ELECTRO
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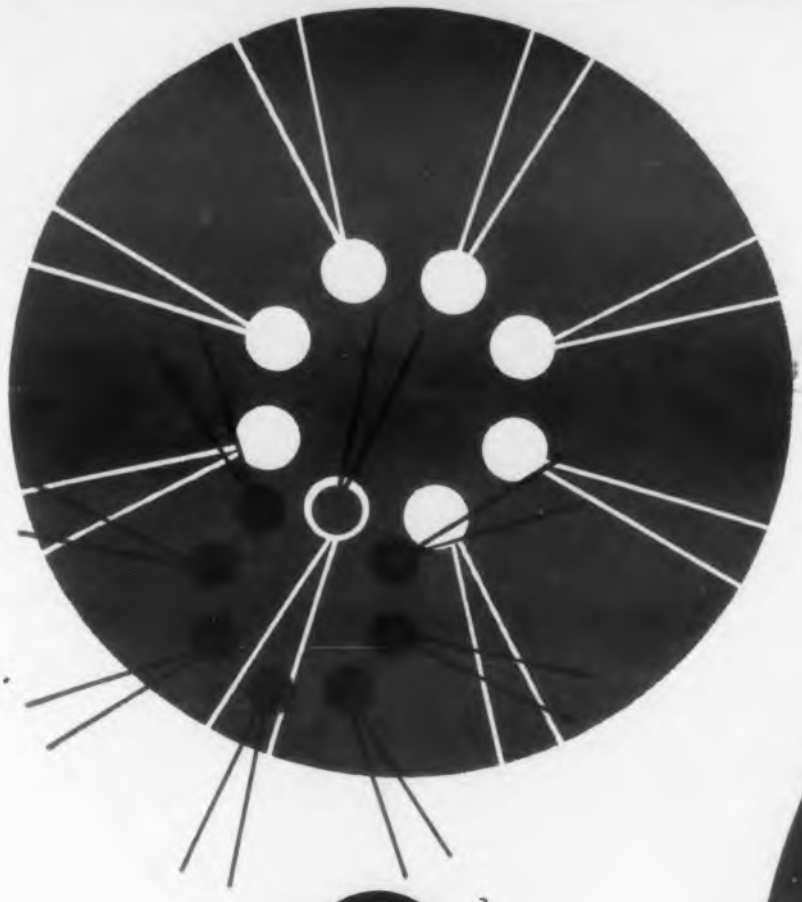

THERMISTOR ISSUE

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U. S. PAT. 2,700,084 OTHER U. S. & FOREIGN PATENTS PENDING

FREED

offers for Immediate Delivery

MAGNETIC AMPLIFIERS AND SATURABLE TRANSFORMERS

FAST RESPONSE MAGNETIC AMPLIFIERS

2 ~ response Phase reversible

Cat. No.	Supply Freq. C.P.S.	Power Out. Watts	Volt. Out. V. AC	AC or DC signal voltage req'd for full output.	
MAF-1	60	13	110	1.0	—
MAF-4	400	5	57.5	Designed to be driven from vacuum tube or transistor preamplifier.	
	400	10	57.5		
MAF-5	400	13	54		
MAF-6	400	5	57.5	1.2	0.4
	400	10	57.5	1.6	0.6
MAF-7	400	15	57.5	2.5	1.0

SINGLE ENDED MAGNETIC AMPLIFIERS

Cat. No.	Supply Freq. C.P.S.	Power Out. Watts	Sig. req'd for full outp. MA-DC	Total res. contr. wdg. K Ω	Load res. ohms
MAG-1	60	4.5	3.0	.685	3800
MAG-2	60	20	1.8	1.3	700
MAG-4	60	400	9.0	10.0	25
MAG-5	60	575	6.0	10.0	25

