or SPST (B-B)	
H	Break, Break, Make, or SPST (B-B-M)	
I	Make, Break, Make, or SPST (M-B-M)	
J	Make, Make, Break, or SPST (M-M-B)	
K	Single pole, Double throw Center off, or SPDTNO	

Form	Description	Symbol
L	Break, Make, Make, or SPST (B-M-M)	
M	Single pole, Double throw, Closed Neutral, (This is peculiar to Spec. MIL-R-5757)	
U	Double make, Contact on Arm. SP ST NO DM	
V	Double break, Contact on Arm. SP ST NC DB	
W	Double break, Double make, Contact on Arm. ST DT NC-NO (DB-DM)	
X	Double make or SP ST NO DM	
Y	Double break or SP ST NC DB	
Z	Double break, Double make SP DT NC-NO (DB-DM)	

Special A	Timed close	
Special B	Timed open	

4. **Contact nomenclature and symbols** for the various primary relay types. Heavy, colored arrow indicates direction of operation.

(continued from p 47)
both circuit impedances and the armature position and speed. The current for each contact case is based upon non-inductive loads.

In the case of de-energization (Fig. 3a) the coil current is affected by arcing and external circuit transients, as well as by circuit impedances. Here, too, the performance of three distinct types of contacts and their respective transient phenomena are demonstrated.

The contact-spring combinations available on a relay are defined in standard terms of the number of poles, number of throws, normal position (open or closed contacts) and the sequence of make and break. To simplify their designation, letter symbols have been applied in Fig. 4 to the most common types of sets. These representations are useful in relay selection and design. Engineers are likely to come across them in catalogs, specification sheets, technical articles, schematic diagrams and, occasionally, on the relay can itself.

Any treatment dealing with the standardization of relay terminology would be incomplete, unless some mention were made of classification. The proper identification of a relay may hinge on this. Moreover, a widely-embraced set of classification standards helps engineers to select the best relay for the job.

Relays may be classified by the electrical input they require. Thus dc and ac types would constitute the main areas. Dc types should be sub-classified according to whether the relay is neutral (non-polarized) or polarized. The ac specification should also include a mention of the frequency range in question.

The contact requirements (the load) may also establish a set of classification standards. The most prevalent and useful terms here would be dc, ac (including frequency range), power (heavy duty), radio-frequency and coaxial.

The categorizing of relays by duty is also desirable. With this means of classification, a statement containing quantitative information about contact capability, the number of contacts, their rating and the number of operations in their useful life will be useful. These items are preferable to such descriptions as light, medium and heavy duty. As an adjunct to this mode of classification, such terms as commercial, industrial, military, etc., may be used to further delineate the relay's purpose.

Relays may also be classified by performance and/or industrial application. The article on page 57 of this report covers this aspect in detail. ■ ■

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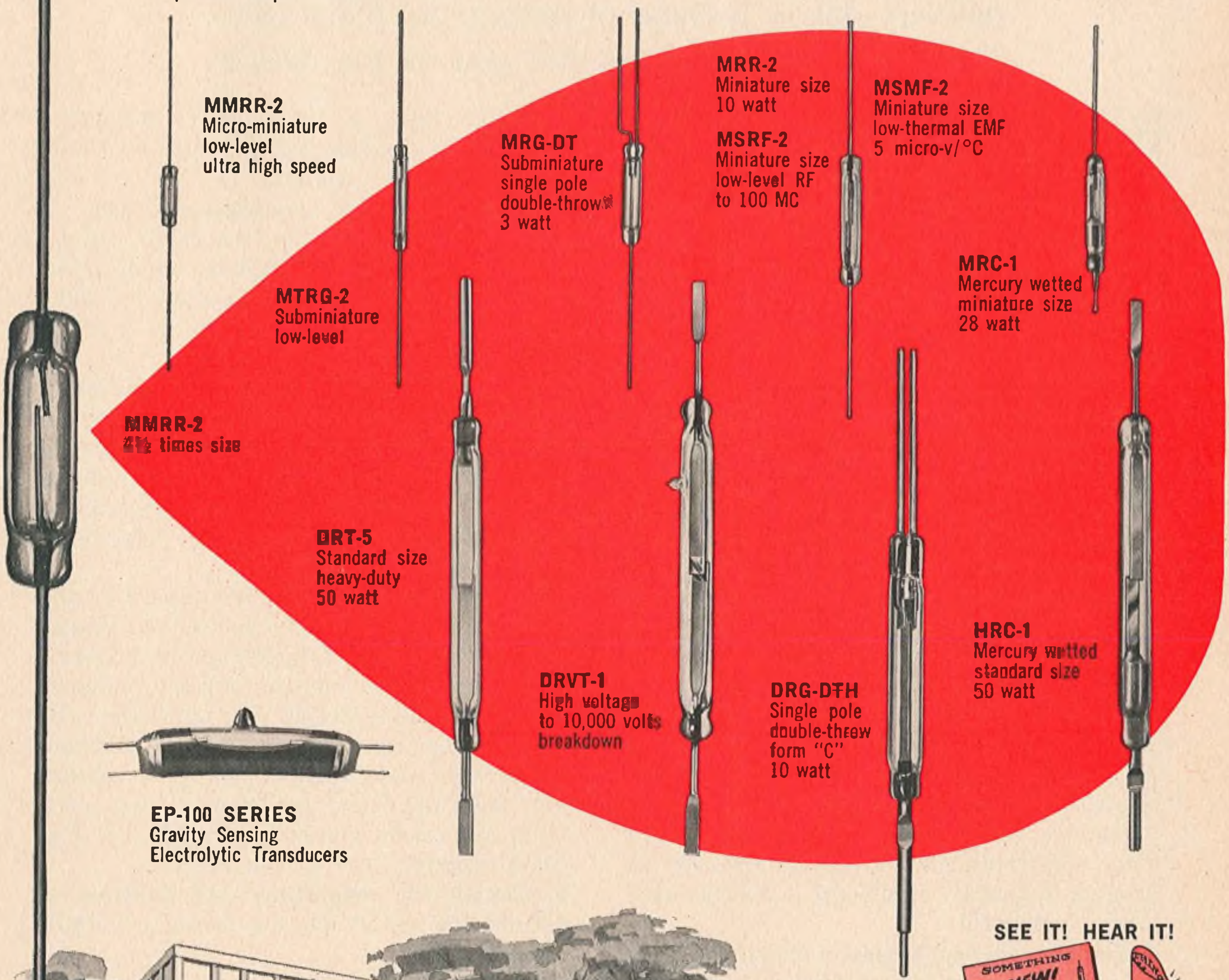

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ON READER-SERVICE CARD CIRCLE 14

Pinpoint your relay needs by writing complete specifications

Don't risk excessive costs, poor performance, or delivery delays because of incomplete relay specs. Here's a checklist to remind you of the details.

BEFORE WRITING a relay specification, establish a checklist that is even more comprehensive than the final specification itself. This will insure that the relay is neither overspecified nor underspecified. And it will help you and the supplier to settle on the best relay for the job.

The suggestions that follow can help you draw up such a checklist. Remember that they are broad reminders, though. You may have to modify them to suit your needs. Moreover, the suggestions don't mention such commercial factors as quantities, delivery, etc. These depend on your particular needs. Once you have drawn up your checklist, refer to it and proceed to write your relay specification.

Here are prime factors to consider in drawing up any checklist:

1. Establish the broad class of application to identify what industrial, commercial and military standards apply, as well as the types of relays that meet the general requirements. A partial list of application categories for the checklist includes military, commercial, industrial, automotive, communication and home entertainment. Sub-categories such as ground, vehicular, shipboard, airborne, etc., might be helpful.

2. Describe the equipment in which the relay is to be used. Alert the supplier to the safety, operational and environmental requirements that generally apply.

3. Describe the specific function of the relay. For example: "The relay shall respond to a 120-volt ac ON-OFF signal. It will switch a 120-volt ac circuit from a 6-watt tungsten pilot light to a 1/2-hp, capacitor-start motor. The pilot light is connected to normally-closed (NC) contacts and the motor to normally-open (NO) contacts."

4. Refer to general specifications—such as MIL and NASA—but use only these sections that pertain to your particular application. General specifications often contain multiple choices which must be selected by a detail specification.

5. Consider the environmental conditions. Include high and low temperature, temperature cycling, humidity, salt spray, sand or dust, oil, sulfur fumes, road-conditioning chemicals, vibration, shock, etc. These can be further classified as operational, non-operational, static, dynamic, etc.

Although ambient air temperature and velocity are generally recognized as important, three other associated factors should be considered: (a) mounting surface temperature, mass and heat-sink characteristics; (b) temperature, size and distance of adjacent bodies that could radiate heat to or absorb heat from the relay; (c) temperature, proximity and orientation of adjacent bodies that could transfer heat by convection.

6. Specify the magnitude and duration of permissible contact chatter during a shock or vibration test.

Don't underestimate physical considerations. At times handling or manufacturing procedures in the relay user's plant call for protective mounting or a protective enclosure. In the soldering of components adjacent to the relay, for instance, solder flux or flux vapors may contaminate the relay. A relay enclosure can prevent this. Similarly, connected or adjacent wires, dangling into the open relay, may cause enough damage to warrant an enclosure. Watch out for oil,

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This article represents a condensed version of material extracted from Section IV of the forthcoming NARM Engineers Relay Handbook.

Sample relay specifications

(1) Class of application
A. Military B. Commercial C. Industrial D. Electronic E. Communications F. Commercial airborne G. Other

(2) Description of equipment in which relay is used

(3) Relay function

(4) Applicable documents
A. Military specifications
(1) MIL-R-5757D (2) MIL-R-6106E (3) MIL-STD-202 (4) Other
B. Underwriters Laboratories (UL)
C. Canadian Standards Association (CSA)
D. National Electrical Manufacturers Association (NEMA)
E. Electronic Industries Association (EIA)
F. Quality assurance specifications
G. Reliability specifications

(5) Environmental tests
A. Non-operative
(1) Thermal shock (2) Sealing (3) Salt spray (4) Humidity
B. Operational
(1) RF noise (2) Vibration (3) Altitude (4) Shock (5) Random drop (6) High & low temperature operation
(7) Temperature cycling (8) Acceleration (9) Temperature range

(6) Contact specifications
A. Form designation
B. Loads (specify each pole separately if loads are different)
(1) Current (2) Voltage (3) Ac or dc (4) Frequency (5) Resistive (6) Inductive (7) Motor (8) Lamp
C. Transient conditions D. Circuit diagram E. Rate of operation F. Overload

(7) Coil specifications
A. Resistance
B. Current
(1) Nominal (2) Minimum (3) Maximum
C. Duty cycle
(1) ON-OFF ratio
(2) Magnitude of ON time
(a) Minimum (b) Maximum
D. Impedance
E. Ac or dc
F. Frequency
G. Voltage
(1) Nominal (2) Minimum (3) Maximum
H. Repetition rate
I. Circuit diagram

(8) Electrical characteristic specifications
A. Contact resistance B. Dielectric strength C. Insulation resistance

(9) Operational specifications
A. Pickup values C. Operate time E. Contact bounce G. Instrumentation
B. Dropout values D. Release time F. Contact chatter H. Temperature

(10) Enclosures
A. Open B. Dust cover C. Hermetically sealed D. Size limitations

(11) Mounting methods

(12) Termination
A. Terminal type B. Terminal strength

(13) Marking
A. Type designation B. Part number C. Date code D. Manufacturer's code

(14) Life expectancy
A. Mechanical B. Electrical

(15) Failure criteria
A. Minor B. Major C. Catastrophic

(16) Qualification tests

(17) Acceptance tests

(18) Procurement factors
A. Quantity required B. Delivery schedule C. Cost limitations

Checklist of detailed relay specifications

Note: Numerical identification preceding each item in this sample specification corresponds to numbered items on the Specification Checklist.

(1), (4) This equipment will be used on commercial airlines, and the following documents are applicable: MIL-R-5757D, MIL-STD-202A and MIL-R-6106E Specifications. Only those paragraphs specifically mentioned in this detail specification apply. In case of any discrepancy, the detail spec shall govern.

(2) Model 9999 airborne equipment.

(3) Relay is required to switch audio-frequency circuitry in radio receiver.

(5) The following environmental specifications apply:
- (A) Thermal shock per test condition B of method 107 of MIL-STD-202A
- (B) Sealing test 2 per paragraph 4.7.7.2. of MIL-R-5757D
- (C) 100-hour salt spray per paragraph 4.7.10. of MIL-R-5757D
- (D) Humidity per moisture resistance test method 106A of MIL-STD-202A, except eliminate paragraph 2.4.2
- (E) Vibration test 1 of paragraph 4.7.7.2..of MIL-R-5757D
- (F) Shock test of 30 g per MIL-R-5757D shock test 4 paragraph 4.7.12.2
- (G) High altitude performance at 70,000 ft.
- (H) Relay shall operate over ambient temperature range of –65°C to +125°C.
- (I) High and low temperature test per MIL-R-5757D, paragraph 4.7.16. shall apply

(6) This relay shall have a contact form C (spdt). Both A and B portions of the pole shall handle similar loads of audio-frequency levels of 30 ma min to 1 amp max at voltage of 100 mv to 8 volts. Load will be basically resistive with power factor exceeding 0.8. Normal rate of operation in equipment will be 4 cpm with equal ON and OFF times.

(7) The relay coil resistance shall be 250 ohms min at 25°C. The nominal dc coil voltage shall be 28 volts dc with a range of 24-32 volts dc. Coil shall be capable of continuous duty over temperature range of –65°C to +125°C.

(8) Contact resistance shall not exceed 0.02 ohms initially when checked by voltmeter-ammeter method with an open-circuit voltage of 1 volt dc and a closed-circuit current of 100 ma. Relay contact shall be closed before applying test circuit voltage. Dielectric strength at sea level shall be as required by paragraph 4.7.4.1.1. of MIL-R-5757D. Dielectric strength at 70,000 ft shall be in accordance with paragraph 4.7.4.2 of MIL-R-5757D. Insulation resistance of 1 Meg min shall be determined per paragraph 4.7.3. of MIL-R-5757D.

(9) Relay shall pick up at 20 volts dc max over the temperature range of –65°C to +125°C and shall drop out at 1 to 10 volts dc over the temperature range of –65°C to +125°C.

(10) Relay shall be hermetically sealed.

(10), (11), (12) Size, mounting and solder terminals to be per drawing 9999-1 (to be included as part of the specification).

(13) Relay shall be marked per paragraph 3.2.3.1. of MIL-R-5757D, item b, e, f and g only.

(14) Electrically loaded life expectancy shall be per paragraph 4.7.18. of MIL-R-5757D, except switching rate shall be 4 cpm.

(15) Failure criteria are categorized as follows:
- (A) Minor
  - (a) marking dimensions in error
  - (b) 0.1-volt deviation beyond allowable limits of pickup and dropout.
- (B) Major
  - (a) contact resistance exceeds 0.02 ohms but is less than 0.5 ohms.
- (C) Catastrophic
  - (a) failure of normally open contacts to make contact when coil is energized at 28 volts
  - (b) open coil circuit.

(18) 5,000 relays required, with delivery to begin 60 days after receipt of order at a rate of 100 relays per week.

paint-spray or particle contamination, too.

Various terminations—such as solder, screw, plug-in and others—should be considered. Terminal spacing, pullout or deflection forces, voltage drop and current limitation must also be evaluated.

In the relay drawing, include only those dimensions necessary for proper factory installation of field application. Allow options, wherever possible, to give the supplier the widest latitude. This may allow several relay manufacturers to qualify, and may cut costs. If the application dictates limitations on coil resistance or impedance, these should be noted. Maximum allowable power to operate a relay affects its cost and performance. Do not specify it unless absolutely necessary.

7. State whether the coil voltage or current is ac or dc. Also tell its frequency, waveshape, details of pulse shape, nominal, minimum, and maximum values. In the specification of duty cycle, an ON-OFF ratio alone is inadequate; absolute magnitudes of ON and OFF times are essential. Specify the range of rate of operation. Indicate the voltage or current at which the temperature rise is specified and explain the method of determining this rise.

With regard to the field requirements, be sure to specify the position of the relay with respect to gravity. Power-source impedance, regulation, ripple and waveshape are also important. If the relay's resistance varies with temperature, as it does in most types, some correlation problems may be circumvented by specifying current instead of voltage values (for the coil).

When relay coils are operated ON-OFF in the field, do not specify slowly rising or falling voltages to test the relays. You may thus avoid relay noise due to improper test procedures.

Timing specifications should clearly differentiate operate and release times from bridge or transfer time and contact-bounce time. Power supply impedance, instrumentation and the means of switching have significant effects on timing, and these should be considered, too. In specifying the sequence of operation of multiple contacts, be aware of the short time differences. Allow enough time for all of the contacts to complete their operation in the circuit. Note that the time differentials (which are of the order of microseconds) may not be large enough for sequential operation.

8. Bear in mind the functions that the relay must perform when specifying such characteristics as contact resistance, insulation resistance and dielectric strength. Consider the voltages and times usually involved in insulation resistance or dielectric strength test specifications. Although one minute exposure of the specimen to dielectric stress is frequently specified, shorter periods of one to five seconds at higher voltage are occasionally substituted for economic reasons. Failure criteria should be established at some level of leakage current. Avoid excessive transient voltages in the test set resulting from switching the high-voltage.

List the equipment to be used in a "miss" test (usually associated with low-level switching). Specify open and closed-circuit voltage and current, maximum allowable contact resistance and its time duration, number of permissible misses, rate of operation, total operations and ambient temperature.

9. Specify the load for each contact circuit. "Standard" load specifications do not help to attain field reliability. There is no such thing as a single ampere rating for a specific contact. Varied results will be obtained on different types of relays, and even on the same relay, with different voltages, types of loads, temperatures and rate of operation.

Fully describe the nature of load (motor, lamp, L/R ratio, power factor, etc.) and indicate the magnitude and the duration of transient voltages and currents, as well as the nominal, or steady-state, values. An oscillogram may be helpful to "fingerprint" inductive, motor, lamp or capacitive loads. Describe the type of contact protection that can be used, if any.

Include a complete circuit diagram. Note conductor types and sizes to be connected to the relay. Indicate the polarities to be switched. If possible, connect only one polarity to all transfer contacts of a given relay to avoid short-circuits during service. In selecting polarity, consider electrolytic corrosion of the devices being switched. Mechanical or elecrically loaded life expectancy should be defined, with indication of whether loads are to be switched, made or carried only, broken, or a combination thereof.

Failure criteria should be established with field functions in mind. In each area, define the minor, major and catastrophic categories.

Qualification and acceptance tests procedures are intimately associated with relay specifications and should also be included. ■ ■

Which relay is right for you? . . . Here's help in deciding

Zero in on the relay for your design by knowing the salient characteristics of the major types.

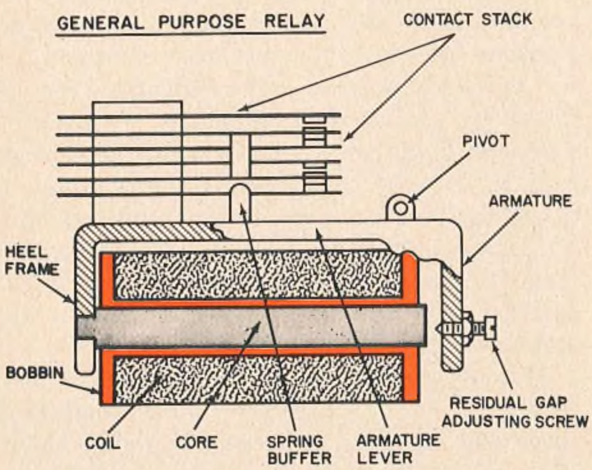
IF YOU WANT to find the best relay to do a particular job, here is a handy guide. It takes a fast look at 22 primary relay types and stresses the salient characteristics of each. There is also a relay chart on p 64 that names the manufacturers of all of the different types of relays. Titles alone aren't always the perfect guide to choosing the best relay. So let's examine the types one by one:

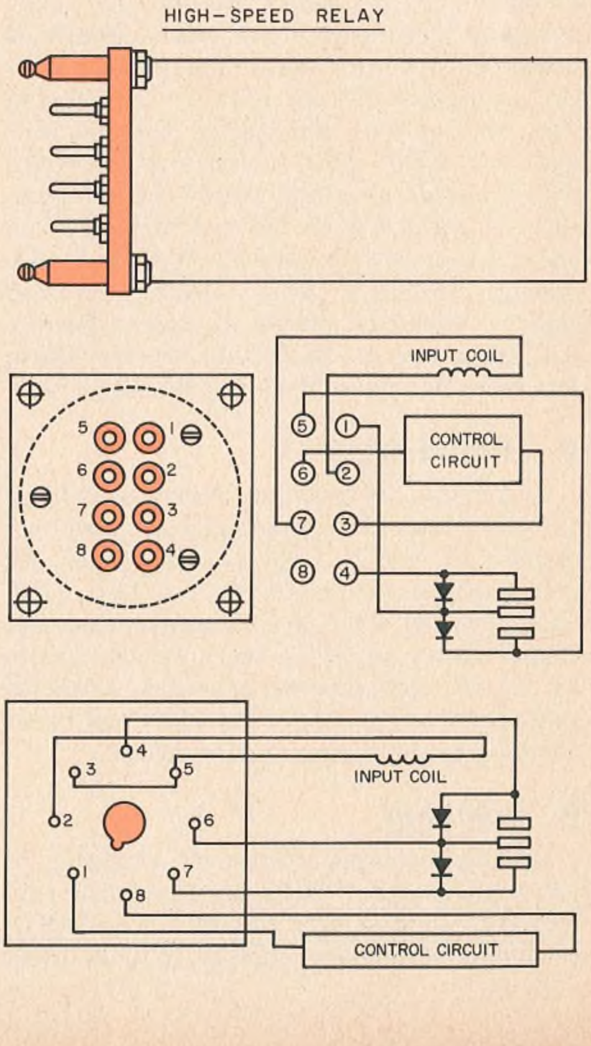
1. General Purpose

This broad category takes in many different kinds of relays that have one thing in common: They have multiple rather than specific applications. While general-purpose relays are often thought of as clapper relays, they can be of almost any type, depending, of course, upon the industry in which they are being used.