PUSH-PULL MAGNETIC AMPLIFIERS

Phase reversible

Cat. No.	Supply Freq. C.P.S.	Power Out. Watts	Volt. Out. V. AC	Sig. req'd for full outp. MA-DC	Total res. contr. wdg. K Ω
MAP-1	60	5	115	1.2	1.24
MAP-2	60	15	115	1.6	2.4
MAP-3	60	50	115	2.0	0.5
MAP-3-A	60	50	115	7.0	2.9
MAP-4	60	175	115	8.0	6.0
MAP-7	400	15	115	0.5	8.8
MAP-8	400	50	115	1.75	0.0
MAP-11	400	10	115	.7	6.6

SATURABLE TRANSFORMERS

Phase reversible

Cat. No.	Supply Freq. in C.P.S.	Power Out. Watts	Volt. Out. V. AC	Sig. req'd for full outp. MA-DC	Total res. contr. wdg. K Ω
MAS-1	60	15	115	6.0	27
MAS-2	400	6	115	4.0	10
MAS-5	400	2.7	26	4.0	3.3
MAS-6	400	30	115	4.0	8.0
MAS-7	400	40	115	5.5	8.0

All units designed for 115V-AC operation

Write for detailed information on these and other components for military and commercial applications. Send for NEW 48 page TRANSFORMER CATALOG. Also ask for complete LABORATORY TEST INSTRUMENT CATALOG.

MILITARY TRANSFORMERS BUILT TO MIL-T-27A SPECIFICATIONS

AUDIO TRANSFORMERS — STANDARD

Frequ. resp. 300 to 10000 c.p.s. ± 2 db.

Cat. No. MGA	Type Designation TF1RX	IMPEDANCE LEVEL Prim. KΩ	Ct.	Split	Sec. Ω	Ct.	Split	Ratio	Max. Power DBM	Max. MA DC Unbal.
-1	-15AJ	10.	√		90K	√	√	1:3	+15	10
-2	-16AJ	.6		√	4, 8, 16			6.12:1	+33	0
-3	-10AJ	.6		√	135K	√		1:15	+15	0
-4	-16AJ	.6		√	600		√	1:1	+15	0
-5	-13AJ	7.6/4.8			600		√	3.56:1	+33	40
-6	-13AJ	7.6/4.8			4, 8, 16			21.8:1	+33	40
-7	-13AJ	15.	√		600		√	5:1	+33	10
-8	-13AJ	24.	√		600		√	6.32:1	+30	1
-9	-13AJ	60.	√		600		√	10:1	+27	1

POWER TRANSFORMERS — STANDARD

All primaries 105/115/125 v., 60 c.p.s.

Cat. No. MGP	Type Designation TF1RX	Hi V	V DC	A DC	Fil. #1 V	Fil. #1 A	Fil. #2 V	Fil. #2 A
-1	-03HA001	400/200	185	.07	5/6.3	2	6.3	3
-2	-03HB002	650ct	260	.07	5/6.3	2	6.3	4
-3	-03KB006	650ct	245	.15	6.3	5	5.	3
-4	-03LB003	800ct	318	.175	5.	3	6.3	8
-5	-03MB004	900ct	345	.25	5.	3	6.3	8
-6	-02KB001	700ct	255	.25	400~ single and 60 and 400~ three phase on special order			
-7	-02LB002	1,100ct	419	.25				
-8	-02NB003	1,600ct	640	.25				

FILAMENT TRANSFORMERS — STANDARD

All primaries 105/115/125 v., 60 c.p.s.

Cat. No. MGF	Type Designation TF1RX01	V	I A	Test KV	Cat. No. MGF	Type Designation TF1RX01	V	I A	Test KV
-1	-EB002	2.5	3	2.5	-6	-GB007	6.3	5	2.5
-2	-GB003	2.5	10	2.5	-7	-JB008	6.3	10	2.5
-3	-FB004	5.	3	2.5	-8	-KB009	6.3	20	2.5
-4	-HB005	5.	10	2.5	-9	-JB012	2.5	10	10.
-5	-FB006	6.3	2	2.5	-10	-KB013	5.	10	10.