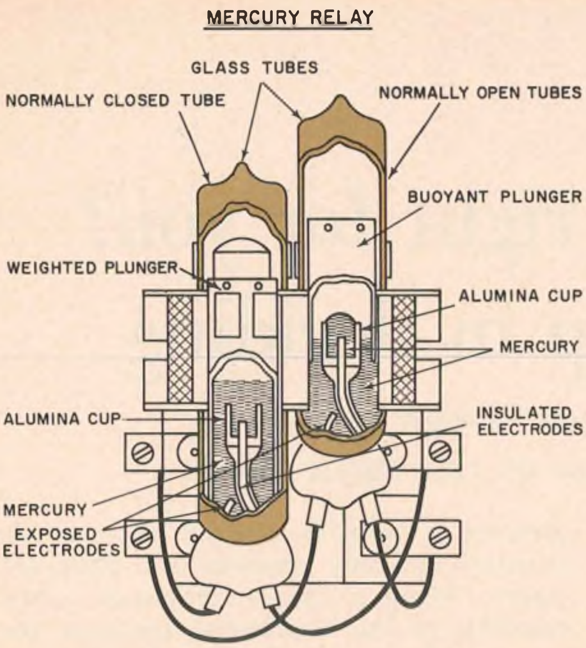
2. Frequency Sensitive/Selective

These are more properly classified as resonant-reed relays. They have an electromagnetic coil, arranged so that its flux, when energized, drives a vibrating reed. The reed, carrying a movable contact, acts as the armature and only responds to a given frequency. When a specific frequency, corresponding to the mechanical resonant frequency of the reed, is impressed on the coil, the reed will vibrate. This causes its contact to touch a stationary contact and thereby close a circuit one time for each electrical cycle. Variations are obtained by biasing the reed with a permanent magnetic or by employing more than one resonant reed, each with a different frequency response.





This article is a condensed version of material extracted from Section VIII of the forthcoming NARM Engineers Relay Handbook.



3. High-Speed

High-speed refers to the response of a relay when its coil is energized. Representative of this group are dc-operated relays that can close a contact in less than 1.0 msec.

From a design standpoint, high speed is obtained through the use of a low moving mass, low travel and a minimum of eddy currents. The design may use a polarized magnetic structure. High operating speeds can sometimes be obtained by overdriving the coil—applying abnormally high coil voltage or current. This presents no problems where limited duty and pulse-type energization are called for. In the case of longer coil energization periods, overdriving may cause damage. In these cases, a current-limiting resistor should be placed in series with the coil. High-speed ac relays that operate within less than half-cycle time are also available.

4. High-Voltage

In general, high-voltage relays switch up to 10,000 volts at 1 ampere or less ac and 0.2 ampere or less dc. These relay types are recommended for operation at a high reference potential. Coil power requirements are comparatively high—in the area of 5 watts dc or 25 volt-amperes ac—with solenoids quite common. Vacuum relays are used to accommodate the highest rating needs.

5. Latching

Broadly, latching relays are available in two types: magnetic latching and mechanical latching. Magnetic latching relay types usually employ permanent magnets to make them magnetically bi-stable. Thus their armatures are magnetically held in the operated position after the coil power has been removed. Reset is accomplished by either applying a voltage of proper polarity to a separate reset coil or by employing the same coil for both latch and reset, but reversing the polarity of the voltage for each function.

Mechanical latching relays are of two basic styles: mechanical reset and electrical reset. Mechanical reset types employ a coil and armature mechanism, plus a mechanical reset device. The latter locks the armature in the operated position after the coil has been deenergized. Rest is accomplished by manually tripping the locking mechanism or by some means other than electrical. Electrical reset types employ a second coil and armature to trip the latch mechanism and allow the relay to reset to its original position.

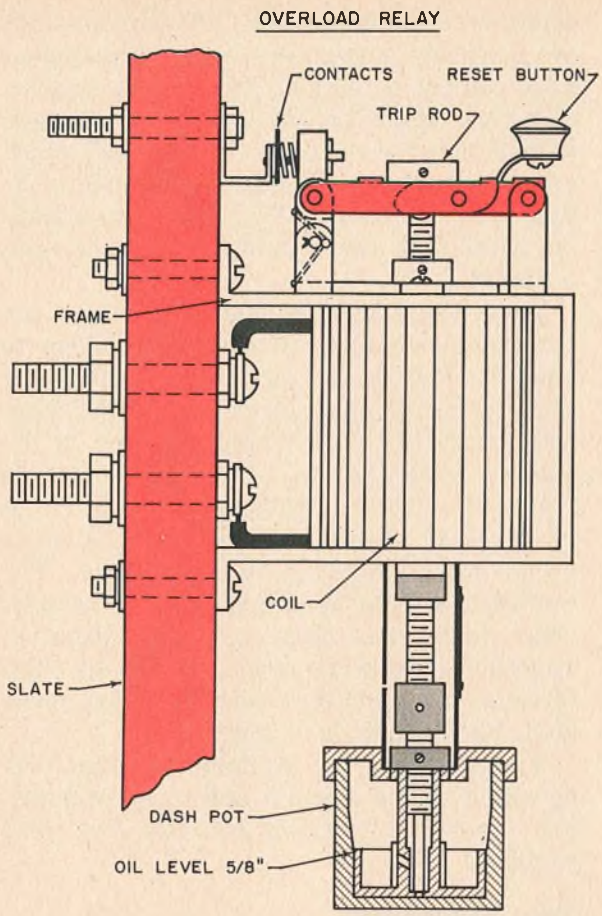
6. Mercury-Wetted Contact

The mercury-wetted contact relay is a special form of reed relay. It consists of a glass encapsulated reed, with its base mounted in a pool of mercury and the other end arranged so as to move between two sets of stationary contacts. By capillary action, the mercury flows up the reed to coat the movable and stationary contact surfaces, thus assuring mercury-to-mercury contact during MAKE.

There are two basic types. One, whose moving element is a magnetic, spring-biased armature, has platinum-tipped contacts. These contacts will typically carry a maximum current of 5 amperes, have a maximum voltage rating of 500 and a maximum switching load capacity of 250 volt-amperes.

In the second type, which features a smaller package size than the former, the armature consists of a magnetic alloy reed, which is not spring biased and is adjusted to a neutral position between the stationary contacts in the unbiased position. The movable reed is biased by means of a permanent magnet or magnets. These contacts have a maximum load capacity of 100 volt-amperes, limited by a maximum current capacity of 2 amperes and a maximum voltage rating of 500. Permanent magnets may be used with both types of capsules to provide single-side-stable, bistable or chopper operation.

Mercury-wetted contact relays are extremely fast in operation, have relatively good load carrying capacity, extremely long life and excellent low-level load characteristics. They also are free from contamination and bounce. But they have poor resistance to



shock and vibration, and are position-sensitive. Both types must be protected with suitable arc-suppression devices.

7. Miniature

This is a relative term (not recognized by NARM). It refers to a package size that is smaller than the general types and larger than the subminiature types. It does not describe any particular relay but is sometimes defined as one whose length is not less than one inch and not more than two inches, exclusive of terminals.

8. Motor-starting/armature

This term is usually applied to two different functions performed in starting motors. One is the "across-the-line" starter, usually nothing more than a power relay that, when energized, connects the line to the motor terminals.

The other is designed to open the motor-start winding circuit as the rotor approaches rated speed. This is achieved by sensing either voltage or current. In the voltage-sensing method, the relay coil is connected in parallel with the start winding of the motor. As the motor comes up to speed, the voltage generated in the start winding increases, causing the relay to pickup, thereby disconnecting the start winding.

The current sensitive relay types are connected in series with the motor winding. The initial "locked rotor" current energizes the relay and causes the contacts to close, thus placing the start winding in operation. When the motor reaches its operating speed, the line current finishes and allows the relay to drop out, thereby permitting the contacts to re-open.

9. Overload

An overload relay is an alarm, or protective, device. It is designed to operate when its coil current or voltage reaches a predetermined, or unsafe, value above normal. Such relays are often, but not always, mechanical latching types. A time-delay function may be included to permit short-duration overloads.

10. Plunger (Solenoid-Actuated)

Solenoid-actuated relays are generally used where a relatively large movement of the contacts is desirable or where considerable contact pressure is required. Because the solenoid provides relatively high pull in the open position and even higher pull in the closed position, it is an ideal method for actuating contacts that carry high power loads. It also is used in multiple contact systems. The majority of contactor designs use solenoid-actuated relays.

Plunger (Mercury)

This is a specialized form of solenoid-actuated relay in which a magnetic plunger displaces mercury. The mercury is moved relative to a contact system and thus makes or breaks a circuit. The mercury plunger and contacts are hermetically sealed in a glass or metal envelope, which is placed inside the actuating coil. Both normally open and normally closed contact forms are available. Mercury-plunger relays are position sensitive and are not useful for severe shock and vibration environments. They are suitable for heavy load applications and, being hermetically sealed, are excellent under environmental conditions that produce dust and humidity. A unit featuring a time-delay capability is also available.

11. Polarized

Polarized relays vary in size and design, depending upon the control application for which they are used. Their styles include Telegraph, Crystal Can, Ferreed, Dry Reed, Mercury-Wetted Contact and Armature with a remanent core. They usually employ one or more permanent magnets to provide the polarizing magnetic flux, which normally can flow in either of two symmetrical paths. The relay armature aligns itself according to the forces produced by the two flux paths.

Utilization of permanent magnet flux permits greater efficiency for a given size, when compared with non-polarized electromagnetic relays. This added efficiency is often used to make the relay more sensitive, to increase its operating speed, or to improve its vibration and shock resistance. For magnetic-latching (bi-stable) applications, this relay has the added advantage of consuming no power after contact transfer. Depending upon the design, polarized relays may be operated by a series of high-speed pulses (as encountered in telegraph and pulse-code equipment) or by infrequent ON-OFF signals, or by slowly varying signals (as found in controls and instrumentation circuits).

12. Power

This is a general term that varies from industry to industry, but usually it denotes relays capable of switching loads above 15 to 25 amperes at either 28 volts dc or 115/230 volts ac. They encompass a wide variety of styles—armature, solenoid actuated or rotary balanced armature.

13. Rotary

Rotary relays are defined as those whose armatures move in a rotary motion to close the gap between two or more pole faces. By far the great majority have balanced armatures and are used primarily under conditions of shock or vibration. They are manufactured in a very wide variety of sizes and shapes, from the smallest of microminiature to large relays designed to withstand very severe shock.

14. Radio-Frequency

These relays are designed to switch radio-frequency currents from one circuit to another with a minimum of losses. Of the broad range of shapes and sizes available, all use dielectric materials selected for their insulating qualities and for low losses at frequencies up to 150 Mc or higher. Large contact gaps and long dielectric leakage paths are employed to withstand the high voltages that are often encountered.

15. Dry-Reed

Dry-reed relays consist of one or more capsules containing contact mechanisms that are generally surrounded by an electromagnetic coil for actuation. The capsule consists of a glass tube with a flattened ferro-magnetic reed sealed in each end. These reeds, which are separated by an air gap, extend into the tube so as to overlap. When placed in a magnetic field they are brought together and close a circuit.

When the magnetic field is removed, the spring tension in the reeds causes them to separate. Multiple-contact systems employ as many capsules as required within the magnetic actuating field. Contact rating is dependent upon the size of the reed and the type and amount of plating. It ranges from low-level to 3 amperes. Effective contact protection is essential in most cases. The contacts have the advantage of being hermetically sealed and thus are impervious to atmospheric contamination. They are also fast-operating and have long life when operated within their load limits.

Vacuum types are available for high-voltage applications. Form A and form C operating types are common to most dry reed switches.

16. Sensitive

Sensitive relays require small amounts of power to be applied to their coils to cause them to operate—usually 100 mw or less. They encompass a very wide variety of styles: clapper, crystal can, dry reed, instrument, mercury-wetted contact and polarized, among others.

17. Snap-Action

Snap-action usually refers to the storing of energy during the initial motion of an actuating member, until a point is reached at which the contacts snap to a new position of equilibrium. This can be mechanically achieved by over-center devices, armature pre-travel or by circuitry designed to store energy from a sliding current source, triggered and applied to the relay for rapid contact transfer.

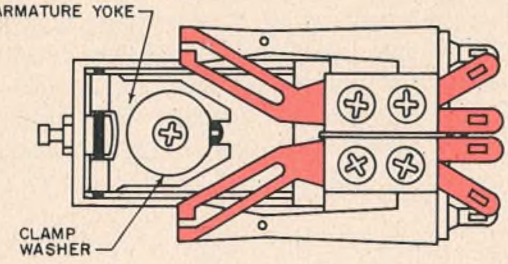
18. Subminiature

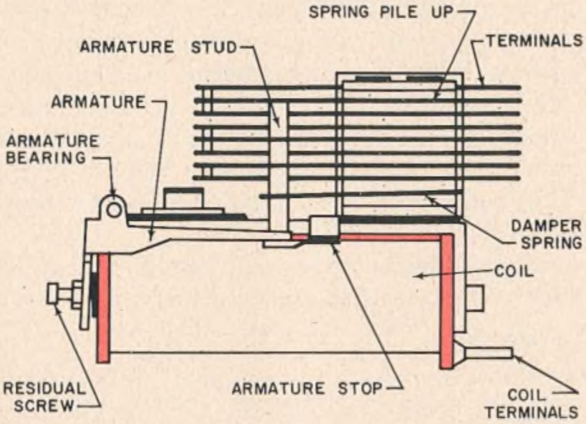
This is a relative term (not recognized by NARM) describing any sort of relay smaller than miniature but, presumably, not as small as microminiature. It is occasionally found on specification sheets. One definition in usage is that of a relay whose length (independent of terminals) is less than one inch.

19. Stepping Switches

There are many switching devices on the

TELEPHONE RELAY





market that are operated by a series of pulses and that perform sequential switching. Many are devoted to specific applications. Two types are available: commercial and rotary (telephone).

Two means of driving mechanisms are used in stepping switches: indirect and direct, with the former enjoying wider usage. When the armature-pawl combination acts directly on the ratchet under the magnetic attraction generated by the electromagnet, the stepping switch is said to be directly driven. The indirect type is a spring-driven stepping switch that is considered more consistent in performance, with longer life, greater efficiency and faster stepping than the directly driven device.

Commercial Stepping Switches

These are primarily intended for use in applications other than the telephone or communications industry. The basic design incorporates an electromagnetic driving mechanism that causes a contact-wiping mechanism to rotate over a series of contacts, arranged in a circle. A rather wide variety of contact and driving mechanism combinations is available. Some are bi-directional, having two coils and ratchet mechanisms so arranged that the wipers rotate in one direction when one coil is energized and in the opposite direction when the other coil is energized. Other types rotate the wiper mechanism against a spring that returns the wiper to a home position when a pawl is released. Some are designed so that pawl can be released electrically; others release manually. The electromagnetic driving mechanism may be a clapper type or solenoid. The number of steps available varies considerably.

Telephone Stepping Switches

The basic design is quite similar to that of the commercial type. The switches may be either simple rotary or two-motion selectors. They usually feature an electromagnetically operated mechanism, having one or more wiping spring sets fixed on a shaft that is moved and controlled by a pawl engaging a ratchet.

This moves the rotor (wiper assembly) one step per pulse and causes the attached wipers, successively, either to contact or break contact with a semi-circularly arranged row of contacts, called a bank level. The basic wiper contact forms of the stepping switch can be either of the make or break variety. The make form is commonly used and may be arranged to cause either "break before make" contacting (nonbridging) or "make before break" contacting (bridging). Bank contact levels are available in various switch types from different manufacturers, with 10, 11, 20, 22, 25, 26, 30, 33, 50, and 52 contacts per level.

20. Telephone Relay

This is a misnomer, as the use of this type is not confined to the telephone industry. Moreover, that industry does not often make use of the term.

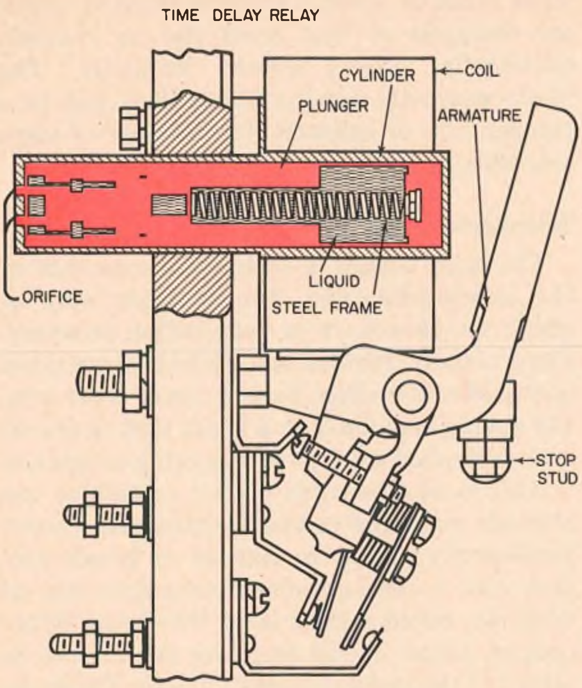
Commonly the telephone relay has a relatively long coil compared with the relay's diameter. Both dc and ac types are available. Slight time delays on pick-up or drop-out can be obtained on the dc units. These relays offer a very wide choice of contact forms and have relatively long lives.

21. Time Delay

When current is supplied to the coil or heating element in this relay, the contact mechanism doesn't move until the pre-set time-delay period has elapsed. A time delay can also be provided between the moment when the coil or heating element is de-energized and the contact mechanism is released.

Dashpot

In its earliest form the dashpot time-delay relay consisted of a plunger relay on which the armature or plunger was connected to a dashpot. The relatively slow transfer of air volume in or out of the cylinder regulated the



movement of a piston, which in turn controlled the movement of the armature or plunger, thus producing a time delay when the relay was energized or de-energized. However, variable friction between the cylinder and the piston tended to cause erratic performance. This difficulty was overcome by replacing the dashpot with a flexible bellows. Further refinements included passing the air from one chamber to another through an adjustable orifice, thus reusing the same air or gas without introducing contaminants that might clog the orifice.

Other modifications of the dashpot principle are now used. One device employs a closed hollow tube that is extended through the coil and some distance through the heel piece or frame. Inside this hollow tube is a movable magnetic core, held away from the face of the tube and armature by a spring. The hollow tube is filled with a liquid that surrounds the movable core. When the coil is energized, the armature of the relay does not immediately close, because the magnetic path is insufficient to produce the necessary flux. When the flux path is sufficient, the armature closes. Various time delays can be obtained by using liquids of different viscosities and by varying the clearance between the magnetic core and the inside of the tube.

Most dashpot relays operate on dc or rectified ac, although a few versions operate directly on ac.

Delay Slug

A time delay can be produced on dc relays by placing one or more shorted turns around the magnetic circuit (usually the core) in such a manner as to produce an opposing flux. This flux delays the regular flux build-up on energization and sustains the flux present when de-energization occurs. This shorted turn (or turns) is called a slug. It usually consists of a copper collar on the core of the relay.

This method of time delay is applicable to any dc relay that has sufficient physical space to accommodate the slug. However, it is most commonly used on long telephone types of relays that have comparatively long coils. For maximum delay on pull-in, the slug is placed on the armature end of the coil. For a delay on drop-out, the slug is placed on the heel end of the core. This location minimizes the effect on pull-in.

Pull-in delays up to 120 msec and drop-out delays to 500 msec can be achieved.

Hot-Wire

Hot-wire relays are a form of linear expansion relay in which the longitudinal expansion of a wire, when heated, provides the mechanical motion to open or close contacts. The time required to heat the wire constitutes the delay.

Thermal

Most thermal relays have a heating element of some type to provide the necessary temperature differential for mechanical expansion. This provides the movement to actuate the contacts. Since time is required for the heating element to attain the desired temperature and to transfer this heat to the expansion element, these devices are often used as time-delay relays. They are available in both fixed and adjustable types.

22. Vacuum

Vacuum relays have contacts sealed in a high vacuum. They range from the simple dry-reed, single-pole, single-throw device through small, multi-pole relays and on to rather large switching devices capable of carrying thousands of amperes at thousands of volts. The small, dry-reed type makes contact from an externally provided magnetic field in the same manner as the gas-filled dry reed does. Other vacuum relays have their contacts actuated mechanically by an exernal source. The moving element is a flexible member mounted in glass or a rigid member supported by a metal bellows, thus allowing sufficient movement to provide contact actuation while still maintaining the necessary vacuum. Vacuum relays tend to be more expensive than conventional relays. ■ ■

Relay manufacturers and their lines

(According to relay type)

To find the manufacturers of a specific relay, locate the relay type in the columns on top of the chart. The dots in the column identify the manufacturers of that type (as listed at the left of the chart).

To determine the relay product line of a specific manufacturer, locate the company name in the horizontal rows at the left. The dots in that manufacturer's row under relay types indicate his product line.

The relays are divided into 22 primary types and 35 special purpose devices, according to application (see page 6 for the literature offered by the manufacturers).