*400~ single and 60 and 400~ 3 phase on special order

FILTER REACTORS

Cat. No. MGC	L Hy.	I DC MA	R DC Ω	Test KV	Case	Cat. No. MGC	L Hy.	I DC MA	R DC Ω	Test KV	Case
-1	100.	10	3.500	1.	AJ	-17	4.	200	80.	2.	GA
-2	4.	50	230	1.	AJ	-18	7.	200	135.	2.	HB
-3	10.	50	325	1.	EB	-19	10.	200	125.	2.5	JA
-4	20.	50	475	1.5	FA	-20	2.5	300	50.	2.	GA
-5	30.	50	650	1.5	FA	-21*	4.	300	62.	2.5	HB
-6	3.	75	175	1.	AJ	-22	6.	300	85.	2.5	JB
-7	6.	75	235	1.5	EB	-23*	8.	300	65.	2.5	KB
-8	12.	75	265	1.5	FA	-24	10.	300	100.	2.5	LA
-9	3.5	100	145	1.	EB	-25*	2.	400	37.	2.5	HB
-10	8.	100	180	1.5	FA	-26	6.	400	60.	2.5	KB
-11	12.	100	190	2.	GA	-27*	2.	500	35.	2.5	JA
-12	2.	150	92	1.5	EB	-28	4.	500	45.	2.5	KB
-13	4.	150	115	1.5	FA	-29*	7.	500	50.	2.5	MB
-14	8.	150	125	2.	GA	-30*	2.	700	20.	2.5	LB
-15	11.	150	120	2.5	JB	-31*	1.75	1,000	12.5	2.5	MB
-16	2.5	200	70	1.5	FA	*Not stocked, available on short del.					

PULSE TRANSFORMERS

Cat. No. MPT	Pulse Kilovolt	Duration Microsec.	Duty Rate	No. of Windings	Test KV	Zo Ω
-1	.25/.25/.25	0.2-1.0	.004	3	.7	250
-2	.25/.25	0.2-1.0	.004	2	.7	250
-3	.5/.5/.5	0.2-1.5	.002	3	1.	250
-4	.5/.5	0.2-1.5	.002	2	1.	250
-5	.5/.5/.5	0.5-2.0	.002	3	1.	500
-6	.5/.5	0.5-2.0	.002	2	1.	500
-7	.7/.7/.7	0.5-1.5	.002	3	1.5	200
-8	.7/.7	0.5-1.5	.002	2	1.5	200
-9	1./1./1.	0.7-3.5	.002	3	2.	200
-10	1./1.	0.7-3.5	.002	2	2.	200
-11	1./1./1.	1.0-5.0	.002	3	2.	500
-12	.15/.15/.3/.3	0.2-1.0	.004	4	.7	700

TELEMETERING COMPONENTS

BAND PASS FILTERS

Cat. No. Z0—500 Ω FBP	Cat. No. Z0—2,500 Ω FBP	3DB Bandwidth per cent of Fo + 9¾	+ 19½	Center Frequency Fo (KC)
-10	-34	√		.4
-11	-35	√		.56
-12	-36	√		.73
-13	-37	√		.96
-14	-38	√		1.3
-15	-39	√		1.7
-16	-40	√		2.3
-17	-41	√		3.0
-18	-42	√		3.9
-19	-43	√		5.4
-20	-44	√		7.35
-21	-45	√		10.5
-22	-46	√		12.3
-23	-47	√		14.5
-24	-48	√		22.0
-25	-49		√	22.0
-26	-50	√		30.0
-27	-51		√	30.0
-28	-52	√		40.0
-29	-53		√	40.0
-30	-54	√		52.5
-31	-55		√	52.5
-32	-56	√		70.0
-33	-57		√	70.0

DISCRIMINATORS

Per cent Deviation of Fo 8½	15.	Per cent Linearity 0.5	1.0	Cat. No. DST
√		√		-10
√		√		-11
√		√		-12
√		√		-13
√		√		-14
√		√		-15
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√		√		-26
	√		√	-31
√		√		-27
	√		√	-32
√		√		-28
	√		√	-33

DISCRIMINATOR LOW PASS FILTERS

Cat. No.	Center Freq. Fo (cps)	Cat. No.	Center Freq. Fo (cps)	Cat. No.	Center Freq. Fo (cps)	Attenuation
OUTPUT						
LPO -10	6	LPO -19	81	LPO -28	790	.2 DB to 0.5 Fo
-11	8	-20	110	-29	900	.7 DB to 1 Fo
-12	11	-21	160	-30	1,050	20 DB to 2 Fo
-13	14	-22	185	-31	1,200	30 DB from 2.5 Fo
-14	20	-23	220	-32	1.600	
-15	25	-24	330	-33	2,100	
-16	35	-25	450	-34	7,200	
-17	45	-26	600	-35	10,000	
-18	60	-27	660			

Characteristic impedance of all—330Ω

INPUT						
LPI -10	400	LPI -17	3,000	LPI -23	14,500	.05 DB at ±9¾% Fo
-11	560	-18	3,900	-24	22 000	30 DB at third
-12	730	-19	5,400	-25	30,000	50 DB at fifth
-13	960	-20	7,350	-26	40.000	Harmonics
-14	1,300	-21	10 500	-27	52,500	
-15	1.700	-22	12,300	-28	70,000	
-16	2,300					

Characteristic impedance of LPI-10 thru 23—30,000Ω of LPI-24 thru 28—5,100Ω

MINIATURE BAND PASS FILTERS

Cat. No.	Center Freq.	Band width ±3% of CF < 2 DB	40 DB att. at .5 and 2 times Fo
IBP-400	400	±3%	.5 & 2
IBP-1,000	1.000	±3%	.5 & 2
IBP-1,500	1,500	±3%	.5 & 2
IBP-2,000	2.000	±3%	.5 & 2
IBP-3,000	3,000	±3%	.5 & 2
IBP-10,000	10,000	±3%	.5 & 2
IBP-5,600	5,600	±3%	.5 & 2
IBP-15 000	15,000	±3%	.5 & 2
LBP-300	300	±3%	.5 & 2
LBP-400	400	±3%	.5 & 2
LBP-600	600	±3%	.5 & 2
LBP-1,000	1,000	±3%	.5 & 2
LBP-1,500	1,500	±3%	.5 & 2
LBP-2,000	2,000	±3%	.5 & 2
LBP-3,000	3,000	±3%	.5 & 2
LBP-10,000	10,000	±3%	.5 & 2

Impedance
IBP's—Input 10,000 Output 5 Meg Ω
LBP's—Input 500/600 Output 5 Meg Ω
Low pass and high pass filters also available, write for catalog.

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1720 WEIRFIELD ST., BROOKLYN (Ridgewood) 27, N. Y.

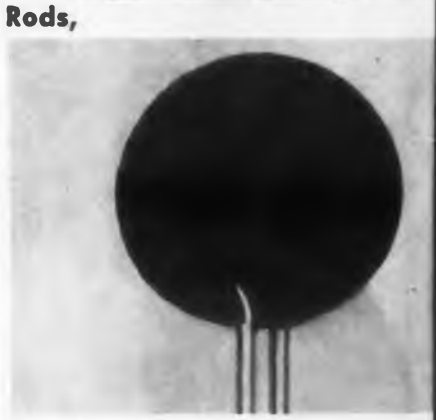
COVER STORY

Thermistors—Silhouettes of the basic thermistor shapes—beads, rods, discs and washers—form the pattern of this month's cover. Photographs of these types (not to scale) are shown below. Manufacturing steps are shown on p 44

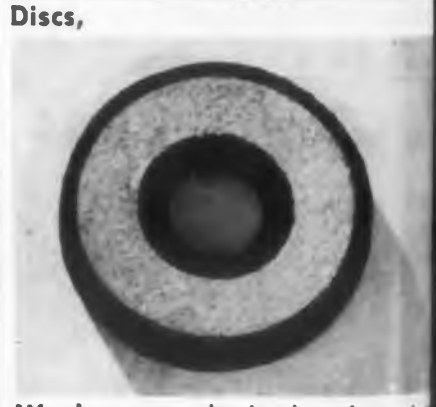
The entire feature section of this issue is devoted to articles on designing with thermistors.