A – Antenna	CR – Chopper/Modulator	FC – Fuse Contactor	MP – Micropositioner	SL – Surge-Limiting
AE – Aerospace	CS – Crossbar	I – Impulse-Type	MV – Moving Coil	SQ – Phase-Sequence
AM – Amplifier	D – Differential	L – Light Sensitive/Photo	μM – Microminiature	SS – Solid-State
AS – Adjustable Set-Point	DP – Data-Programing	LL – Low-Level	N – Nanoampere	ST – Static
AU – Audio-Operated	E – Electronic	M – Meter/Indicating	PI – Plug-In	TH – Thermal
C – Coaxial	EM – Electromechanical	MA – Magnetic Amplifier	RR – Radiation Resistant	VC – Voltage Comparing
CL – Clapper	EP – Explosion-Proof	MC – Microwave	S – Solenoid-Actuated	VS – Voltage/Current Sensing

Manufacturer	General Purpose	Frequency Selective or Sensitive	High Speed	High Voltage	Latching	Mercury	Miniature	Motor-Starting/Armature	Overload	Plunger	Polarized	Power	Rotary	Radio Frequency	Reed	Sensitive	Snap Action	Subminiature	Stepping Switches	Telephone	Time Delay	Vacuum	Special Purpose Types
Acromag Inc.																•							D, E
Adams & Westlake Co.	•		•			•	•		•	•	•	•				•					•		
Ad-Yu Electronics																							MA
Agastat Timing Instruments																					•		E, S
Airborne Accessories Corp.	•	•	•						•			•				•	•				•		D, E, EP, I, L, M, MC, TH
Airpax Electronics, Inc.		•	•				•									•		•					D, E, L, M
Allen-Bradley Co.	•								•			•			•						•		
Allied Control Co.	•	•	•	•	•		•	•	•	•	•	•	•	•		•	•	•		•	•		A, C, CL, E, EP, I, L, RR, S
Amphenol RF Div.														•									C, MC
Amtron, Inc.			•				•				•	•				•	•				•		E, L, SS
API Instruments Co.																	•						M, MV
Artisan Electronics	•				•							•				•			•		•		
ATR Electronics, Inc.	•		•				•					•		•		•				•			A
Automatic Electric Co.	•				•	•	•					•			•		•		•	•	•		CL
Automatic Metal Products Corp.														•									A, C, MC
Automatic Switch Co.	•	•							•			•				•					•		CL, D, E

Manufacturer	General Purpose	Frequency Selective or Sensitive	High Speed	High Voltage	Latching	Mercury	Miniature	Motor-Starting/Armature	Overload	Plunger	Polarized	Power	Rotary	Radio Frequency	Reed	Sensitive	Snap Action	Subminiature	Stepping Switches	Telephone	Time Delay	Vacuum	Special Purpose Types
Automatic Timing & Controls, Inc.																					•		
Avtron Manufacturing, Inc.																							SQ, VC
Babcock Relays	•		•		•	•	•				•			•		•		•					E, EP, I, RR
Barber-Colman Co.											•					•							MP
Blonder-Tongue Labs, Inc.																							TH
Bourns, Inc.																•		•			•		VS
Bramco Controls Div. of Ledex Inc.		•													•								
Branson Corp.	•				•		•		•		•	•	•	•		•		•			•		CL, E, TH
Bristol Company, The			•				•				•					•		•					
Butler Roberts Assoc., Inc.							•								•					•			C, CS
Cardinal Control Co.	•						•	•				•			•	•	•				•		L, TH
Clare, C.P. & Co.	•		•	•	•	•	•		•		•				•	•		•	•	•	•		C, CL, E, I, LL, S
Comar Electric Co.	•			•			•						•		•			•		•			
Computer Components, Inc.			•	•	•	•	•								•	•						•	EP
Control Data Corp.			•		•						•					•							AS, E, MV, SS
Cook Electric Co.	•				•		•				•							•			•		TH
Cornell Dubilier Electronics	•		•		•		•				•		•			•		•	•	•	•		D, E, L, S
Corona Engineering Service						•																	
Coto-Coil Company, Inc.	•		•	•		•	•								•							•	
Couch Ordnance, Inc.	•						•					•	•			•	•	•			•		
Cunningham, James, Son & Co., Inc.																							CS
Cutler-Hammer, Inc.	•							•	•			•									•		E, EP, L, S, TH
Davis Electric Company	•				•		•					•						•		•			CS
Donner Electronics, Inc.																							L
Dormeyer Industries	•											•			•			•					S
Douglas Randall, Inc.						•									•								
Dow-Key Co.														•									A, C
Eagle Signal	•				•							•				•					•		A, E, EP
Ebert Electronics Corp.	•			•	•	•		•	•	•	•	•				•					•		E, L, TH
Elec-Trol, Inc.	•			•		•	•								•						•		
Electronic Applications Co.											•												CH
Electronic Controls, Inc.	•				•		•				•										•		CS, I, S
Electronic Specialty Co.	•		•	•	•		•				•		•	•	•	•		•			•		C, E, MC, RR
Electro-Tec Corp.	•				•		•	•	•	•	•	•						•					LL, S
E-T-A Products Co. of America								•	•								•				•		TH
Farmer Electric Products Co.																							E
Filtors, Inc.	•		•		•		•				•		•			•		•			•	•	E, I, L
Fisher-Akin Co.															•				•				CS
Furnas Electric Co.	•		•	•				•	•			•									•		
GE Construction Industries Div.	•				•			•	•		•	•			•	•	•			•	•		AU, E, EP
General Automatic Corp.	•		•		•		•		•						•	•	•			•	•		AM, CL, D, E, EP, I, L
General Electric Co.	•		•	•	•		•				•				•	•		•				•	C, E, L, RR
General Reed Co.			•		•		•								•								M
Globe Electrical Mfg. Co.	•			•	•		•	•				•				•				•			CL, E
Gordos Corp.						•									•								
Grigsby-Barton, Inc.			•	•		•	•								•			•					E, EP
Guardian Electric	•		•	•	•		•	•	•	•	•	•	•			•	•	•	•	•	•		A, CL, I, L, S
Guardian Electric Mfg. Co. of Calif., Inc.																				•	•		
Guide Industries, Inc.		•													•	•					•		C, D, E, EP, MC, VS
G-V Controls, Inc.		•							•												•		E, TH
Hart Manufacturing Co., The	•		•				•	•			•	•				•		•					
Hathaway Instruments					•		•							•	•			•					
Haydon, A. W. Co.																					•		E

A – Antenna	AE – Aerospace	AM – Amplifier	AS – Adjustable Set-Point	AU – Audio-Operated	C – Coaxial	CL – Clapper	CR – Chopper/Modulator	CS – Crossbar	D – Differential	DP – Data-Programing	E – Electronic	EM – Electromechanical	EP – Explosion-Proof	FC – Fuse Contactor	I – Impulse-Type	L – Light Sensitive/Photo	LL – Low-Level	M – Meter/Indicating	MA – Magnetic Amplifier	MC – Microwave

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EP – Explosion-Proof
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M – Meter/Indicating
MA – Magnetic Amplifier
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MP – Micropositioner
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S – Solenoid-Actuated
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SQ – Phase-Sequence
SS – Solid-State
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VC – Voltage Comparing
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Manufacturer	General Purpose	Frequency Selective or Sensitive	High Speed	High Voltage	Latching	Mercury	Miniature	Motor-Starting/Armature	Overload	Plunger	Polarized	Power	Rotary	Radio Frequency	Reed	Sensitive	Snap Action	Subminiature	Stepping Switches	Telephone	Time Delay	Vacuum	Special Purpose Types
Heinemann Electric Co.									•												•		
Hi-G, Inc.	•	•	•	•	•		•		•		•	•	•		•	•		•			•		EP, RR, SQ, VS
High Vacuum Electronics, Inc.			•	•			•							•								•	A, CS, E, EP
Hillburn Relay Corp.	•				•							•				•			•	•			A, CL
Hurletron Control Products	•		•	•			•	•				•	•					•	•		•		E, EP, S
IBM	•		•		•		•								•	•	•						E, EP, I
Industrial Instruments, Inc.				•																			
Integrated Electronics Corp.						•									•				•				
ITT General Controls Inc.	•					•		•									•				•		L, S, TH
Jaidinger Mfg. Co., Inc.	•		•		•		•								•	•	•				•		CL, I, TH
James Electronics, Inc.			•				•				•			•	•	•	•						C, E, EP, I, L, M, MC, RR
James G. Biddle Co.		•													•								
Jay-El Products, Inc.																					•		E
Jennings Radio Mfg. Corp.			•	•	•		•	•	•			•		•					•			•	A, C, CS, EP, S
Kurman Electric Co.	•		•				•				•	•		•	•	•	•	•		•	•		A, CL, E
Larson Instrument Co.																							L, M, MV
Leach Corporation	•		•	•	•		•		•	•	•	•	•			•		•			•		CL, E, EP, I, RR, S
Ledex, Inc.													•						•				DP, M, S
Life Instrument Co.	•		•	•	•		•	•	•		•	•		•	•	•					•		A, D, E, L, TH
Line Electric Co.	•				•	•	•	•				•			•	•				•	•		EP
Livingston Electronic Corp.																					•		
Luft Instruments, Inc.																							DP, E
Machinery Electrification, Inc.	•								•			•									•		L, M
Mack Electric Devices, Inc.						•				•		•				•					•		E
Magnecraft Electric Co.	•		•	•	•	•	•	•	•			•	•		•	•	•	•		•	•	•	A, C, CL, E, EP, I, MC
Magnetic Components, Inc.			•	•		•	•				•				•	•		•				•	EP, I, TH
Master Specialties Co.																					•		SQ
McElroy Electronics Corp.																					•		
McKee Automation Co.					•										•								CS
Mercoid Corp.	•					•				•													EP
Microwave Associates, Inc.	•		•		•							•	•	•				•		•			A, C, E, MC, S
Milwaukee Relays, Inc.	•				•			•	•		•	•				•							CL, D, I
Mobil Electronics, Inc.											•												AU
Monitor Controller Co.														•									A
Mossman-Elliott Corp.	•				•							•			•	•	•			•			
Naybor, E. V., Laboratories, Inc.	•						•						•				•	•			•		
New Product Engineering, Inc.			•	•	•	•	•				•			•	•	•		•	•		•	•	A, C, CS, E, EP, I, L
Ohmite Mfg. Co.	•				•							•				•	•			•			
Parelco, Inc.	•															•							VS
Parker Instrument Corp.																•							L, MV
Payne Engineering Co.								•				•									•		EP
Philadelphia Scientific Glass Co., Inc.	•		•	•		•	•	•		•		•				•					•		E, EP
Phillips-Advance Control Co.	•		•	•	•		•	•	•	•		•	•	•		•	•	•		•	•		A, C, CL, E, S, TH
Phipps Precision Products	•		•	•	•	•	•				•		•		•	•		•	•		•		D, E, EP, I, TH
Photobell Co., Inc.																					•		E, L

Manufacturer	General Purpose	Frequency Selective or Sensitive	High Speed	High Voltage	Latching	Mercury	Miniature	Motor-Starting/Armature	Overload	Plunger	Polarized	Power	Rotary	Radio Frequency	Reed	Sensitive	Snap Action	Subminiature	Stepping Switches	Telephone	Time Delay	Vacuum	Special Purpose Types
Potter & Brumfield	●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●		A, CL, D, E, I, RR, S
Precision Thermometer & Instrument Co.							●									●		●					TH
Price Electric Corp.	●			●			●					●	●			●		●		●			
Printact Relay Div., Executone Inc.	●		●		●		●				●						●			●			
Quantatron					●		●							●									C, MC
Raytheon Co.																							L
R B M Controls	●	●		●			●	●	●		●	●		●	●	●	●			●	●	●	A, CS, D, E, I, L, M, S, TH
Regent Controls, Inc.	●		●		●							●				●					●		E, L, SS
Relaymatic, Inc.	●				●		●								●	●		●		●			
Relay Sales	●	●	●		●	●	●	●		●	●	●	●	●		●		●	●	●	●		A, C, S, TH
Rixon Electronics, Inc.			●																				
Ro Associates, Inc.			●				●									●							E
Rochester Instrument Systems, Inc.		●	●	●																			D, E
Rowan Controller Co.	●			●				●	●			●									●		E, EP, FC, LL, S, TH
Schrack Electrical Sales Corp.	●			●	●		●	●	●			●	●			●		●	●	●			TH
Sealectro Corp.																			●				
Sensitak Instrument Corp.					●		●		●							●							M, MV
Sigma Instruments, Inc.	●		●		●		●		●		●	●				●	●	●		●			D, EP, I, L
Solenoid Devices, Inc.	●				●							●	●						●				I, S
Solid State Electronics Corp.		●	●		●						●				●	●		●			●		E, L
Standard Instrument Corp.									●						●						●		E, I, L
Stearns-Lyman Electronic Corp.	●		●			●	●						●		●	●	●	●	●		●		EP, VS
Stromberg-Carlson	●																			●			
Struthers-Dunn, Inc.	●		●	●	●	●	●	●	●		●	●			●	●		●	●	●	●	●	AE, CL, CS, D, E, EP, I, M, S, TH
Suttle Equipment Corp.		●																					E
Systems Matrix, Inc.	●		●									●									●		E, EP, L
Teledyne Precision, Inc.	●		●		●		●		●		●	●				●	●	●					E, EP, I, M, μM, RR
Telex/Aemco	●			●	●		●	●	●			●		●				●		●	●		A, C, CL
Teltronics, Inc.														●									C
Tempo Instrument, Inc.		●																			●		E
Texas Instruments Inc.							●	●	●	●							●				●		TH
Thermal Controls, Inc.	●						●										●				●		L
Thermosen, Inc.															●								
TIA Electric Co.																							E, VC, N
Torotel, Inc.															●								
Torr Labs, Inc.			●	●	●		●				●	●		●	●	●	●	●				●	A, E, EP, I, MC, RR, S
Touch-Plate Mfg. Corp.	●																						
Tri-Tronics Co.																							E, L
Tru-Connector Corp.														●									A, C
Tung-Sol Electric, Inc.			●														●				●		EP, TH
Union Switch & Signal	●						●						●					●					E
Vanguard Relay Corp.	●				●		●	●	●		●		●		●						●		A, CL, I
Vapor Corp.	●									●		●									●		CL, D, S
Wacline, Inc.		●														●							E, M, VS
Warco Industries, Inc.	●							●															
Ward Leonard Electric Co.	●				●				●			●				●					●		CL, PI, S
Westinghouse Electric Corp.	●	●	●	●				●	●	●	●	●	●								●		CL, D, EM, I, MC, MV, S, ST, TH
Weston Instruments, Inc.																●							M, MV
Wheelock Signals, Inc.	●		●	●	●	●	●					●		●	●	●		●		●			A, C
Wilson, G. C., & Co.																					●		
Win-Elco	●		●	●	●	●	●		●		●	●	●		●	●		●			●	●	C, D, E, EP, I, L, TH
Wuerth Products Corp.																							SL
Zenith Electric Co.	●																				●		

Specifications applicable to relays

Following are most of the active government specifications (MIL and NASA) and two non-government specifications applicable to relay evaluation and qualification. They can help the relay user in specification writing (see article on p 52).

Specification & Agency	Remarks
I. General specifications applicable to relays	
MIL-Q-9858A Dept. of Defense Washington, D.C.	• Quality program requirements. • Covers all areas of contract performance, including design, development, fabrication, etc. • Devoted to quality assurance.
NPC-200-2 NASA Quality Publication NASA 1875 Connecticut Ave., N.W. Washington, D.C.	• Quality-control provisions for space-systems contractors. • More stringent than MIL-Q-9858A. • Contains common, general requirements requiring specific clarification for each contract. Should not be invoked in whole unless specified.
NPC-200-3 NASA Quality Publication (See above)	• Inspection-system provisions for suppliers of space materials, parts, components and services. • Contains common, general requirements requiring specific clarification for each contract. Should not be invoked in whole unless specified.
MIL-STD-105D U.S. Army Munitions Command Pentagon, Washington, D.C.	• Sampling procedures and tables for inspection by attributes. • Applicable to end items, components and raw materials, operations, materials in process, supplies in storage, maintenance operations, data or records, administrative procedures, among others. • A statistical rather than a general document.
MIL-STD-202C Defense Supply Agency, Cameron Station, Alexandria, Va.	• Standard test methods for electronic and electrical component parts. • Establishes uniform testing methods. • Devoted to environmental tests (100 class), physical-characteristics tests (200 class) and electrical-characteristics tests (300 class).
MIL-STD-810 Air Force Aeronautical Systems Div. Wright-Patterson AFB Dayton, Ohio	• Standard environmental test methods for aerospace and ground equipment. • For determining the resistance of aerospace and ground equipment to the deleterious effects of natural and induced military environments. • Intended for new engineering and design. Should not be applied in retrospect. • Established in 1962, it contains more exotic tests than MIL-STD-202.
MIL-E-5272 Aeronautical Standards Group Dept. of Defense Washington, D.C.	• General specification for environmental testing of aeronautical and associated equipment. • Relatively old (1960) document containing tests procedures (many of which have been discontinued). • Covers climatic and environmental conditions for any global locality.

Specification & Agency	Remarks
MIL-I-45208A U.S. Army Munitions Command (See above)	• Specification for inspection-system requirements. • Sets up requirements for contractors' inspection systems. • Part of MIL-Q-9558A. • To be used concurrently with MIL-C-45662.
MIL-C-45662A Army Ordnance Corps. Rock Island, Ill.	• Specification for calibration-system requirements. • For the control of accuracy in measuring and test equipment.
II. Specific relay specifications	
MIL-R-5757D, Amendment 3, April 1964 Navy Bureau of Ships (Project 5945-0089) Washington, D.C.	• General specification for electrical relays (excluding thermal types) that are used in electronic and communication equipment. • Covers general requirements for relays with contact ratings up to and including 10 amperes. • DOD-approved for use by Army, Navy and Air Force.
MIL-R-6106E Air Force (85) Pentagon, Washington, D.C.	• General specification for electric aerospace relays. • Covers more relay types than any other relay specification. • Applicable to relays with up to 400-ampere contact load. • Companion specification QPL-6106-15 is QPL list for MIL-R-6106.
MIL-R-19648 Navy Bureau of Ships Washington, D.C.	• General specification for thermal, time-delay, hermetically sealed relays. • For relays with contact ratings up to and including 6 amperes. • Fills voids in MIL-R-5757D.
MIL-R-19523 Navy Bureau of Ships Washington, D.C.	• Specification for auxiliary relays used on Navy ships. • Covers high-impact (class H1) shock-proof auxiliary relays. • Use includes submarine and nuclear-propulsion-plant environments.
MIL-R-39016 Navy-Ships (Project 5945-0049) Washington, D.C.	• General specification for establishing reliability in electromagnetic relays. • For hermetically sealed types (excluding thermal). • For relays with contact ratings up to 10 amperes. • Relatively new (1964) and applicable to relays not used in plug-in-socket applications.
SMFC-SPEC-339 George C. Marshall Space Flight Center Greenbelt, Md.	• General NASA specification for hermetically sealed dc relays in space vehicles and ground-support equipment • For general-purpose switching, using contact ratings up to and including 10 amp.
III. Non-government documents applicable to relays	
NAS-728 National Aerospace Standard, National Aerospace Service Association, 1725 De Sales St., N.W. Washington, D.C.	• Test methods for electromagnetic relays. • For relays that must qualify for use in military equipment. • Application does not preclude its use for relays intended for use in commercial equipment.
AIR-875 Aeronautical Information Report, Society of Automotive Engineers, Subcommittee A-2R, 485 Lexington Ave., New York	• Government relay-specification comparison. • Compares various military relay specifications in detail.

Relays in action

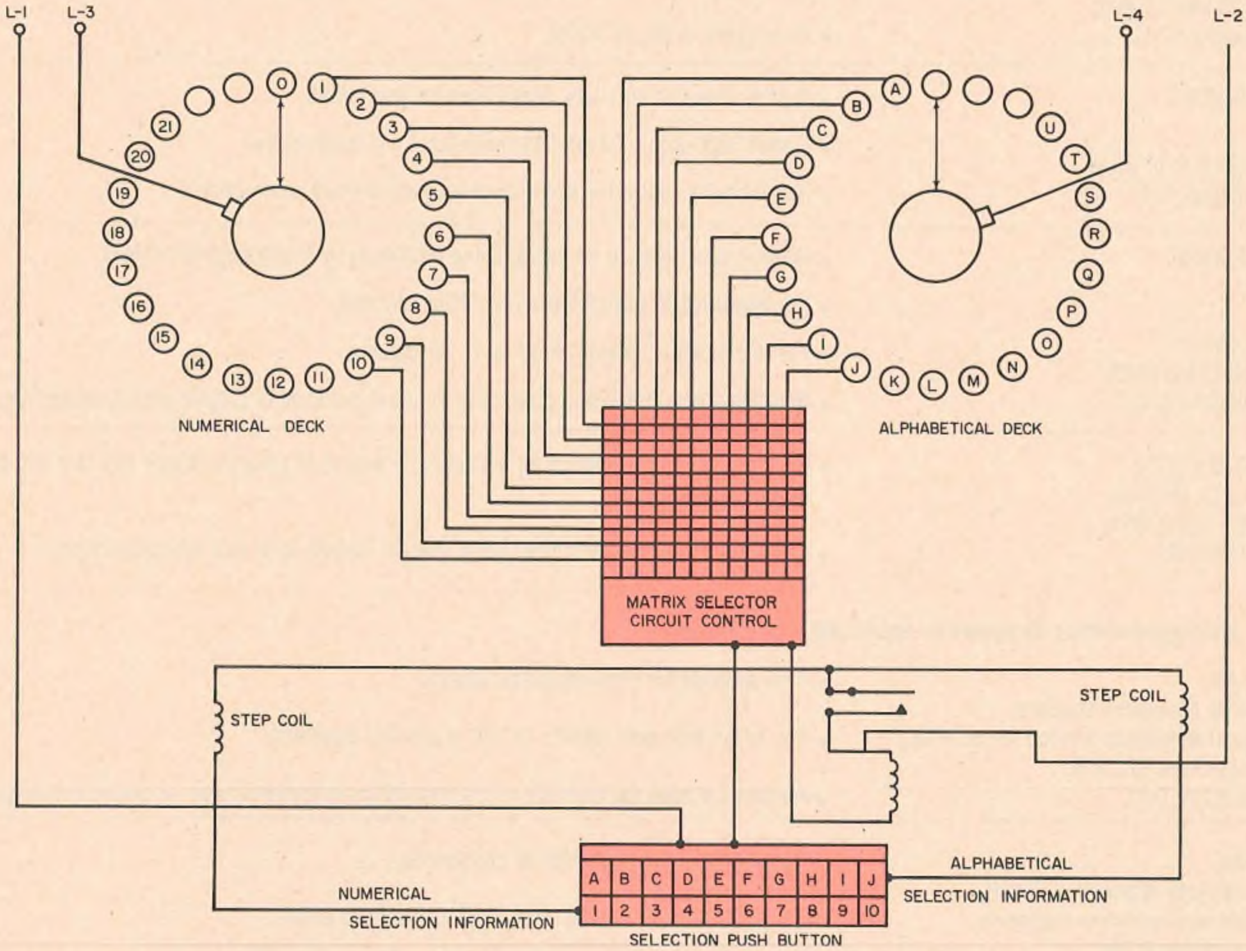
This collection of useful relay circuits shows the versatility of this "old standby."

Stepping relay establishes matrix selector control

A 24-point stepping-relay can easily permit the selection of any one of a hundred circuits through a 10 × 10 matrix arrangement. The relay is directly connected to a push-button selector for system simplicity.

The control circuit in the illustration uses a dual-deck, 24-point stepper. Direct drive on each of the step magnets and indirect operation on the reset magnet is provided. The normally open switch (contacts) on the reset magnet completes the selection circuit.

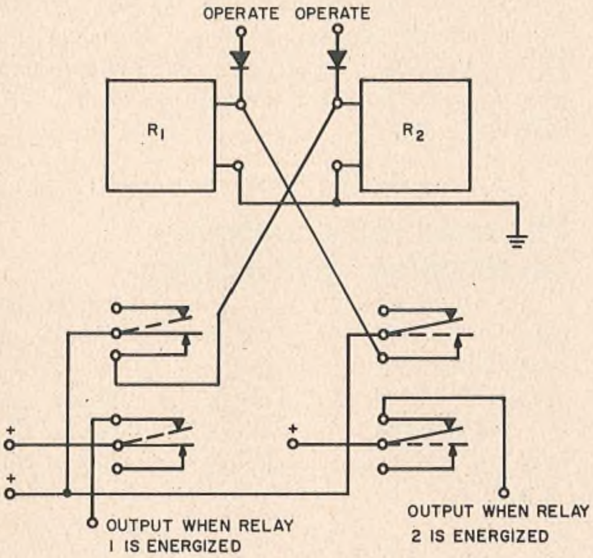
Action is initiated by depressing a push-button selector. This puts the scanning device into operation. The pulse output of the scanner moves the wipers to the desired position, as determined by the push buttons.
SOURCE: *Guardian Electric Mfg. Co.*



Stepping-relay matrix selector control locates any one of a hundred circuits through a 10 × 10 matrix arrangement.

Two relays form bistable trigger circuit

Two single-coil relays can be used to make a bistable trigger circuit (see illustration). The trigger is always in one of two states: either Relay *1* or Relay *2* is energized, with its corresponding contacts transferred. The trigger remains in one state until a pulse is received to switch it to the other state.



Bistable trigger circuit switches states each time a pulse is applied to the coil of the de-energized relay.

As shown, Relay *2* is held operated by the normally-closed contacts of relay *1*. The circuit remains in this state until an operate pulse is applied to the coil of Relay *1*. When this happens, Relay 1 becomes energized, and its normally closed contacts open. As a result, the holding circuit for the coil of Relay *2* is opened, and Relay *2* drops out. The contacts of Relay *2* then provide a holding circuit for the coil of Relay *1*.

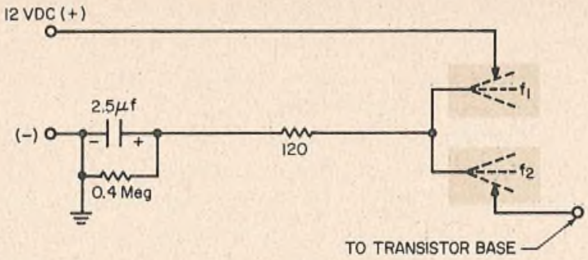
The trigger remains in this state, with Relay *1* energized and Relay *2* de-energized, until an operate pulse is applied to the coil of Relay *2*.

SOURCE: *IBM*

Multiple-reed relay acts as 2-frequency decoder

A simple 2-frequency decoder circuit uses a resonant-reed relay that has two resonant reeds and a single coil. Each reed is resonant at a different audio frequency. The circuit will switch a desired control function only when the two reeds are activated, in sequence, by their respective frequencies.

When the first frequency, f_1, is received, its corresponding reed vibrates. This charges the 25 μf capacitor. When the second frequency, f_2, is received, its reed vibrates, transferring the charge on the capacitor to a tube grid or transistor base. The 0.4 Meg resistor serves as a bleeder across the capacitor to prevent the switching action from being activated by undesirable codes.



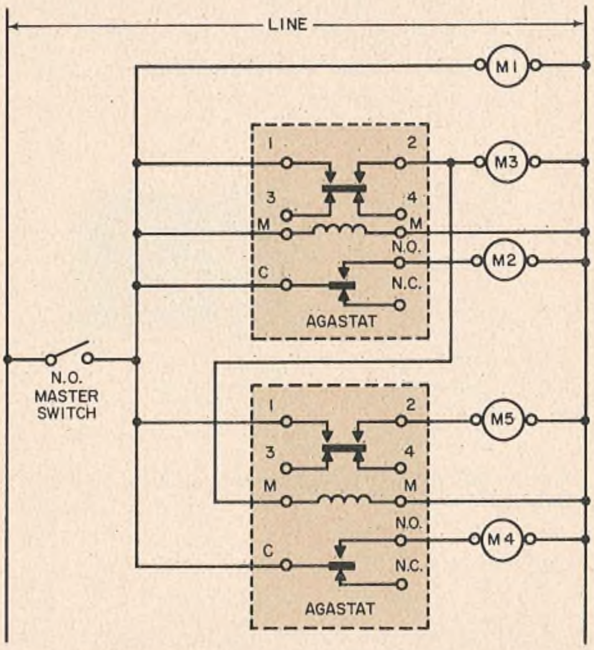
Multiple-reed relay performs a control function by decoding two audio frequencies.

SOURCE: *Bramco Controls Div., Ledex, Inc.*

Time-delay relays sequentially switch motor starting system

Many industrial installations employ a series of electric motors that must be started at the same time, and preferably with one switch. A two-step type of time-delay relay can perform this function, while still preventing overcurrent damage.

Drive motors of progressive stands in mill operations that use multi-stand reduction are examples of such usage, as are the multiple motors used in long conveyor systems. Placing the combined load of all the motors across the line at once would create an excessive current demand and risk the possibility



Two double-step, time-delay relays sequentially switch five motors and prevent them from being damaged by high starting currents.

of motor burnout. The relays in the illustration each provide a series of sequential time delays. The starting sequence of the five motors is programed as follows:

1. Closing of the master switch energizes starter circuit of Motor *1* and the coil of the first relay. This starts the first motor and initiates time delays in the starter circuits of Motors *2* and *3*.
2. After the preset delay has expired, the auxiliary contacts of Relay *1* close, thereby energizing the starting circuit of Motor *2*.
3. At the end of second preset delay, the main contacts of the first relay close and energize the starting circuit of Motor *3* and the solenoid coil of the second relay.
4. Motors *4* and *5* are started sequentially in similar fashion, as the two time-delay periods of the second relay first close the auxiliary contacts and then the main contacts of that unit.

SOURCE: *Agastat Timing Instruments*

Double-coil relay simplifies AND circuit

The number of contacts in a relay-logic AND circuit can be reduced by using a double-coil relay. With conventional single-coil relays, two separate relays are used to make up an AND circuit (Fig. 1). The contacts of the relays are wired in series, so that both must be energized to produce an output.

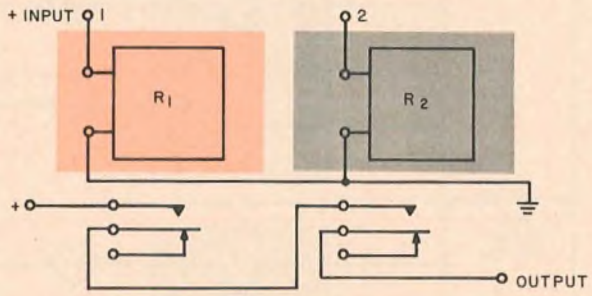


Fig. 1. **Two single-coil relays** are required to produce an AND circuit.

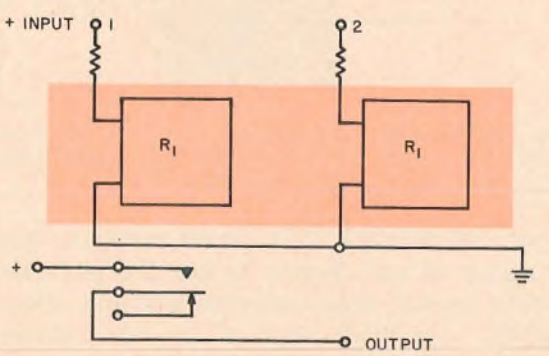


Fig. 2. **Double-coil relay** reduces the number of contacts in an AND circuit.

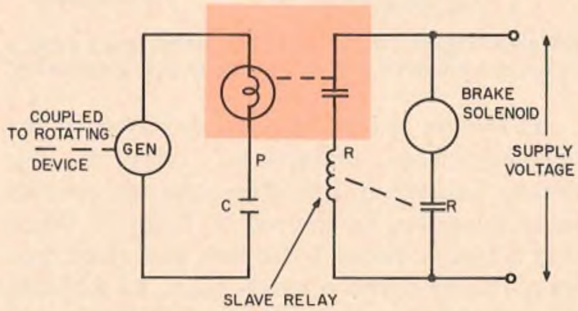
A double-coil relay requires only one set of contacts to provide the AND function. The circuit of Fig. 2 has two coils wound on the same core. An input to either of the coils will not cause the relay to operate, because of the resistor in series with each coil. But when both coils receive an input simultaneously, the combined flux is sufficient to operate the relay.

Once the double-coil relay operates, only one input is required to keep it energized. This is because one coil can provide the flux necessary to hold the armature sealed.

SOURCE: *IBM*

Polarized relay controls acceleration, deceleration

An ultrasensitive micropositioner-type of polarized relay forms a simple means of controlling the acceleration (or deceleration) of a rotating device. The pre-calibrated coil trip adjustment on the relay permits the braking action to be set anywhere below the skid level.



Micropositioner-type polarized relay forms acceleration/deceleration control.

In this system (see illustration), a Barber-Colman micropositioner, capable of operation with inputs as low as 40 μw, is connected in series with a capacitor across the output of a permanent-magnet dc generator. The generator is coupled to the rotating device (in this case, a wheel). When the wheel acceleration is zero, the generator velocity is constant and no voltage appears across the micropositioner coil.

A change in velocity produces a coil input proportional to the acceleration. When the acceleration reaches the predetermined trip limit, the coil is momentarily energized. This closes the micropositioner contacts, *P*, which in turn energize the slave relay, *R*. The contacts of *R* close and permit the brake solenoid to be supplied with power.

SOURCE: *Electro-mechanical Products Div., Barber-Colman Co.*

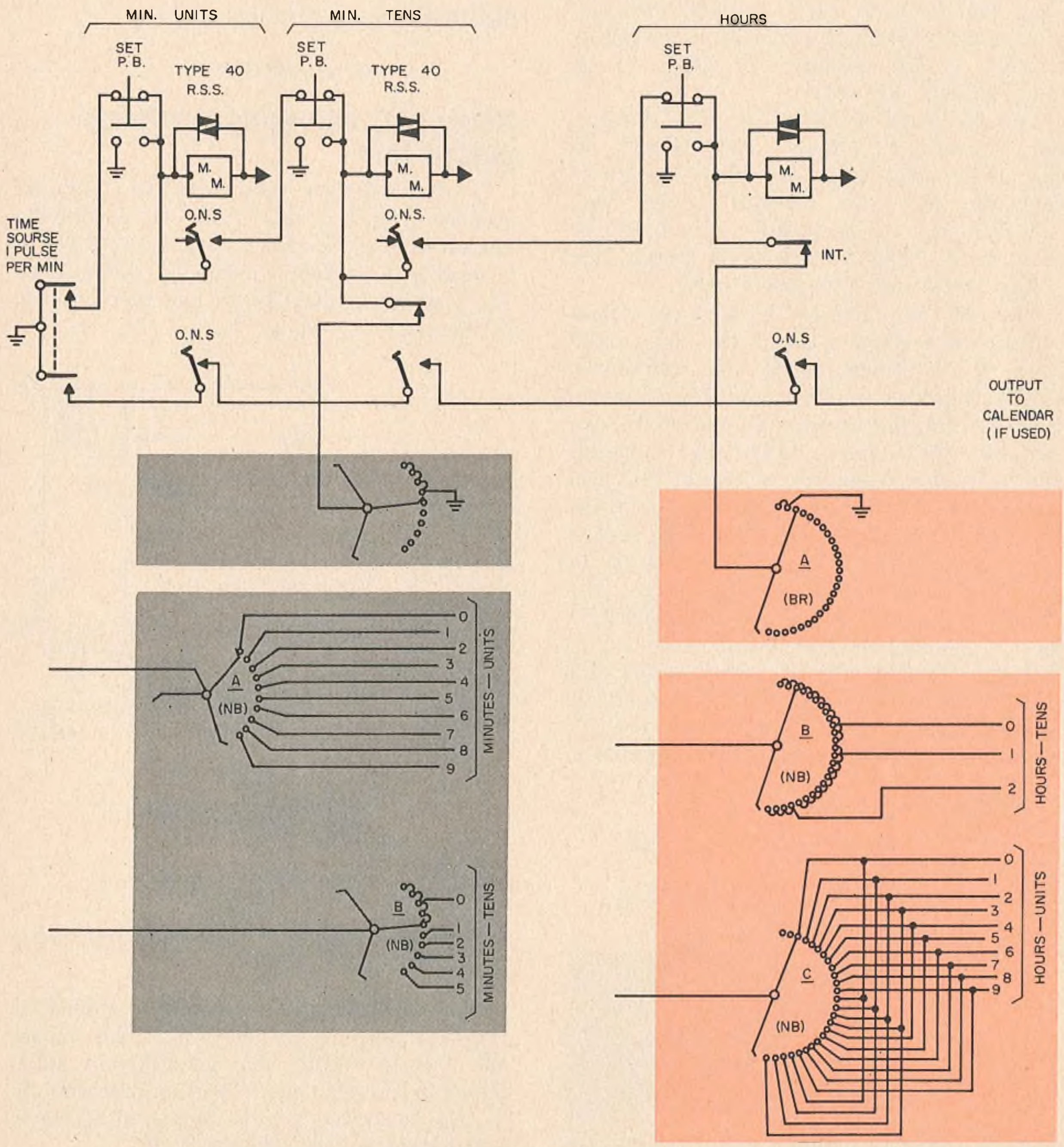
Digital clock uses 3 rotary stepping switches

A 24-hour clock that gives a decimal readout in minutes, tens of minutes, hours and tens of hours uses three rotary stepping switches. The clock is driven by a time source, which delivers one output pulse a minute.

Associated with each stepping switch is a pushbutton used for setting the clock. As shown, the clock is set at 0000, which normally corresponds to midnight.

When the pulse contacts of the time source close, the motor magnet of the minutes-units switch is energized. When the pulse contacts open, the minutes-units switch advances one step to its second, or one-minute, contact. This sequence occurs for each time pulse, until nine minutes have been registered, at which time the off-normal contacts of the minutes-units switch close. The next time pulse therefore steps the minutes-tens switch, as well as the minutes-units switch.

The interrupter (INT) contacts of the minutes-tens switch, together with their associated contact bank, cause the minutes-tens switch always to skip the first four bank contacts. So after the tenth time pulse, the minutes-units switch is at zero, and the



Digital clock uses rotary stepping switches to count time pulses and give 24-hour readout.

minutes-tens switch at one.

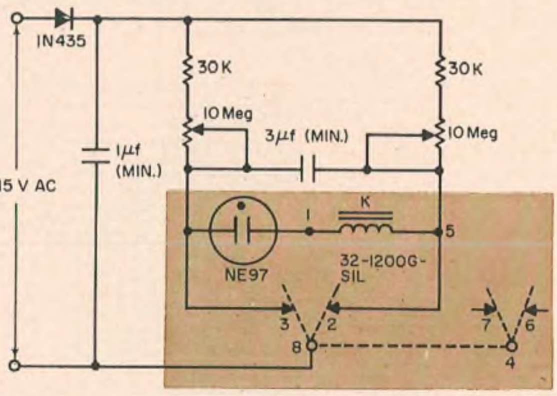
The minutes-hours switch operates in a similar manner when both the minutes-units and minutes-tens switches are on their tenth bank contact. If a digital calendar is used, a pulse will be sent along the off-normal switch chain to the calendar once each day.
SOURCE: *Automatic Electric*

Polarized latching relay forms free-running flip-flop

A free-running multivibrator with a cycling capability of up to 20 minutes can be designed using a bistable magnetic-latching relay and a neon lamp. A dual, variable-potentiometer arrangement within the multivibrator circuit permits the delay to be independently adjusted.

The free-running oscillator (see illustration) operates as follows: The 115-volt, 60 cps power is rectified by the diode. The 1.0 μf capacitor filters the rectified voltage such that the output is reasonably smooth and of the order of 150-175 volts dc for normal line voltage variations (105-130 vo Hs).

The relay is connected so that one of its contact sets always grounds one side or the other of the timing circuit. One side of the timing capacitor is also grounded, while the other is charging up through one of the two variable resistances. When the capacitor charges to the breakover voltage of the neon tube (110-140 volts), a pulse discharge through the relay coil occurs until the capacitor discharges to the maintaining voltage of the lamp (60-80 volts). This discharge pulse transfers the relay to its other stable position so that the positive-voltage side of the capacitor now becomes ground and the other side of the capacitor reaches 60 to 80 volts. From this value, it starts to charge in the positive direction. The next transfer will occur when the capacitor reaches the positive polarity value of 110-140 volts. Then, the second portion of the cycle commences.



Bistable, magnetic-latching polarized relay and neon lamp form long time-delay (up to 20 min), free-running multivibrator.

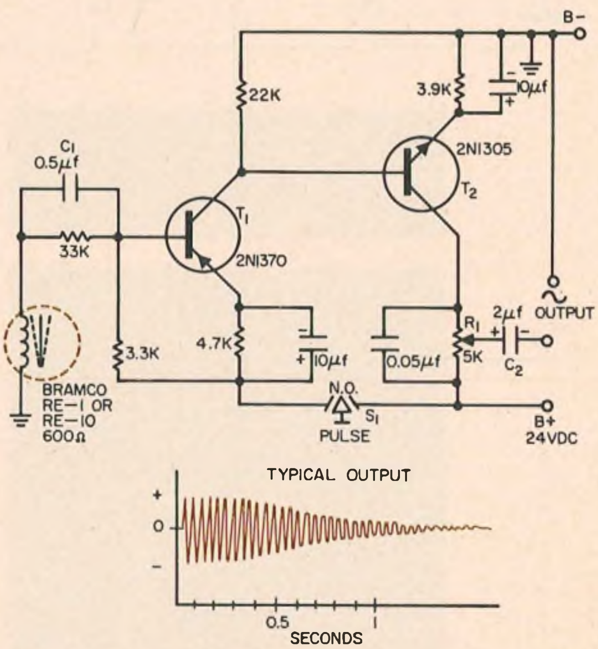
Three times the product of the potentiometer resistance and the capacitor gives the time in seconds (approximately) from one transfer to the next. With 10 Meg and 10 μf, the delay is 3 x 10 x 10 = 300 seconds per half cycle. The limit is determined by the leakage currents of the insulation or the capacitor.

The accuracy of the cycling primarily depends on the tolerances of the resistor and the leakage associated with the capacitance and secondarily on the characteristics of the relay and the neon tube.

SOURCE: *Sigma Instruments Inc.*

Resonant reed-relay produces pulsed tone

A resonant-reed relay can be used to produce a pulsed tone with an extremely narrow bandwidth. Each time the reed relay is pulsed, it produces a damped audio tone. The tone is amplified by T_1 and then clipped to the desired level by T_2.



Damped tone is produced each time the reed relay is activated by a dc pulse.

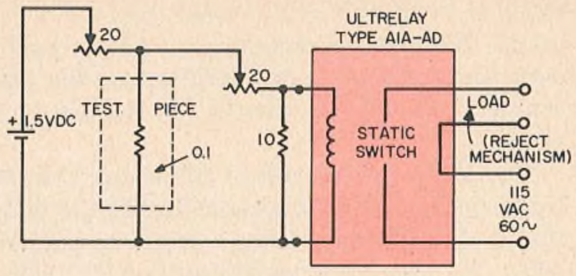
When S_1 is closed, a dc pulse is applied to the reed relay by means of C_1. This causes the reed to vibrate and generate an audio signal in the relay coil. After amplification by T_1, the generated tone is clipped at the level determined by the setting of R_1.
SOURCE: *Bramco Controls Div., Ledex, Inc.*

Sensitive static relay detects resistance limits

An ultrasensitive static relay that responds to fractional microwatt excitation can be used to detect resistance changes as small as 0.1 ohm. The relay also conveniently plugs directly into a 115-volt, 60-cps line.

The relay's sensitivity is derived from solid-state components built into its case. A magnetic-amplifier-driven SCR performs the actual switching. The trip point, which is adjustable through an external control, varies between 0.1 and 0.5 mv.

In the sensing system (see illustration), the 20-ohm potentiometers are adjusted such that if the resistance of the test piece has increased less than 0.1 ohm, the Airborne Accessories "ultRelay" coil is maintained below its energization level. A resistance increase of 0.1 ohm (or more) will cause a greater flow of current into the relay coil. The relay contacts then activate a solenoid reject mechanism, which can either label or remove the faulty test piece.



Ultrasensitive static relay placed in a bridge configuration detects resistance changes as small as 0.1 ohm.

SOURCE: *Airborne Accessories Corp.*

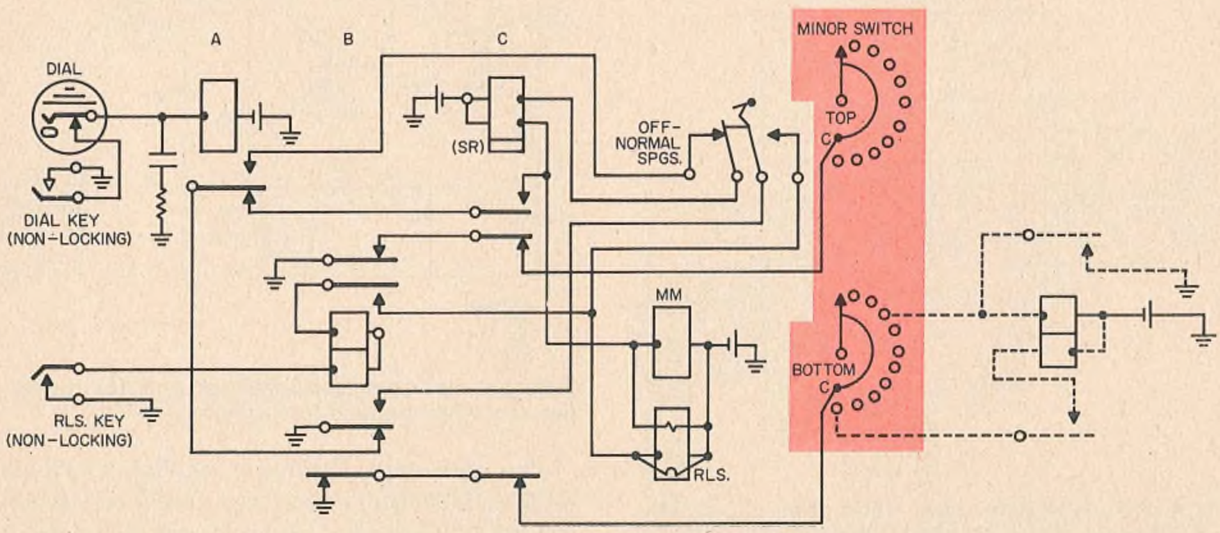
Telephone dial controls rotary stepping switch

Any one of various control functions can be selected by a directly driven rotary stepping switch remotely controlled by a telephone dial.

When a particular digit is dialed, the stepping switch, an Automatic Electric Minor Switch, advances to its corresponding contact. This actuates a control relay connected to that contact, and the relay, in turn, performs the required control function. Although only a single control relay is shown in the illustration, there can be as many relays as there are bank contacts on the stepping switch.

A key is used with the dial to prevent unauthorized dialing. The operation of the dial key closes the circuit to the coil of relay A. This applies a ground to the coil of relay C. The ground is applied through the normally closed contacts of the stepping switch. With relay C energized, the stepping switch's motor magnet (MM in the illustration) is under the control of relay A.