Beads,

Rods,



Discs,



Washers, are basic thermistor ty

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2	12	22	32	42	102	112	122	132	142	202	212	222	232	242	302	312	322	332	342	402	412	422	432	442	502	512	522	532	542
3	13	23	33	43	103	113	123	133	143	203	213	223	233	243	303	313	323	333	343	403	413	423	433	443	503	513	523	533	543
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5	15	25	35	45	105	115	125	135	145	205	215	225	235	245	305	315	325	335	345	405	415	425	435	445	505	515	525	535	545
6	16	26	36	46	106	116	126	136	146	206	216	226	236	246	306	316	326	336	346	406	416	426	436	446	506	516	526	536	546
7	17	27	37	47	107	117	127	137	147	207	217	227	237	247	307	317	327	337	347	407	417	427	437	447	507	517	527	537	547
8	18	28	38	48	108	118	128	138	148	208	218	228	238	248	308	318	328	338	348	408	418	428	438	448	508	518	528	538	548
9	19	29	39	49	109	119	129	139	149	209	219	229	239	249	309	319	329	339	349	409	419	429	439	449	509	519	529	539	549
50	60	70	80	90	150	160	170	180	190	250	260	270	280	290	350	360	370	380	390	450	460	470	480	490	550	560	570	580	590
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56	66	76	86	96	156	166	176	186	196	256	266	276	286	296	356	366	376	386	396	456	466	476	486	496	556	566	576	586	596
57	67	77	87	97	157	167	177	187	197	257	267	277	287	297	357	367	377	387	397	457	467	477	487	497	557	567	577	587	597
58	68	78	88	98	158	168	178	188	198	258	268	278	288	298	358	368	378	388	398	458	468	478	488	498	558	568	578	588	598
59	69	79	89	99	159	169	179	189	199	259	269	279	289	299	359	369	379	389	399	459	469	479	489	499	559	569	579	589	599

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EDITORIAL

Exploiting Thermistors In ELECTRONIC DESIGN

This is our third issue this month. The "extra" edition permits us space to bring you a special feature section devoted entirely to thermistors. Thermistors have been around for quite some time, but we expect you'll be working with them more in the near future. We expect units will be available with closer tolerances at no increase in cost.

A deterrent to the wholesale use of thermistors has been the wide tolerance to which they were made. It has been difficult to match a thermistor to a transistor to compensate for temperature change (some people will certainly take exception to this statement, but as a generalization there has to be much hand work in making or picking thermistors). There has been no specification on thermistors which a customer could specify to insure a constant quality. The "Specifying Military Thermistors" by Bernard Schwartz of RCA, page 34 should prove a helpful guide to the inexperienced buyer.

In gathering material for this issue, we are deeply appreciative of the efforts made by thermistor manufacturers to supply us with information that would be most helpful to designers. An abundance of design information exists in the manuals and data books put out by manufacturers. We have not warmed this over, but bring instead new approaches to designing with thermistors. More new design articles will appear in succeeding issues. We think you'll particularly appreciate Mr. Schwartz's design aids which boil the problem down to using curves and nomograms.

Thermistors can be used in the following applications: temperature measurement, temperature compensation, temperature control, liquid level gauges, time delays, surge suppression, switching, microwave power measurement, volume limiting, voltage regulation, compressors and expanders, agc, overload protection, and oscillator amplitude stabilization. If you're not now using thermistors, you ought to look into them. If you've found them inadequate in the past, watch future developments closely.

James G. Kippax

ENGINEERING

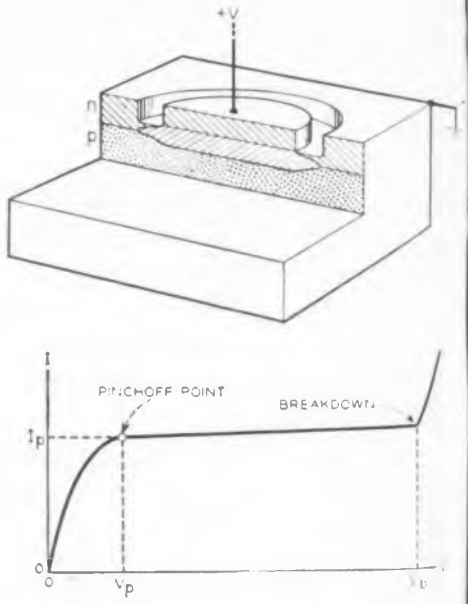
For more information on developments described, write directly to the address given in the individual item.