After a digit is dialed, relay A is alternately de-energized and energized as the dial restores. Each time it de-energizes, ground is applied to the holding winding of relay C to keep it energized and to the magnet of the stepping switch to cause it to step once. Each time relay A energizes, ground is removed from the holding winding of relay C and the magnet of the stepping switch. This de-energizes the stepping switch. However,



Rotary stepping switch counts the pulses produced by a telephone dial and actuates a specific control function corresponding to the digit dialed.

relay C is of the slow-release type and remains energized momentarily. As a result, each time relay A is de-energized by the dial contacts, the minor switch is stepped one position.

The dial comes to rest at the completion of the series of pulses corresponding to the digit dialed. At this time, relay A is energized and relay C, after the expiration of its slow-release interval, de-energized.

The stepping switch is returned to its normal, or inoperative, position by operation of the release key. When the key is closed it energizes relay B, which applies ground to the coil of the stepping switch's release magnet.

To de-energize the control relay and thus discontinue the external control function, digit 0 is dialed. This causes the stepping switch to stop on the tenth contact, which is wired to the secondary winding of the control relay. When relay C becomes de-energized, ground is applied to the control relay's secondary winding. The resulting magnetic field cancels the field of the primary winding, and the control relay releases.

SOURCE: *Automatic Electric, General Telephone & Electronics*

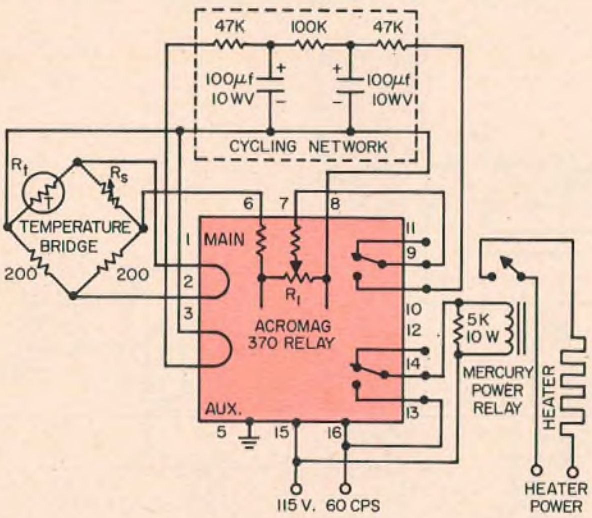
Ultrasensitive relay forms precise temperature controller

An ultrasensitive, low-level relay incorporating solid-state circuit features can control temperature to within a fraction of a degree. In addition, it accommodates the standard 115 vac, 60 cps power line.

The circuit is basically a Wheatstone Bridge configuration (see illustration). The relay trips on as little as 50 μv of input. A VECO type-31D38 thermistor and two very-stable, high-precision 200-ohm resistors form the fixed legs of the bridge. The bridge is arranged to be in balance at the set-point temperature. The set-point temperature is selected by adjusting R_s so that its resistance equals the thermistor's resistance. The thermistor changes from 350 ohms at 50°C to 70 ohms at 100°C. Therefore, R_s must cover this span or slightly more.

Adjusting R_1 on the printed-circuit board assists in optimizing the system's dynamics by varying the ON-to-OFF time ratio near the set point. This reduces the oven's temperature variations. In this example, a temperature change as small as 0.02°C operates the output relay. For higher power control, a mercury power relay should be interposed before the low-level relay and the load currents.

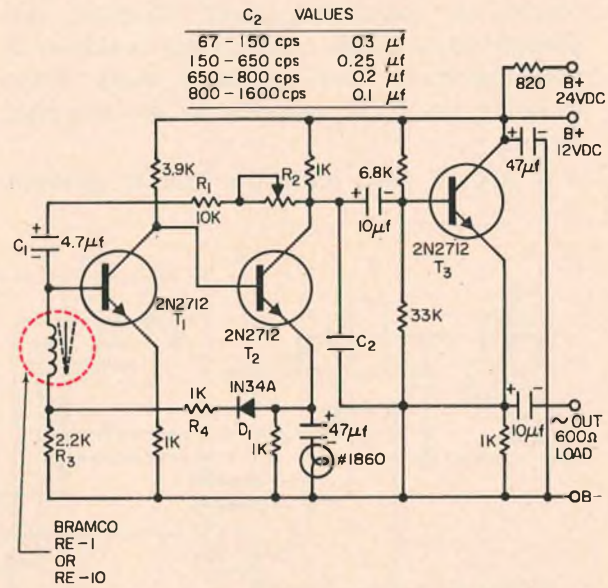
SOURCE: *Acromag, Inc.*



Low-level, solid-state relay, which trips on as little as 50 μv dc, forms the heart of a precision temperature controller system. By adjusting R_8 and R_1, the temperature may be controlled to within a fraction of a degree.

Resonant reed stabilizes audio oscillator frequency

Resonant-reed relays can act as accurate frequency-determining elements for audio frequency oscillators. They permit the frequency of a transistor oscillator to be controlled to within ±0.1%.



Resonant-reed stabilized oscillator uses the properties of a vibrating reed to sustain oscillation.

The two-stage feedback oscillator circuit in the illustration has two feedback paths: one path, C_1-R_1-R_2, controls amplifier gain; the other, C_2-R_3, provides a return signal to the reed coil to sustain oscillation. Oscillator frequency is determined by the characteristics of the reed relay. For any particular relay, various frequencies can be obtained by changing the value of C_2. Using Bramco reed relay type RE-1 or RE-10, various values for C_2 and their corresponding oscillator frequencies appear in the table below.

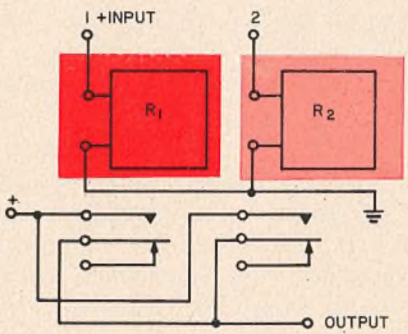
Random noise starts the reed oscillating, and the resulting inductive swing is amplified by T_1 and T_2. Variable resistance element 1860 varies the gain of T_1 and T_2, by varying the amount of emitter bypassing. The oscillator output is coupled to emitter follower T_3, which provides a low-impedance output.

Oscillator buildup time will vary from 0.1 to 60 seconds, depending on the frequency and feedback setting.

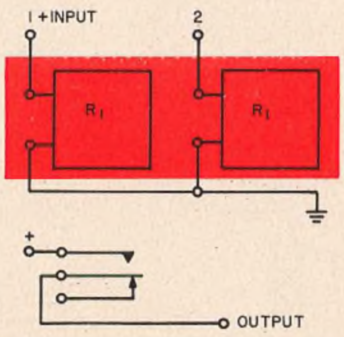
SOURCE: *Bramco Controls Div., Ledex, Inc.*

OR circuits simplified with double-coil relays

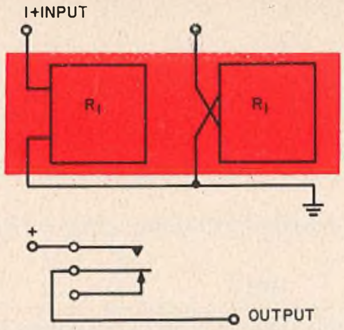
Double-coil relays can greatly reduce the hardware requirements in relay-logic OR circuits. With single-coil relays, the OR function is accomplished by two separate relays having their contacts connected in parallel (Fig. 1). The same OR function can be accomplished with one double-coil relay (Fig. 2). If either coil is energized, the contacts close to produce an output.



1. **Two single-coil relays** are used to make up this OR circuit.



2. **One double-coil relay** can be used for an OR circuit.



3. **EXCLUSIVE OR circuit** will produce an output only when one coil of the double-coil relay is energized.

The double-coil relay can also be used for a simple exclusive-OR circuit (Fig. 3). When both coils are energized, their fluxes buck. Because of this canceling effect, the relay contacts are not transferred. If only one coil is energized, the contacts transfer and produce an output.

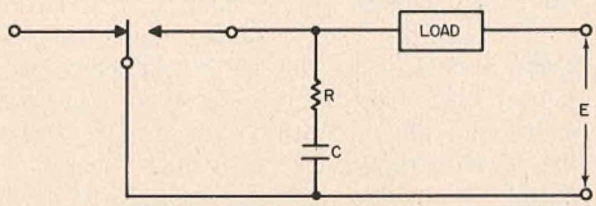
SOURCE: *IBM*

Table speeds RC network design for relay contact protection

A guide for designing RC overvoltage suppression networks can be established by using peak voltage amplitudes as the governing parameter. Although this RC network is commonly used to protect the contacts of mercury relays, it is applicable to general types of relays as well.

Mercury relays typically exhibit a rapid BREAK action. This results in the generation of large, transient peak-voltages across the load. These peaks are particularly dangerous when other than light loads (less than 0.5 amp) are being switched.

The RC network is placed between the load and the contacts (see illustration). It is placed as close as possible to the relay terminals. The design equations are:



RC contact protection network suppresses overvoltage transients

$$C = I^2/10 \quad \text{(in microfarads)} \qquad (1)$$

$$R = E/10I(1 + 50/E) \quad \text{(in ohms)}, \qquad (2)$$

where I is the load current in amperes that was flowing immediately prior to the opening of the contacts, and E is the source voltage (in volts) that existed immediately prior to the closing of the contacts.

The accompanying design table was derived from a test program. Equations 1 and 2 were applied to actual circuits, and the parameters and results were observed. The table is based upon the value of voltage encountered and the minimum safety margin needed to protect the contacts for that value of voltage.

SOURCE: *Adams-Westlake Co.*

RC contact protection network design

E (volts)	I (amp)	C (μf)	R (ohms)
Less than 50	Less than 2.5	Use calculated value	May be omitted
50 to 70	All other conditions	Use calculated value	3 X calculated value permissible
70 to 100	All other conditions	Use calculated value	Within 50% of calculated value
100 to 150	All other conditions	Use calculated value	Within 10% of calculated value
Above 150	All other conditions	Use calculated value	Use calculated value

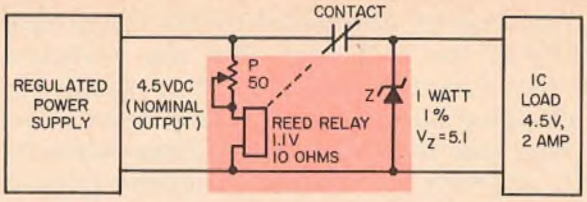
Note: for any voltage more than 50, the value of R must not be less than 0.5 ohm.

Integrated circuit protected by reed relay-diode combination

A reed relay and a zener diode can unite to provide overvoltage protection to integrated-circuit (IC) modules. The relay and diode are placed in a series-parallel configuration to open the IC load circuit.

The widespread use of low-voltage type IC modules has developed a need for overvoltage protection from power-supply defects. A typical industrial IC module has a nominal voltage rating of 4.5 volts and a maximum rating of 5.5 volts. A short-circuit in the series pass transistor (within the supply) can raise havoc with the IC. The supply's output votage will instantaneously double in value and damage the module.

A typical IC load requiring 4.5 volts at 2 amp connected to a series-parallel combination of reed relay and a zener diode appears in the illustration. With a sudden increase in the power supply's output voltage due to a regulation failure—for example, a rise to 9 volts—the zener diode reacts. It is rated at 5.1 volts and thus will immediately clamp the IC load at the safe 5.1-volt level. However, because the zener diode has a low wattage rating, its protection time is limited. This is where the reed relay comes in. Note that the relay will not open its contacts when the power supply voltage is 4.5 volts. However, with the application of a voltage slightly less



Combination reed relay and zener diode protect an integrated circuit from overvoltage.

than the zener diode voltage, the relay will energize and open the IC load circuit. This action removes the overvoltage from the load and cuts off the zener diode.

The reed-relay trip point is adjusted by means of potentiometer P, so that the contacts open at a voltage slightly less than the V_z of the zener diode. The reed relay is then supplied with a small current that is below its operating value (under normal supply voltage conditions). It will thus react rapidly to the larger voltage applied during power-supply failure.

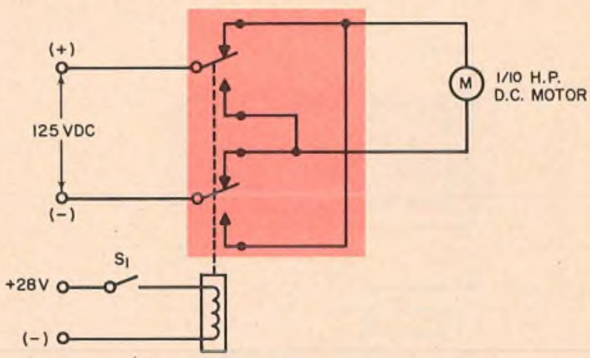
John J. McManus, Senior Project Engineer, Western Union Telegraph Co., New York, N. Y.

Relay provides simple reversal of dc motor

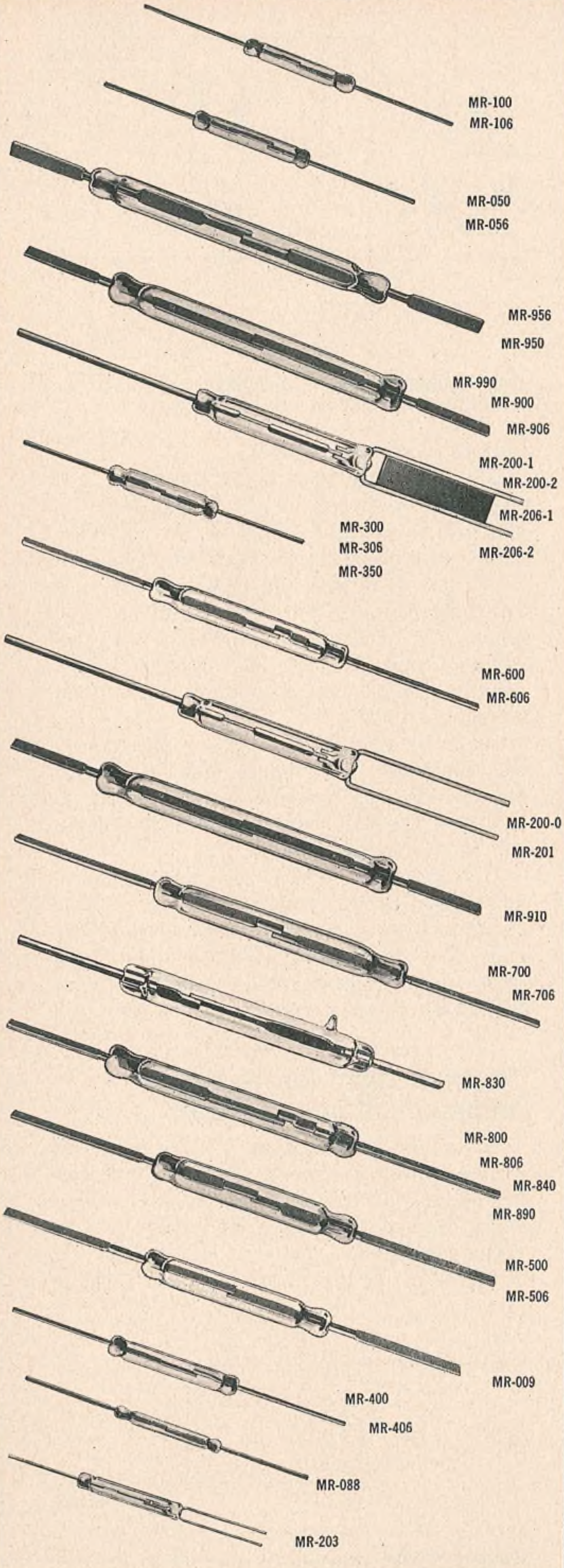
A common, dual-pole relay can be used to reverse a dc motor. It is less expensive than the approach that uses two interlocking relays, and it is far simpler than competing electronic circuitry arrangements.

The circuit (see illustration) reverses the voltage applied to the motor by having the relay contact sets connected in parallel opposition. A reversal occurs each time the coil is either energized or de-energized. Care must be taken to insure that the load current does not exceed the contact ratings. Arc-suppression circuitry may also have to be provided, if the inductive load is large enough to cause severe arcing.

SOURCE: *Leach Corporation*



Parallel-opposition arrangement of relay contacts reverses a dc motor.



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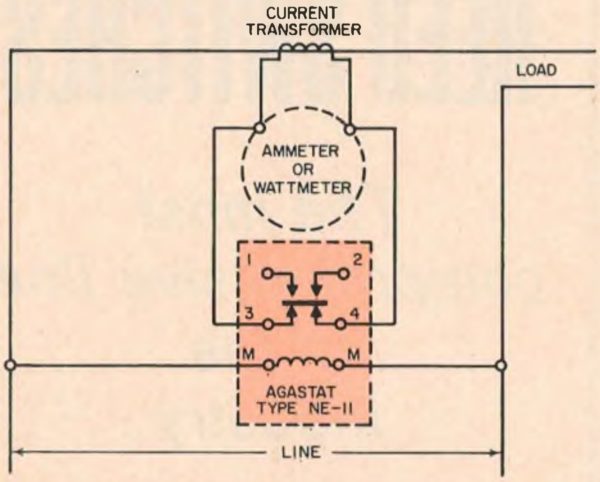
ON READER-SERVICE CARD CIRCLE 17

Time delay relay protects against inrush currents

In many installations of ammeters and wattmeters, provision must be made to protect the sensitive instrument mechanisms from sudden inrush currents beyond their capacity. "Meter slamming," or driving the pointer beyond the limits of the instrument range, may cause loss of calibration or do permanent damage to the moving elements. This protection is easily provided by a time-delay relay.



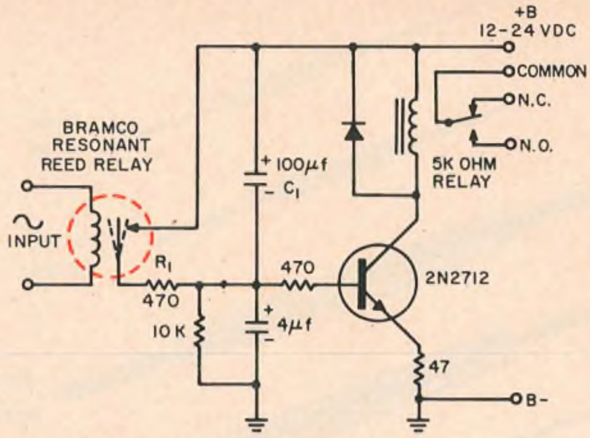
Time-delay relay prevents high inrush currents from damaging sensitive instruments.

As shown in the diagram, the unit's normally closed contacts (*3* and *4*) provide a short-circuit in the transformer line feeding the instrument, when no current is flowing. When voltage is applied, the coil (*MM*) is energized, initiating a time-delay interval while maintaining the transformer line short. This delay period prevents the high inrush currents from being transmitted through the instrument.

At the end of the timing period, the switch transfers, breaking the circuit between Contacts *3* and *4*. This removes the short from the transformer line and permits the instrument to indicate the normal load value. When the current flow is halted, the relay instantly transfers its switch to the original short-circuit position and is ready for the next voltage inrush.
SOURCE: *Agastat Timing Instruments*

Resonant reed controls timed latching relay

A resonant-reed relay can be used to actuate a timed latching relay circuit. The frequency selective characteristic of the reed relay enables it to discriminate between



Latching-relay circuit is energized for a predetermined time when the reed relay is pulsed.

various input frequencies.

The coil of the relay being controlled is in the collector circuit of a grounded-emitter stage. With no input signal to the reed relay, the transistor is biased to cutoff. When the reed relay is pulsed, the reed contacts close intermittently as the reed vibrates. This allows C_1 to discharge through the reed contacts and through R_1. When C_1 discharges, the transistor conducts, closing the secondary relay.

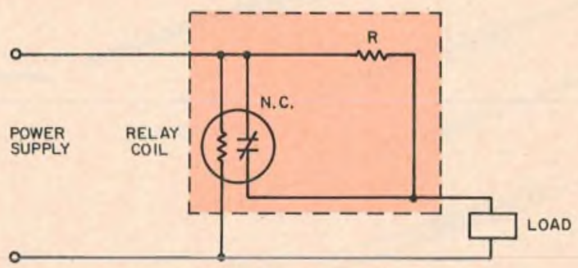
When the reed stops vibrating, the transistor continues to conduct until C_1 again charges up to the transistor cut-off point. At this time the transistor cuts off, de-energizing the secondary relay.

Lock-up time of the secondary relay is determined by the value of C_1. For a 100 μf value, lock-up is approximately 5 to 10 seconds. The diode across the secondary relay protects the transistor from inductive spikes.
SOURCE: *Bramco Controls Div., Ledex, Inc.*

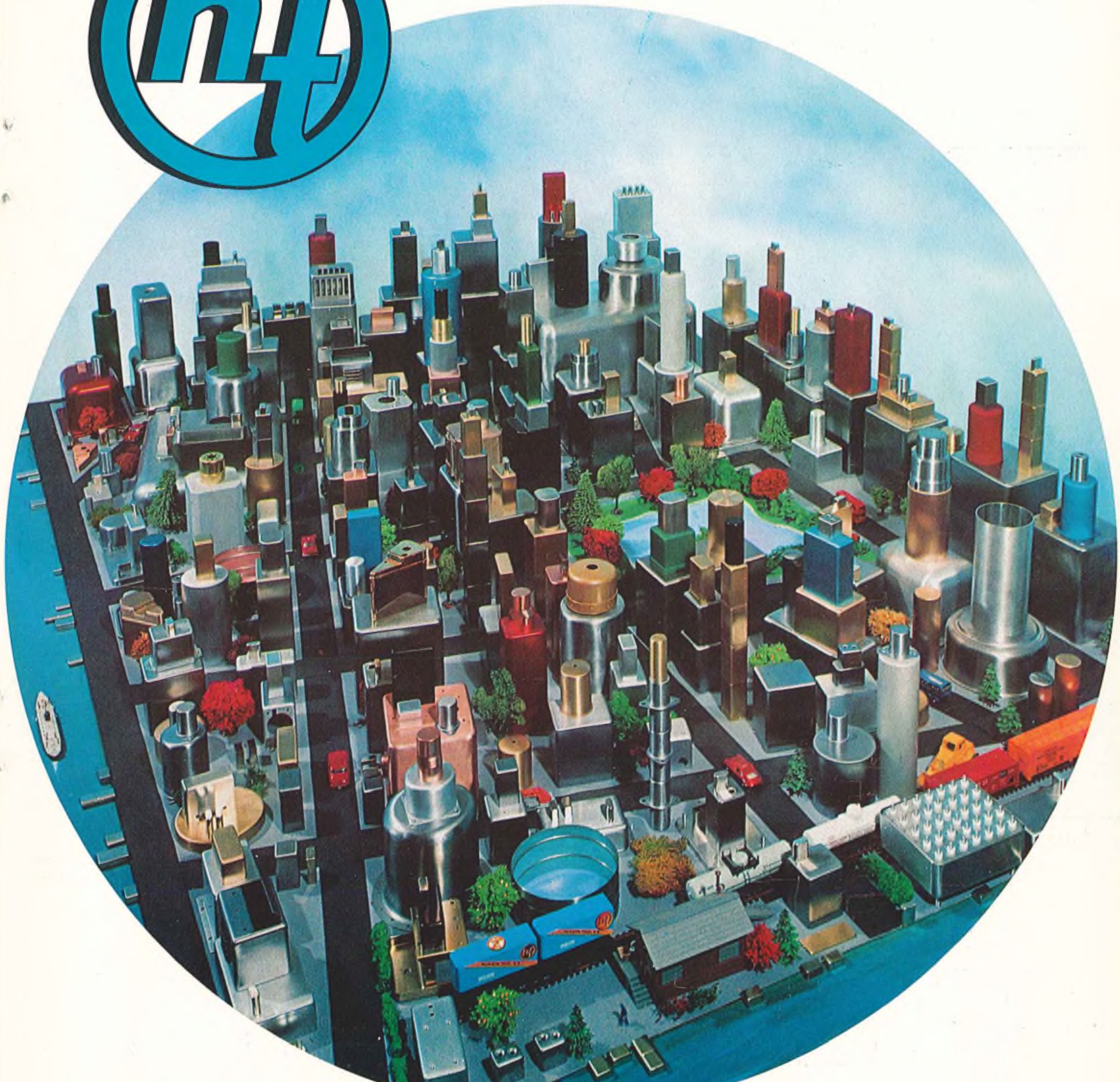
Thermal relay forms simple stepped voltage regulator

A voltage-sensing type of thermal relay can be used as an elementary voltage regulator. Wide variations in the supply voltage being applied to a fixed load may thus be reduced by half.

The relay in the illustration has a set of



Stepped voltage regulation is achieved by the thermal relay-dropping resistor arrangement.



HUDSON'S ELECTRI-CITY... U.S.A.

normally closed contacts. When the voltage level reaches one-half of its extreme fluctuations, the contacts open. This inserts a dropping resistor in series with the load. The resistor is selected to produce a voltage drop equal to one-half the total variation span.

For example, if the supply voltage varies between 24 and 30 volts (very common in portable equipment), the relay is set to operate at 27 volts, and the resistor is designed to bear a 3-volt potential. From 24 to 27 volts, the supply is fed directly to the load. Above 27-volt input, the resistor absorbs the excess voltage.

SOURCE: *G-V Controls, Inc.*

Pulsed relay generates low-level step functions

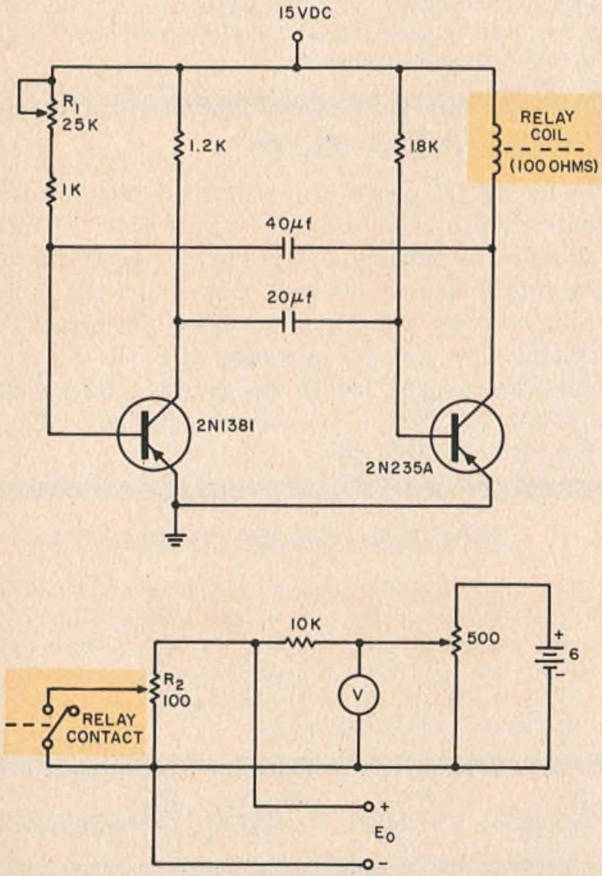
A relay and a multivibrator may be combined to produce a step function waveform to be used to modulate millivolt-level dc signals. Repetitive, low-level steps are generated when the relay's contacts are used to sequentially short out a portion of a voltage-divider network.

In the circuit (see illustration), transistors Q_1 and Q_2 form a free-running multivibrator. The multi's output is used to drive the relay coil. As the multi flips back and forth, the relay's contacts switch the lower half of the R_2 dividing potentiometer in and out of the circuit. This action produces the low-level step voltage waveform.

For the component values shown, the repetition rate may vary between 0.1 and 8.0 pulses-per-second (pps). Potentiometer R_1 in the base of Q_1 permits the user to set the desired pps rate. The amount (percent) of modulation may also be varied by adjusting output potentiometer R_2.

The output voltage, E_o, is approximately 0.01 of the monitored voltage, V. E_o varies between zero and 60 mv.

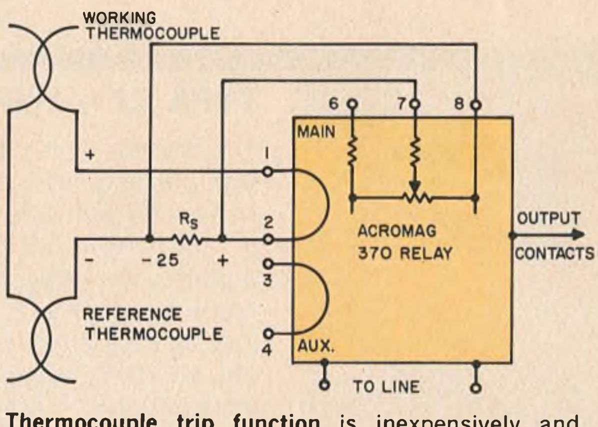
SOURCE: *Portronics, Inc.*



Pulse relay driven by multivibrator step-modulates low-level dc signals. Potentiometer R_1 permits the repetition rate to be varied. For the component values shown, output levels up to 60 mv are generated.

Microvolt dc relay makes inexpensive thermocouple trip

A low-level, solid-state relay can easily and inexpensively function as a thermocouple trip control. It is especially useful for fairly constant ambient-temperature environments.



Thermocouple trip function is inexpensively and simply achieved by ultrasensitive solid-state relay.

A dc-biasing signal is derived from the built-in dc reference in the Acromag Model 370 relay (see illustration). This permits the trip temperature to be adjusted. The circuit is basically a differential voltage comparator that can be adjusted over a range of 0-50 mv. The maximum-temperature trip point is fixed by R_s. For tighter control (lower maximum temperature), R_s should be decreased according to the difference in thermocouples expected and the sensitivity range desired in the comparator.

SOURCE: *Acromag, Inc.*

BRANSON CORP.

RELAYS

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HALF CRYSTAL CAN
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LATCHING
TIME DELAY

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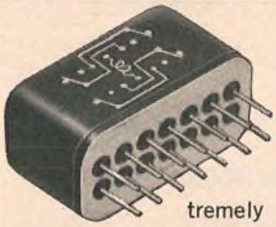
The industry standard, reliable DPDT and 4PDT (4 Form C) relays. Contact rating, dry circuit to 2 amp., 28 v dc. Operate and release times, 5 ms, max. Volume, 0.27 cu. in., Weight, 15-20 grams. Delivery of standard units from stock.

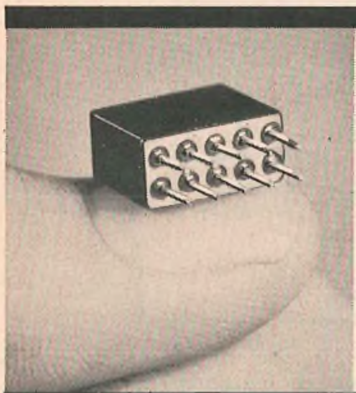


TYPE SR HALF CRYSTAL CAN 2 & 4 POLE RELAYS

Highly compact, light-weight DPDT and 4PDT relays; extremely high switching density per unit volume; Contact rating, dry circuit to 2 amps 28 v dc. Operate and release times, 5 ms, max. Volume, 0.13 cu. in., Weight, 6-10 grams. Delivery of standard units from stock.

TYPE QR HALF CRYSTAL CAN SOLID STATE TIME DELAY RELAY

Provides time delays ranging from 10 ms to 60 seconds over a 20 to 32 v dc range. High speed recovery time of 20 ms permits use in circuits where high recycling is necessary. Type QR weighs less than 10 grams, occupies only 0.13 cubic inches, has a built-in regulator and filter to assure a timing accuracy of ±10% over a wide range of temperatures and voltages. Exceeds all applicable MIL Specs. Other features include elimination of triggering errors caused by normal line transients and diode protection against polarity reversal. Available in a variety of case and header styles.



TYPE LJ – 1/6 SIZE LATCHING RELAY

The Branson LJ is the only latching 1/6 crystal can size DPDT relay available, with contacts rated a 1 amp resistive at 28 v dc. It measures .2″ x .4″ x .5″, weighs 4-6 grams, and is hermetically sealed to operate in a temperature range of −65°C to +125°C. Operating time is 4 ms max. Operated from a short-duration, low power pulse, the contacts will remain in either position without consuming power. It is available with coils for operation at 6, 12, 24 and 48 v dc. in a variety of case and header styles. Meets applicable requirements of MIL-R-5757D. Withstands shock at 100g 11ms, acceleration of 150g and vibration of 0.1″ D.A. or 30g peak 10-3000 cps.

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Specially designed line of relay sockets, molded from glass-filled diallyl phthalate . . . meet rigorous electrical and mechanical requirements compatible with those of Branson relays. Terminals finished in gold over silver plate. Variety of standard terminal and mounting styles.

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The relays illustrated are some of Branson's standard types. They are supplied in a wide variety of standard and custom case and header styles. Modifications to customer requirements are available. An Applications Engineering Department is available for custom designed relays to specific applications and specifications.

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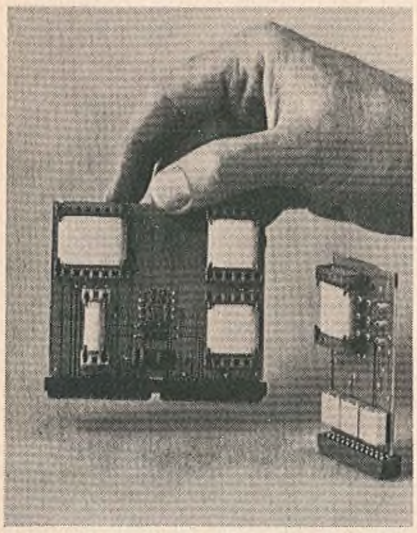
ON READER-SERVICE CARD CIRCLE 18

Reed relays

Quality control tests are said to indicate a reliability level beyond 125 million operations (mean time to first error) for a line of miniature reed relays. The line includes types with one, two, four, and six-pole normally closed, magnetically



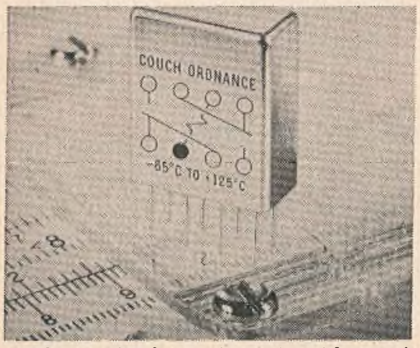
biased contacts, plus various combinations with either pick- or both pick-and-hold coils. They are rated to handle from 10 mv at 100 μamp to 50 v at 500 amp. Contact operate time is 1 msec and release time is 100 μsec.

Price: $3.00-$13.20. IBM Industrial Products Div., 1000 Westchester Ave., White Plains, N. Y. Phone: (914) 696-1900.

ON READER-SERVICE CARD CIRCLE 401

Rotary relay

The hermetically sealed dpdt type 2X relay is provided with a 0.1-in.



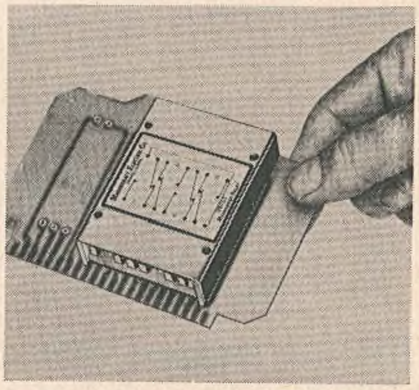
grid terminal spacing. A wide variety of terminals, coil resistance values and mounting styles are available in the line.

Couch Ordnance, Inc., 3 Arlington St., North Quincy, Mass. Phone: (617) 298-4147.

ON READER-SERVICE CARD CIRCLE 402

Multiple reeds

Multiple reed relay circuitry is provided by the Multi-Pak printed circuit assemblies. A large unit



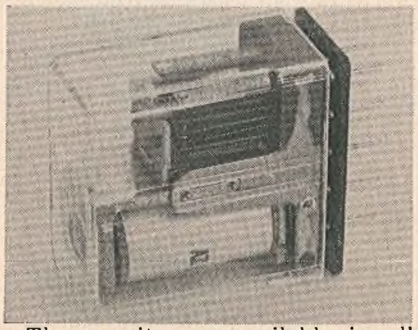
combines dry reed contacts to four form-C, or dry reed and mercury-wetted contacts to seven form-A. A smaller unit combines two form-C dry reed to three form-dry reed and mercury-wetted contacts.

Magnecraft Electric Co., 5567 N. Lynch, Chicago, Ill. Phone: (312) 282-5500.

ON READER-SERVICE CARD CIRCLE 403

Cradle relay

The type AZ 216 relay is available in 2pdt and 4pdt contact configurations rated at 1 amp at 29 vdc. Applications include various types of computer and business machine equipment and other areas where printed circuit board assemblies are used.



These units are available in all popular dc coil voltages and are adapted to low-level signal applications by gold-plated fine silver contacts. Other materials are also available. Maximum dimensions are .620-in. x 1.40-in. x 1.26-in. high.

Price: about $3.00. American Zettler, 401 W. Imperial Hwy., La Habra, Calif. Phone: (714) 879-5800.

ON READER-SERVICE CARD CIRCLE 404

Multi-coil relays

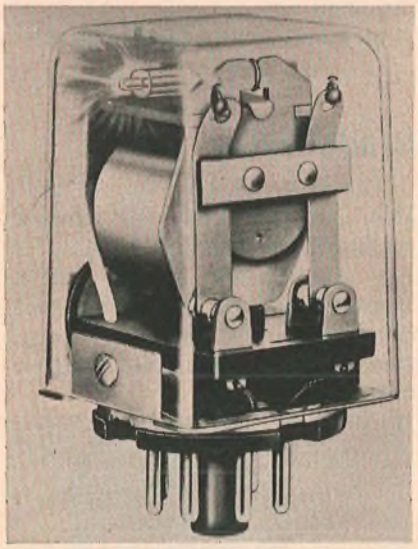
High-speed switching with bounceless contact performance is said to be provided by the MDP series of multi-coil relays. Contact arrangements are bi-stable, single-side-stable, and center-stable. The relays are available with one, two, three or four coils with standard resistances up to 4 K.

Potter and Brumfield, 1200 E. Broadway, Princeton, Ind. Phone: (812) 385-5251. TWX: (812) 291-4125.

ON READER-SERVICE CARD CIRCLE 405

General purpose relay

The Model 22AL incorporates a subminiature neon lamp connected across the coil terminals. This lamp glows whenever the coil is energized. Lack of this glow indicates a circuit failure and aids servicing in relay banks and multiple or isolated relay installations.



A variety of contact arrangements are available. Standard contact material is gold-plated, silver cadmium oxide. Special contact materials are also available. Another feature of the 22AL is a pull-in voltage (dc: 70% of nominal voltage; ac: 75% of nominal voltage).

E. W. Bliss Co., Eagle Signal Div., 736 Federal St., Davenport, Iowa. Phone: (319) 324-1361. TWX: (319) 322-0069.

ON READER-SERVICE CARD CIRCLE 406

Industrial relay

The 200 series is a general-purpose relay with contact combinations up to double-pole double-throw. It is designed to accomplish low cost on-off type of circuit switching in industrial and consumer electronic applications.

Load currents can range up to 1 amp resistive and it occupies less than 0.5 cubic inch when mounted on a printed circuit board.

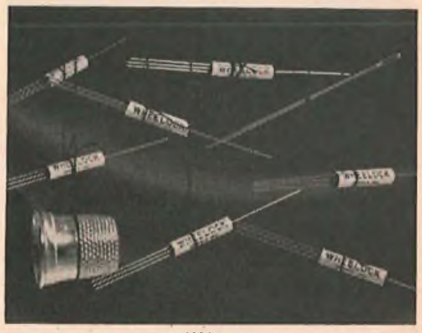
Price: from $1.25. Price Electric Corp., Frederick, Md. Phone: (301) 663-5141. TWX: (301) 553-0462.

ON READER-SERVICE CARD CIRCLE 407

Needle relay

The Needle Relay Series 370 occupies a volume of 0.02 cubic inches, and its diameter is only 0.19 inches.

Nominal coil voltages available are 6 volts and 12 volts with nominal rated coil power of 50 or 60 milliwatts, respectively. Contacts are



rated at 125 milliamperes, 4 watts and have a life rating of 10 x 10^6 operations at rated load. Maximum operate time is 0.40 msec and weight is only 1.1 grams.

Wheelock Signals, Inc., 273 Branchport Ave., Long Branch, N. J. Phone: (201) 222-6880.

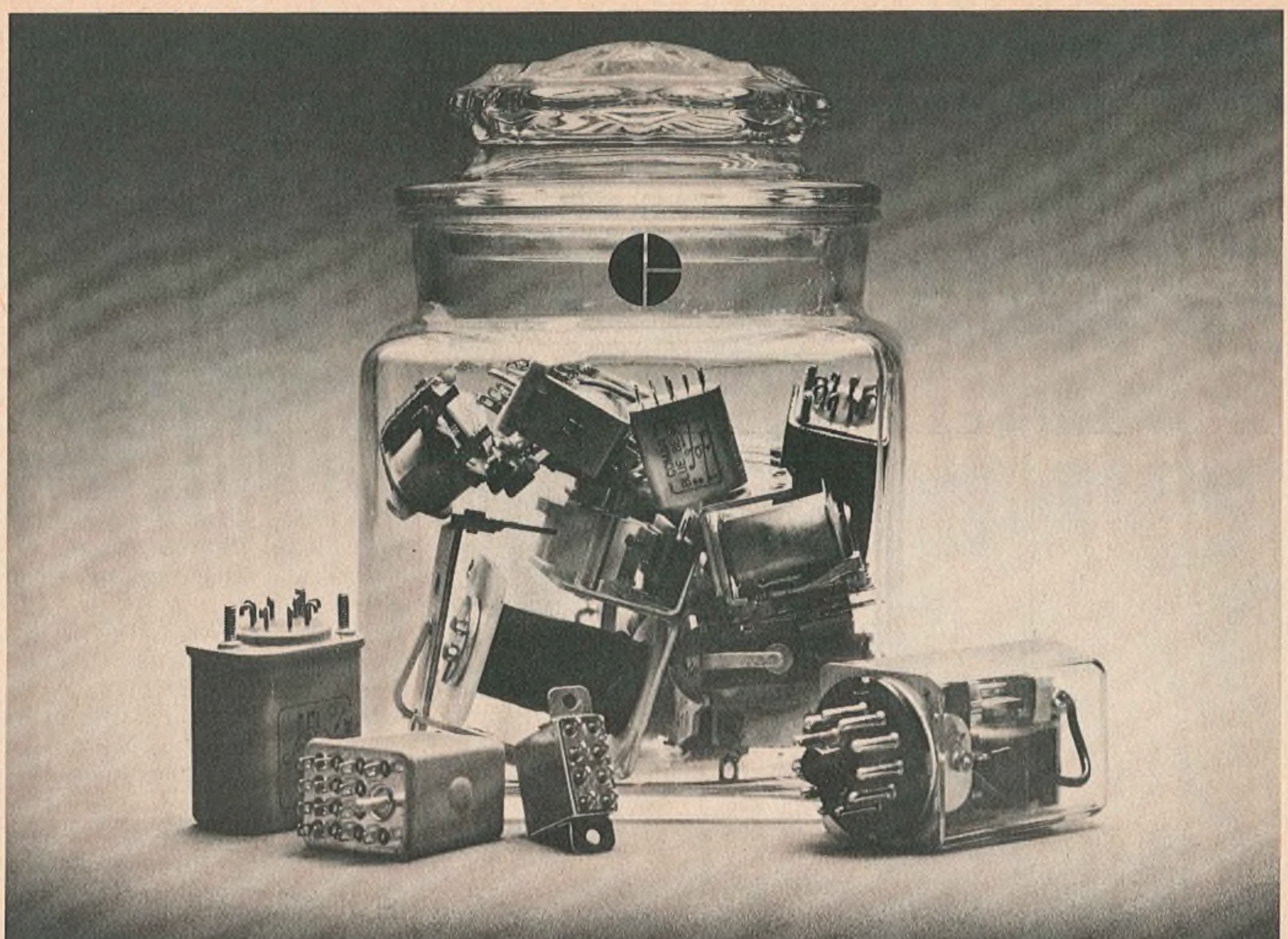
ON READER-SERVICE CARD CIRCLE 408

Polarized relay

A polar relay of dual-coil construction, the Series P is suggested for use in differential operation in such areas as telegraphy. With sufficient drive power, Series P relays can repeat and shape pulses at a rate beyond 1 Kc. Contacts are rated at 1 amp, 115 vac resistive, and life is estimated for 100,000 operations.

Hart Mfg., Co., 110 Bartholomew Ave., Hartford, Conn. Phone: (203) 525-3491.

ON READER-SERVICE CARD CIRCLE 409



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Rocky Hill, Conn.
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Willgold Electronic
Sales Corporation
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Rockville Center, New York
RO 4-4022

ON READER-SERVICE CARD CIRCLE 21

Reed relays

The Chemtron series of reed relays includes 75 stock units featuring vacuum impregnation and magnetic shielding. Printed circuit pins are spaced at 0.1-in. The coils can

be driven by low-power transistors.