Constant-Current Varistor Announced

A field effect varistor with a constant current feature has been announced by Bell Telephone Laboratories, New York City. The two-terminal passive semiconductor component is applicable as a current regulator where load or supply varies over 20 to 120 v.

Still in the experimental stage, the component has other applications as a current limiter or as a pulse shaper; with its high ac impedance, it can be used as a coupling choke or ac switch.

The field effect varistor is related to the field effect transistor. A single planar junction is made by diffusion. Current passing parallel through this junction goes through a constricted channel. As the voltage increases, the current increases and a depletion layer builds up to the entire thickness of the channel. At a "pinch-off" point, voltage increase does not produce any current increase. Before an avalanche breakdown point, and after the pinch-off point, current is essentially constant—and this is the region of primary interest.



Varistor Cross-Section, (top), and a plot of varistor pinch-off and breakdown points.

CIRCLE 5 ON READER-SERVICE CARD

REVIEW

Present varistors are produced in a precision process. Germanium or silicon diodes are heavily plated, on all surfaces, and circular trenches are then cut into diffused junctions, to within 0.1 mil of the junction.

In experiments, the trench was first cut by ultrasonic means and finished by etching. Leads were attached by thermocompression bonding or other convenient means.

Bell research engineers believe varistors which regulate current at any level between 10 μ a and 10 ma could be produced. With improvements in fabrication techniques, higher current levels will be feasible. Germanium units with 10 ma rating have 10 to 25 v range.

Coded TV Pictures

Techniques for improving the efficiency of long-distance television picture transmission were revealed by the Technicolor Corp., Burbank, Calif. Bandwidth reductions of as much as 4 to 1 were reported.

In the complete system a normal television camera output is fed into a small high-speed electronic computer which codes the video signal into a series of dots and spaces as in the Morse code before transmission to the receiver. There a similar computer translates the code before presenting the picture on a television tube. An essential feature of the device is the temporary retention of the coded signal in electrostatic storage tubes to average out the information rate. Laboratory equipment built so far handles pictures with just two levels of brightness, but additional circuitry to permit acceptance of a complete tone scale is approaching completion and will yield the same bandwidth reduction factor. Color TV signals may also be transmitted with only slightly greater bandwidth than for black and white pictures.

CIRCLE 6 ON READER-SERVICE CARD ➤

ENGINEERING REVIEW

Mach 2 Bomber Control System Disclosed

The autopilot and flight control system that makes it possible to fly a Mach 2 bomber was revealed by the Eclipse-Pioneer Division of Bendix Aviation Corp., Teterboro, N.J.

The Convair B-58 Hustler control system continually senses and computes maximum control-surface movement permitted by the structural limitations of the supersonic jet over its entire range of speed. The control system also takes into account the constantly changing atmosphere conditions the plane encounters. In effect, the human pilot is prevented from putting the plane into any maneuver that could instantly destroy it.

Sensing units in the nose of the delta-wing jet pick up data on the plane's air environment—air speed, temperature, air density, and other vital information. This information is evaluated and compared in a central air data computer. Appropriate control information from the computer is then relayed through an amplifier computer to a complex electromechanical device, the power control linkage assembly (PCLA).

In the PCLA the pilot's control-stick movements are translated into correct control-surface action by the power control part of the system. This control-surface action varies from a 20 deg movement under one set of conditions to eight-tenths of one degree under extreme-opposite conditions of speed and air environment. Yet, there is no difference in the "feel" of the controls, as far as the pilot is concerned, between the two

Control signals from the pilot or automatic guidance system of the Convair B-58 Hustler, pass through the power-control linkage assembly. This 267-pound electromechanical device, which contains an array of 17,000 parts, translates into linear motion, electronic signals from a computing system that senses aerodynamic forces.

extremes. The B-58 power control system can develop a maximum torque of 120 ton-foot.