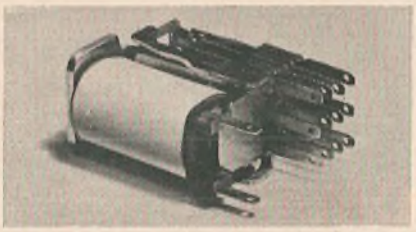
Self-Organizing Systems, Inc., P. O. Box 9918, Dallas, Texas. Phone : (214) 276-9487.

ON READER-SERVICE CARD CIRCLE 410

Miniature relays

A line of miniature general purpose relays, the type R10-N, are designed for use in control systems, computers, industrial equipment, communications equipment and other similar applications.

These open-type relays are available in a choice of solder or printed-



circuit terminals. Contacts rated at 5 amps, 2 amps or dry circuit are offered in 2, 4 or 6 Form C configurations. Mechanical life expectancy is 100,000,000 cycles.

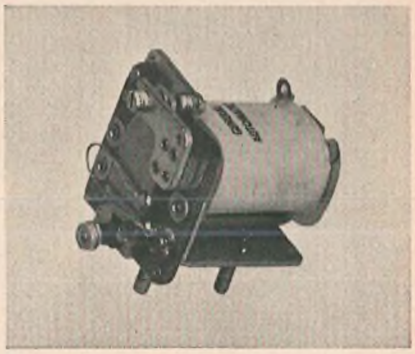
Price: from $2.00. Parelco, Inc., 2288 Westwood Blvd., Los Angeles, Calif. Phone: (213) 474-9553.

ON READER-SERVICE CARD CIRCLE 411

Open frame relay

Designated Series 8, a single-pole, double-throw relay operates on dc with sensitivity starting as low as 1 milliwatt. Featured in the design are a wide range of precision adjustments that are achieved by means of threaded screw contacts.

These contacts permit the user to trim the relay to the circuit requiremens. Among the adjustments possible is one for close



differential applications (also called high release) between operate and release values which may be as high as 80%.

Specifications on coil resistance range from 100 megohms to 27 K. The contacts are rated from low level to 2 amperes resistive at 28 volts dc or 115 volts ac. Special contacts also available for ratings up to 5 amp.

P&A: from $1.85; 4-5 weeks. General Automatic Corp., 7 Sherman Ave., Jersey City, N. J. Phone: (201) 653-8970.

ON READER-SERVICE CARD CIRCLE 412

Voltage sensing relays

Model 3910 is a voltage-sensing relay with a 1.0-amp dpdt electromechanical-relay output while the 3917 voltage sensor features a spst normally-open solid-state output.

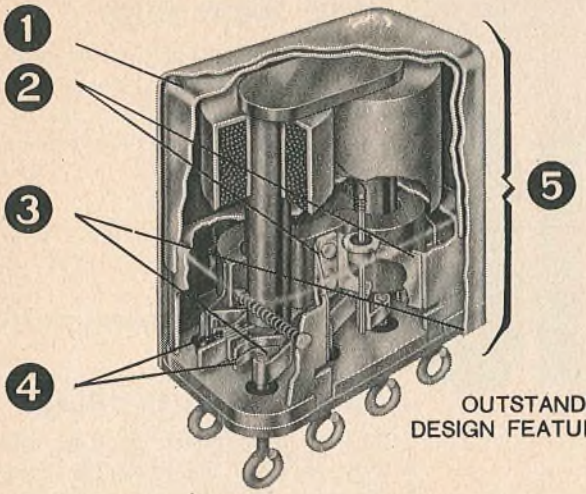
Each unit will sense voltages of 6 to 12 vdc without the use of external components at an accuracy of

±1% of the selected value. Trigger input current is 0.7 ma max and trigger input impedance is 2 K/volt.

Bourns, Inc., 1200 Columbia Ave., Riverside, Calif. Phone: (714) 684-1700. TWX: (714) 682-9582.

ON READER-SERVICE CARD CIRCLE 437

HART SERIES T CRYSTAL CAN RELAY



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❶ **Hermetically Sealed Coil** prevents contact contamination; seals organic coil material from switch section. ❷ **Unique Hinge Design**—no pivot or bearing problems; free from wear particles. ❸ **Welded Construction** increases reliability of joints; further reduces contamination. ❹ **Bifurcated Contacts** increase low level switching reliability. ❺ **Improved Sensitivity**—100 MW or less at pull-in.

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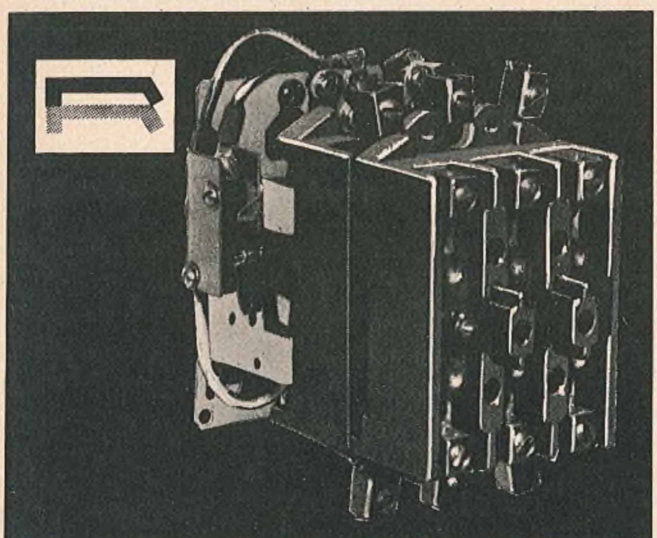
ON READER-SERVICE CARD CIRCLE 23

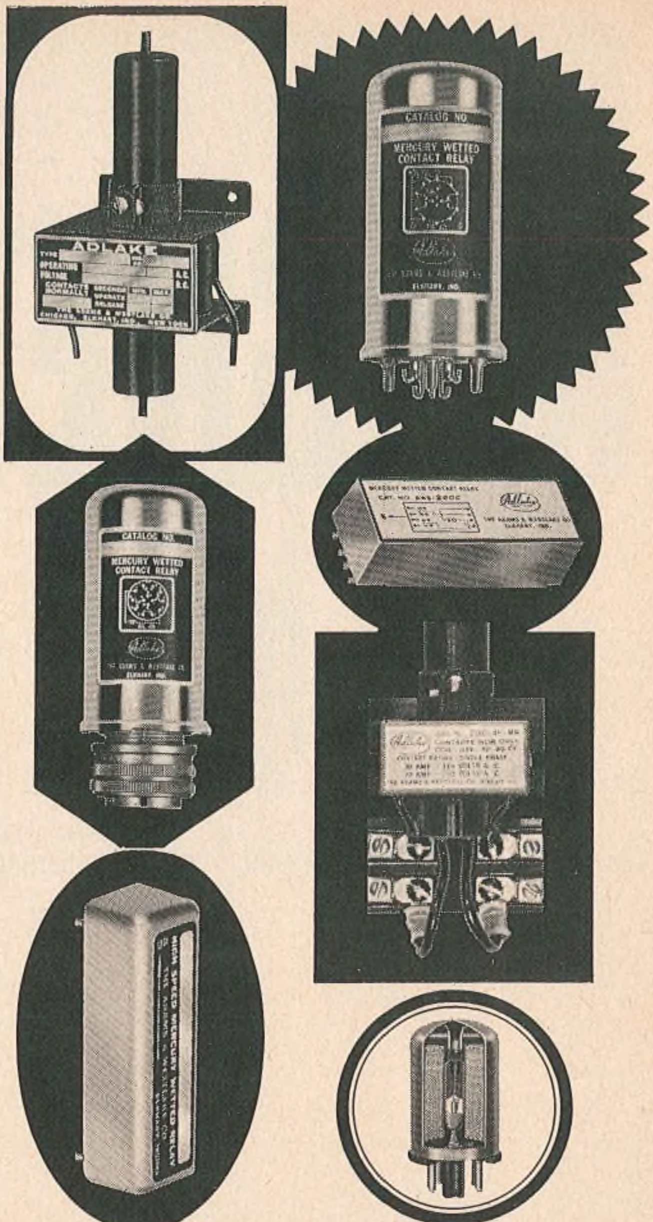


POWER CONTACTOR

Is for applications requiring up to six pole arrangements, 25, 30, 40, 60 or 75 amps, up to 600 volts, plus four auxiliary contacts N/O or N/C, and with either AC or DC coils. Ideal for simultaneous 2-motor operation, or transfer switching needing N/O and N/C main poles, or for additional auxiliaries above main poles. Simple double stacking of contact decks saves money and space. *Write for more information*

THE ROWAN CONTROLLER CO.
P. O. Box 306 • Westminster • Md. 21157

ON READER-SERVICE CARD CIRCLE 24



ADLAKE MAKES MORE KINDS OF MERCURY RELAYS THAN ANYBODY*

You name it! Adlake has: Time delay; load (contacts open or closed); wetted contact (including epoxy encapsulated, polarized and sensitive or bi-stable). For full information call your Adlake representative, or Adlake direct.

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THE ADAMS AND WESTLAKE COMPANY
Dept. R-7711 Relay Division
Elkhart, Indiana, Phone 219
CONGRESS 4-1141

A+dlake® RELAYS

ON READER-SERVICE CARD CIRCLE 25

Time delay relay

The type 1040-M time delay relay uses enclosed mercury-to-mercury contacts. Delay preset range is 0.5 sec to 20 minutes with a single-pole single-throw action.

Adams & Westlake Co., 1025 N. Michigan, Elkhart, Ind. Phone: (219) 264-1141. TWX: (219) 522-3102.

ON READER-SERVICE CARD CIRCLE 419

Plug-in control relays

A line of magnetic plug-in relays, type 6P, are designed for general purpose control use. Available in one, two or three poles double throw, these 5 amp plug-in relays feature mechanical and electrical life to 10 million operations.

They are enclosed in a plastic cover and have pin plugs for use with standard 8- or 11-pin octal bases. Open type relays for single stud mounting are also available. Coils are available for ac or dc operation to 115 volts maximum.

P&A: from $4.40. Ward Leonard Electric Co., Mount Vernon, N. Y. Phone: (914) 664-1000. TWX: (914) 699-4997.

ON READER-SERVICE CARD CIRCLE 420

Power relay

A floating movable contact arm gives the STM power relay a self-wiping action and high contact pressure. The relays are designed primarily for industrial applications where large currents are encountered. Contact rating at 115 vac and 30 vdc is 25 amp.

Line Electric Co., 249 River St., Orange, N. J. Phone: (201) 672-8200.

ON READER-SERVICE CARD CIRCLE 421

Polarity reversing relay

Two normally open contacts and two normally closed contacts are provided by the 16410009 relay. The unit has a contact rating of 5 amp at 600 vdc resistive. Coil rating is 32 vdc. Overall dimensions are 7-5/8 x 3-3/8 x 3-in.

Vapor Corp., 6420 W. Howard St., Chicago, Ill. Phone: (312) 631-9200.

ON READER-SERVICE CARD CIRCLE 422

2pdt relay

A two-pole, double-throw subminiature electromechanical relay in a cylindrical or "lipstick case" configuration weighs only 1-1/2 oz.

Designated the series 400, the unit incorporates the principle of a plunger-type solenoid to actuate the moving contacts. Each of the fully supported movable contacts is positioned between two rigidly mounted stationary contacts. Movement of

the actuator in either the energizing or de-energizing direction is translated into a wedging action of the moving contact against the fixed contact ramp.

Designed for optimum reliability, minimum size and weight, and operation under severe environmental conditions, the series 400 operates in dry or power circuit applications. They meet Mil-R-5757/8.

Measurements are .645-in. max in diameter and 1-25/32-in. high over-all.

Electro-Tec Corp., P. O. Box 667, Ormond Beach, Fla. Phone: (305) 677-1771.

ON READER-SERVICE CARD CIRCLE 423

Crystal can relay

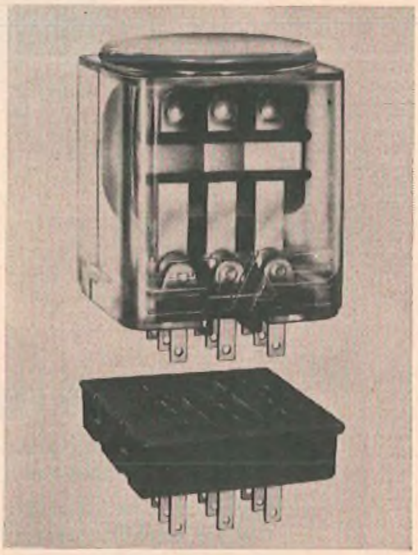
Weighing only 15-20 grams, the Type AR relay meets the requirements of MIL-R-5757D. Connections for the four-pole unit are on 0.1-in. grid spacing. Several mounting styles are available from stock and special types can be made available on special order. Contact rating is 2 amp at 28 vdc resistive.

Branson Corp., Vanderhoff Ave., Denville, N. J. Phone: (201) 625-0600.

ON READER-SERVICE CARD CIRCLE 424

Plug-in relay

The type 155 plug-in relay uses a new socket to permit direct plug-in without the use of octal plug. Advantages are said to include cost reduction by elimination of internal wiring and soldering associated with use of octal plug, increased



reliability by elimination of these solder joints, and a reduction in the overall height of the relay. Sp-through 3-pole relays are available with contacts rated at 10 amp resistive.

Telex/Aemco, 10 State St., Mankato, Minn. Phone: (507) 388-6288. TWX: (507) 890-8118.

ON READER-SERVICE CARD CIRCLE 414

Solid state relay

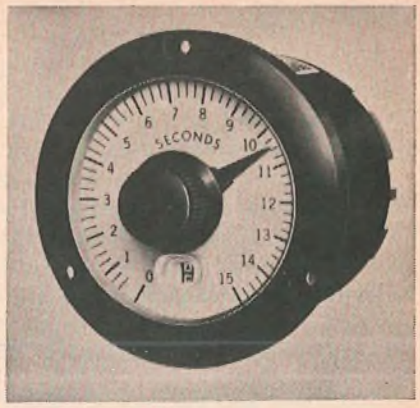
The DEI series solid state relay provides an operate and release time of 0.5 to 2 μsec. Its equivalent coil resistance is 650 ohm and drive voltage is 5 to 15 v. Contact isolation is 1000 Meg, 0.7 pf at 150 v peak.

Ro Associates, 917 Terminal Way, San Carlos, Calif. Phone: (415) 591-9443.

ON READER-SERVICE CARD CIRCLE 415

Time delay relays

Industrial type time delay relays of the K41300 line are panel-mounted with an integral dial, adjustment knob, and a time-remaining indicator. Load switches are two 15 amp spdt snap-action type and two 10 amp open-blade, solenoid operated.



Users can specify any one of fourteen time ranges from 0 to 6 seconds to 0 to 60 hours at 6, 12, 24, 115 or 230 vac, 60 or 50 cps operation. Timing accuracy is ±0.5% of dial scale.

A. W. Haydon Co., 232 North Elm St., Waterbury, Conn. Phone: (203) 756-4481.

ON READER-SERVICE CARD CIRCLE 416

Dc relay

As little as 50 μv will trip the Model 370 dc relay in instrumentation and control applications. It has two isolated signal inputs, an integral dc reference and it is remotely programmable.

Acromag, Inc., 15360 Telegraph Rd., Detroit, Mich. Phone: (313) 538-4536.

ON READER-SERVICE CARD CIRCLE 417

Mercury plunger relay

The Mini Relay is 3-in high x 1-7/8-in. wide x 1-7/8-in. deep and is available with quick connect terminals.

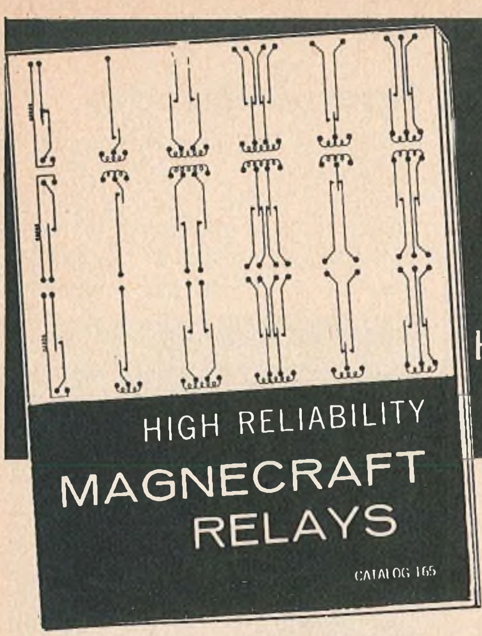
It is rated to control loads up to 20 amperes at 120 vac and it can safely handle 2300 watts resistive.

Using liquid mercury-to-mercury contacts within a hermetically

sealed, shatter-proof tube, the Mini Relay is said to permit millions of makes and breaks without service or repair.

Ebert Electronics Corp., Floral Park, N. Y. Phone: (516) 437-7777.

ON READER-SERVICE CARD CIRCLE 418



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- Air Dashpot Time Delay
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ON READER-SERVICE CARD CIRCLE 29

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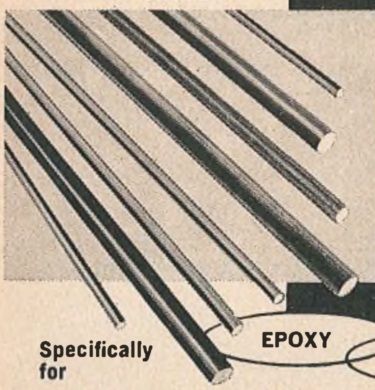

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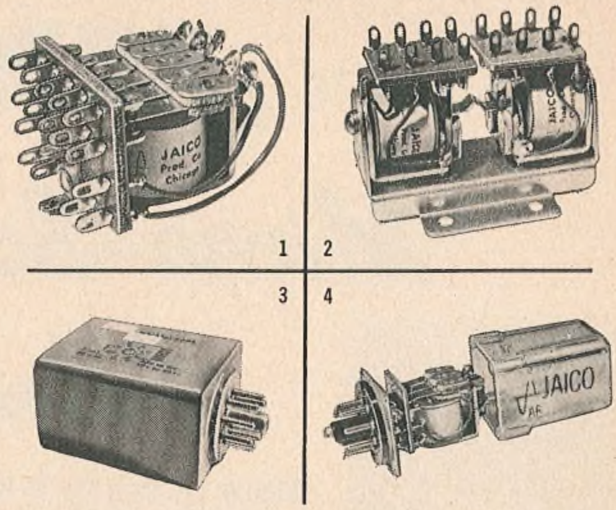
ON READER-SERVICE CARD CIRCLE 30

JAICO RELAYS

THE INDUSTRY'S STANDARD



1. **Standard AR Relays:** Available in AC or DC models up to 5 Form "C" switch combination. Maximum 12 amps at 24 volts DC or 115 Volts AC. Maximum contact voltage, 400 volts AC or 150 volts DC. Coil supplied from .02 to 30,000 ohms with sensitivity of 60 milliwatts per pole for DC operation. 10 amps to 300 volts for AC.
2. **Latching:** Relays to 10 Form "C" available.
3. **Hermetically Sealed:** Can be made with up to 5 form "C" with standard stock seals.
4. **Dust Cover:** Available up to 3 Form "C" plug in type with 8 or 11 pin plug. Colored styrene cases available—neon lamps to indicate circuit function can be supplied.

OTHER QUALITY RELAYS

■ **MD Relays:** Up to 6 Form "C" switch combinations or with snap action switch to 2 Form "C".

AC operation: Maximum contact rating 115 volts AC. Maximum coil, 300 volts. Maximum contact rating, 5 amps. U/L approved.

DC operation: Maximum contact rating 12 amps at 24 volts DC. Maximum coil resistance 35,000 ohms. Maximum power consumption 2.25 watts U/L approved.

■ **MR Relays:** Available in up to 3 Form "C" insulated or uninsulated. The coil resistances to 10,000 ohms. Maximum power to coil is 1 watt. Maximum contact current 8 amps resistive at 24 volts DC or 110 volts AC with .25 watts per pole at normal operation. Available with printed circuit or solder lug.

new from

JAICO

REED RELAYS

	RE Series	RM Series	RL Series
Operating Time (Incl. Bounce)	< .5 ms	< 2.5 ms	< 3 ms
Rated Resistive Load	.125 amps, 4 watts	1 amp, 15 watts	3 amps, 100 watts
Contact Resistance	50-200 milliohms	20-50 milliohms	20-100 milliohms
Capacitance	.2 picofarad	.8 picofarad	.8 picofarad

JAICO

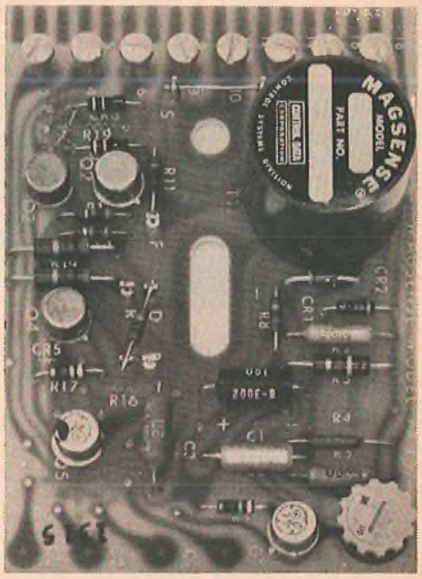
JAIDINGER MANUFACTURING CO., INC.

1921 W. Hubbard St., Chicago, Illinois 60622
Phone HAymarket 1-1090

ON READER-SERVICE CARD CIRCLE 31

Thermocouple relay

Model 73 provides output pulses proportional to the difference between the input from a thermocouple junction and the set-point of an internal adjustment. Operating from 12 to 28 vdc, the controlling



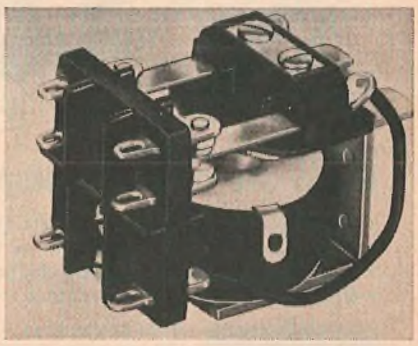
relay responds to variations within 500 msec. Input range is 0-50 mv and input resistance is 105 ohm. Output is 100 to 500 ma.

Control Data Corp., Control Systems Div., 4455 Miramar Rd., La Jolla, Calif. Phone: (714) 453-2500.

ON READER-SERVICE CARD CIRCLE 425

Molded phenotic relay

A general purpose relay for industrial application is of fully molded phenolic construction. It is available for all standard ac or dc voltages and in 1 to 3 poles. Contacts



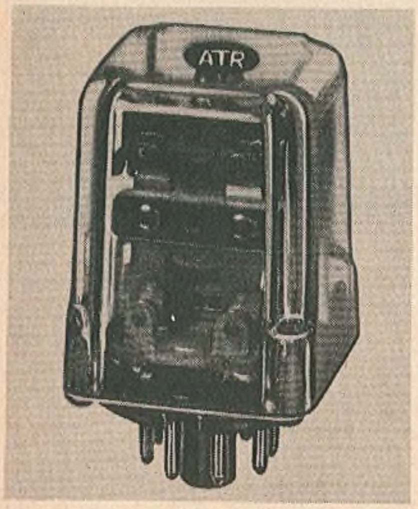
are gold plated as standard with 5 ampere fine silver contacts or 10 ampere 3/16-in. diameter silver-cadmium oxide contacts.

Vanguard Relay Corp., 225 Cortland St., Lindenhurst, N. Y. Phone: (516) 884-5000.

ON READER-SERVICE CARD CIRCLE 426

Plug-in relays

The AKRP plug-in relays are multi-contact units with clear plastic covers and 8- or 11-pin bases. Contacts are 3/16-in. diameter and are rated at 5 or 10 amp. Weight is



approx 3 oz. Seated dimensions are 1-13/32 x 1-13/32 x 2-in.

ATR Electronics, Inc., 300 E. Fourth St., St. Paul, Minn. Phone: (612) 222-3791.

ON READER-SERVICE CARD CIRCLE 427

Reed relays

The CRZ series of sealed-contact reed relays consists of 13 models with 1 to 12 form A, 1 or 2 form B or various combinations of A, B and C contacts.

Typical of the line is CR6Z-1830, with 3 form C contacts and coil resistance of 2300 ohm, coil turns of 9100 and a max voltage rating of 102 v. Operate and release voltages are 53 and 3.4 volts respectively. Coil dissipation is specified 3 w at +35°C.

C. P. Clare & Co., 3101 Pratt Blvd., Chicago, Ill. Phone: (312) 262-7700.

ON READER-SERVICE CARD CIRCLE 428

Thermal timing relays

Thermal timing relays of the JT series feature factory-set delay intervals from 2 seconds to 3 minutes. Timing tolerance is ±15%. Heater voltages of 6.3, 28, 115 and 230 volts are standard and relays will operate interchangeably on ac or dc.

Contacts are single pole, single

throw, either normally open or normally closed. Contact rating for resistive loads is 5 amp at 125 vac, 3 amp at 250 vac and 1 amp at 32 vdc. The case is of stainless steel and is approximately 3/4-in. square and 2-1/4-in. long.

P&A: $5 to $10; 46 weeks. G-V Controls Inc., Okner Parkway, Livingston, N. J. Phone: (201) 992-6200.

ON READER-SERVICE CARD CIRCLE 429

General purpose relays

The type BR relay features gold bonded contacts and is available in any contact configuration up to 3pdt. Coils are available up to 230 vac 50/60 cps. Ac sensitivity is reported to be 2 va and the dc sensitivity is rated at 1.2 w.

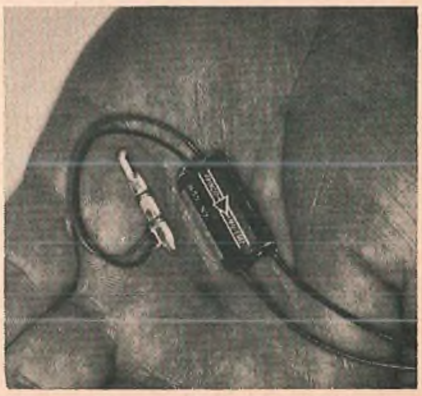
The similar type BP is rated 10 amp and is supplied with silver cadmium oxide contacts. A thermal time delay unit, type SR, is also available.

Cardinal Control Co., Kensington, Conn. Phone: (203) 828-5061.

ON READER-SERVICE CARD CIRCLE 430

Thermal switch

Thermal switch T156 is a combination of a mercury-in-glass ther-



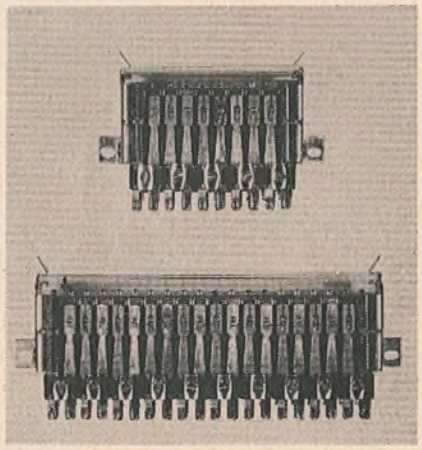
mostat and a solid-state relay weighing less than 1/2 oz. The relay controls 1 amp at 115 vac and can handle loads up to 50 w. The thermal switch requires an input of 85 μa. Temperature range varies 0° to 100°C with differentials of 0.5°C and an accuracy of 0.5°C.

Precision Thermometer & Instrument Co., Southampton Industrial Pk., Southampton, Pa. Phone: (215) 355-1500.

ON READER-SERVICE CARD CIRCLE 431

10-, 20-pole relays

The 410 and 420 are units constructed of 10 and 20 telephone-type relays. Each spring-stack has 4 springs available as 2-pole normally-open or 2-pole normally-closed.



Each 410 and 420 can be arranged with any number of NO and NC sets of contacts.

Automatic Electric Co., 400 N. Wolf, Northlake, Ill. Phone: (312) 562-7100.

ON READER-SERVICE CARD CIRCLE 432

1-amp military relay

Relays of the 3SAK Unimite are rated for 1 amp operation with a 1.5 msec operate time and a 3.5 msec release time. They can be cycled at rates as high as 10,000 operations per minute. A total of 13 coil ratings are offered in the range 4.2-6.2 v to 44.0-66.0 v.

General Electric Control Dept., Waynesboro, Va. Phone: (703) 942-8161.

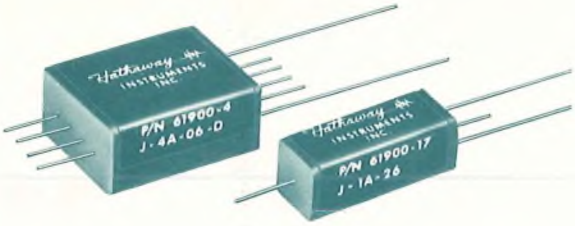
ON READER-SERVICE CARD CIRCLE 433

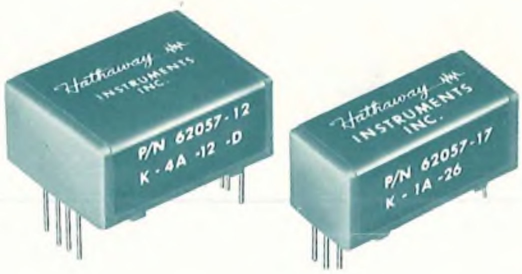
Mercury-wetted relays

Additions to the manufacturer's line consist of 287 relays with mer-

Turn page for descriptive data on computer grade relays.

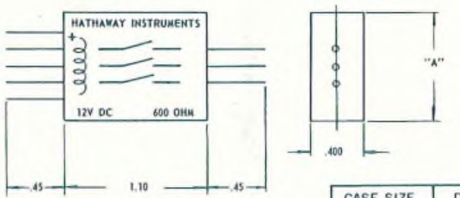
HERE IS ONE OF HATHAWAY'S FOUR STANDARD SERIES RELAYS





Computer Grade Axial J Series

- High operate sensitivity.
- Glass filled nylon case and bobbin construction.
- Full epoxy sealed internal environment, providing a solid component foundation.
- Rated over temperature for continuous duty.
- Specially gold plated contact leads and 180 alloy coil leads.
- Versatile in mounting method.
- Choice of DCD, DCP, DCN or DCR Drireed contacts.
- 100% in-process inspection.



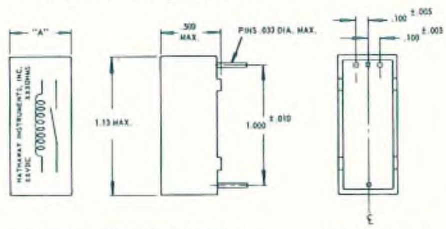
RELAY SHOWN: 3 PST NORMALLY OPEN (A)

CASE SIZE	DIMENSION "A"
−1	.400
−2	.535
−3	.670
−4	.805

WIDTH DIMENSIONS

Computer Grade Printed Circuit K Series

- Gold plated contact pins and 180 alloy coil pins are anchored in the body and are epoxy sealed.
- Risers on the mounting surface allow thorough cleaning of foreign material and also allow flow coating of circuit boards.
- Choice of DCD, DCP, DCN or DCR Drireed contacts.
- 100% in-process inspection.



RELAY SHOWN: SPST NORMALLY OPEN (A)

COMMON DIMENSIONS

CASE SIZE	DIMENSION "A"
−1	.500
−2	.625
−3	.750
−4	.875

WIDTH DIMENSIONS

SPECIFICATIONS FOR BOTH J AND K SERIES

INITIAL CONTACT RESISTANCE: 200 milliohms maximum.
OPERATE TIME: 1.0 millisecond maximum (including bounce).
TEMPERATURE RANGE: −54°C to +75°C operating.
HI-POTENTIAL TEST: 250 V rms, 60 cps, between open contacts.
500 V rms, 60 cps, between contact and coil.
INSULATION RESISTANCE: 5 x 10⁸ ohms minimum.

Nominal Coil Voltage	6 VDC				12 VDC				26 VDC			
Coil Identification	−1	−2	−3	−4	−1	−2	−3	−4	−1	−2	−3	−4
Resistance ± 10% in OHMS	300	200	150	125	1200	800	600	500	5.6K	3.8K	2.8K	2.3K
Nominal Power in Milliwatts	120	180	240	290	120	180	240	290	120	180	240	290
Must Operate @ 25° C.	4.2 VDC				8.3 VDC				16.5 VDC			
Must Operate Over Temperature Range	5.0 VDC				10.0 VDC				20.0 VDC			
Must Release @ 25° C.	0.4 VDC				0.8 VDC				1.5 VDC			

RELAY CODE FOR PROCUREMENT . . . J AND K SERIES

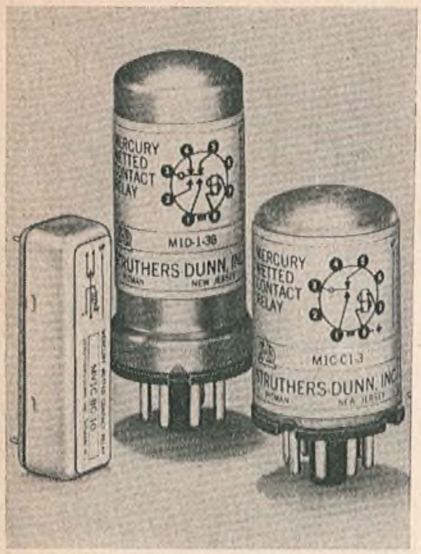
AVAILABLE CONTACTS		CASE SIZE
1A	SPST-NO	−1
2A	DPST-NO	−2
3A	3PST-NO	−3
4A	4PST-NO	−4
1B	SPST-NC	−2
2B	DPST-NC	−3
1C	SPDT-NC	−4
1A, 1B	SPST-NO, SPST-NC	−4

J OR K	1A - 1B	06	D
PACKAGE STYLE	CONTACT NUMBER AND FORM	COIL VOLTS NOMINAL	CONTACT TYPE

HATHAWAY INSTRUMENTS INC.

5250 EAST EVANS AVENUE, DENVER, COLORADO 80222

PHONE (303) 756-8301 TWX (303) 292-2935



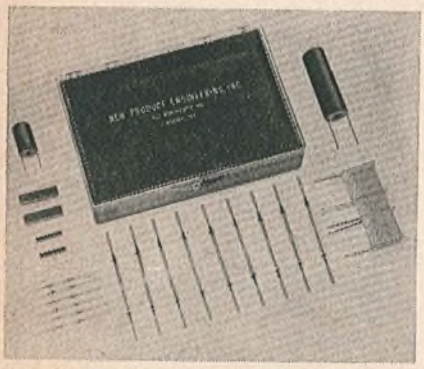
cury-wetted contacts. Available units handle from 2 to 5 amp in break-before-make and make-before-break configurations. Terminals are either 8- or 11-pin keyed-bases. Shielding of coils or contacts is optional in the different styles.

Price: from $8 to $21. Struthers-Dunn, Inc., Lambs Rd., Pitman, N. J. Phone: (609) 589-7500. TWX: (609) 589-1548.

ON READER-SERVICE CARD CIRCLE 434

Reed relay kit

An engineering design kit consists of 9 standard and 6 miniature reed-switches in 3 sensitivity ranges; two standard test coils; one logic coil, and two magnets. An associated 15-page booklet illustrates



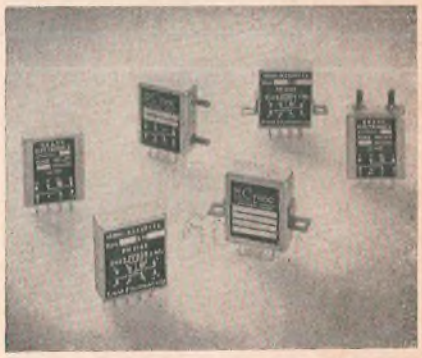
the design of 3-pole normally-open relays, electrical latching relays, magnetically latched relays and an element of a cross-point memory matrix.

P&A: $10; stock. New Product Engineering, Inc., subsidiary of Wabash Magnetics, Inc., 1st & Webster, Wabash, Ind. Phone: (219) 563-3111.

ON READER-SERVICE CARD CIRCLE 435

Time delay relays

Model CR70 timers cover the timing range from 0.01 to 45 seconds with 5% and 10% accuracies. 2pdt output contacts are rated 2 amp resistive. Coil voltages available are



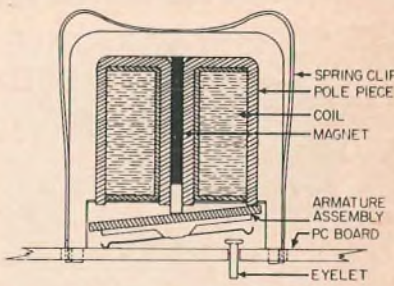
12, 28 and 40 vdc. Operational environments include 50 or 100 G's shock and 25 G's at 2 and 3 Kc vibration.

Crane Electronics Corp., 1401 Firestone Rd., Goleta, Calif. Phone: (805) 967-1193.

ON READER-SERVICE CARD CIRCLE 436

Magnetic latching relay

No hold-in power is required to latch the series LS and LD relays. Features of these single and double coil relays include bifurcated contacts, balanced armature, enclosed housing, encapsulated coil, self-wiping action and inherent snap action.



The plug-in, printed circuit arrangement also allows the relay to be converted to mechanical reset operation through a minor accomodation.

Price: from $1.60. Executone Inc., Austell Place, Long Island City, N. Y. Phone: (212) 392-4800.

ON READER-SERVICE CARD CIRCLE 413

1/6 crystal-can relay

The Model 901 2pdt relay meets the requirements of MIL-R-5757D with a 1/6 crystal-can package weighing 0.15 ounce max. Temperature rating is −65° to +125°C and rated life is 100,000 operations at rated load. Operate and release are 4 msec max including bounce.

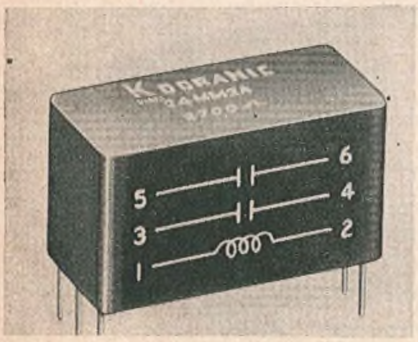
Wabco, Union Switch and Signal Div., Pittsburgh, Pa. Phone: (412) 242-5000. TWX: (412) 642-4097.

ON READER-SERVICE CARD CIRCLE 438

Mercury wetted relays

A line of miniature mercury-wetted-contact relays is available with five standard contact configurations and is designated series HGM. The series, designed for printed circuit mounting, is available in 6, 12 and 24 v nominal coil voltages.

All units are magnetically shielded to prevent interaction with magnetic components and are designed



for operation from −40°C to +50°C. Contacts are rated for 1 amp at 28 vdc with life of 10 million operations at full load. Contact resistance is 50 milliohms with no bounce. Operate and release time is specified 2 msec at nominal voltage. Modifications for octal and miniature socket plug-ins and special pin configuration are also available.

Douglas Randall, Inc., 6 Pawcatuck Ave., Westerly, R. I. Phone: (203) 599-1750.

ON READER-SERVICE CARD CIRCLE 439

PC board relays

The Micro-scan relay ST series includes six models with configurations from dpst to 3pst and switching voltages from 6 to 20 v.

Applications for the units include data sampling, multiplexing, data acquisition, DDC and other low-voltage circuitry.

James Electronics, Inc., 4050 North Rockwell St., Chicago, Ill. Phone: (312) 463-6500. TWX: (312) 222-0745.

ON READER-SERVICE CARD CIRCLE 440

Chopper/relay

The Model 98 solid-state chopper/relay is designed to provide a dynamic signal range of ±75 μv to ±20 vdc or peak-to-peak ac. Typical noise is 25 μv into a 10-K load. Drive voltages of 6 to 12 vdc, peak

pulse or square wave, provide switching rates of dc to 5 Kc.

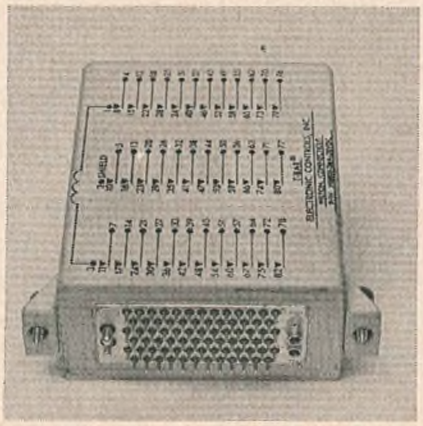
Typical turn-on and turn-off times are 2 μsec and 10 μsec respectively. Drive-input-impedance is specified 850 ohms at 6 vdc inut.

Solid State Electronics Corp., 15321 Rayen Street, Sepulveda, Calif. Phone: (213) 894-2271.

ON READER-SERVICE CARD CIRCLE 441

Multi-pole relays

Series 808 relays are hermetically sealed units available in 20pst to 34ps- or −dt configurations. Coil voltage varies 6, 12, 24, 28, 48 and 100 vdc and 115 vac. The relay is



capable of switching loads up to 3 amp at 115 vac.

P&A: $106.25 for 36pst; 4-6 weeks. Electronic Controls, Inc., Danbury Rd., Wilton, Conn. Phone: (203) 762-8351.

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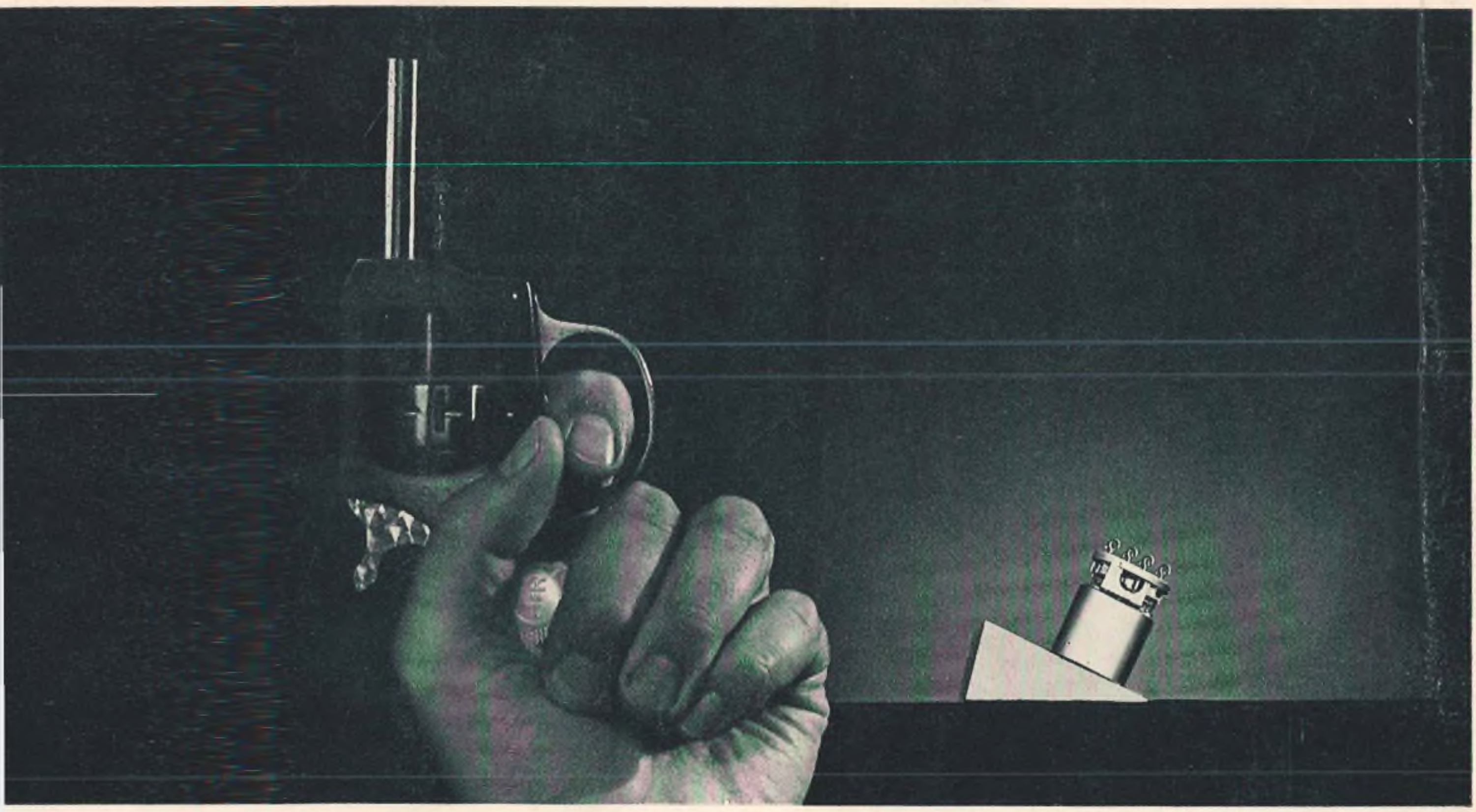

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