Designed into this control system is a process called "mixing." The conventional airplane has both elevators for up or down movement and ailerons for banking. The delta-wing Hustler, however, has just one set of control surfaces, elevons, which "mixes" the work of both elevators and ailerons.

Automatic Missile Launcher

This is a prototype of the automatic missile loading and launching equipment for firing a series of ground-to-air defense missiles of the Talos type. Designed and built by American Machine & Foundry Co., 261 Madison Ave., New York, N.Y., the equipment has been delivered to White Sands Proving Ground, New Mexico, where it is installed in the Talos Defense Unit.

On command from computers in the control station, the launcher turns toward the cell in the circular storage magazine which contains the desired type of missile for the tactical mission. A cart runs out to the automatically preselected cell, picks up a missile and returns to the launcher. The missile is then positioned in the launcher where it is elevated and rotated to firing position. When the firing signal is received, the missile is fired automatically and the launcher recycles for the next round. Unloading is also automatic.

In Case You Wondered—HSD=HHoffman Electronics Corp.

We're sorry. In "Zener Diode Characteristics" (Mar. 19, 1958 ELECTRONIC DESIGN), the code HSD went unexplained. It stands for Hoffman Electronics Corp., Semiconductor Div., 930 Pitner Ave., Evanston, Ill.

We're sorry, too, that the following Hoffman types were not listed: IN465; IN466; IN467; IN468; IN469; and IN470. These types span the zener voltage range of 2.0 to 8.0 v at $I_z = 5$ ma dc.

THE NATIONAL SCENE

ENGINEERING REVIEW

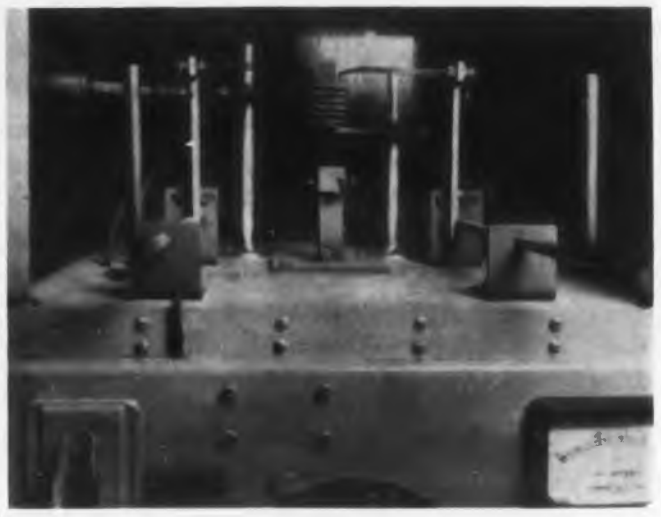
Electrical Cable Guides Car

An automobile automatically steered by an electrical cable beneath a concrete surface cruised along a one-mile check road.

During the demonstration held at General Motors, Warren, Mich., the car rolled along the two-lane road and negotiated the banked turn-around loops at either end without the driver's hand on the steering wheel. To turn off the road or pass another vehicle, the driver switched back to manual steering.

Guidance was accomplished by a circular magnetic field created by the low frequency ac line. A pair of tuned pickup coils on the front bumper of the vehicle straddled the field. Any deviation or lateral motion of the car produced a difference in voltage from one pickup coil to the other. These voltage variations were fed into a small analog computer on the instrument panel. The computer was linked with a servo system that controlled the modified power steering unit.

The computer transmitted command signals to the servo mechanism which positioned the front wheels. Thus, if the car underwent any deviations from its straight-ahead course the automatic steering system brought it back into the straight-ahead path.



Flammability Testing of Laminates

A flammability test unit is aiding research and development programs on flame-retardant laminates. Installed recently at Continental Diamond Corp., Bridgeport, Pa., test equipment provides detailed and specific information on flammability characteristics.

The specimen is placed within the unit's heating coil, which can heat the specimen to temperatures in excess of 860 C. Specially designed electrodes located immediately adjacent to the test specimen emit a constant stream of high-voltage sparks which ignite the gases arising from the heated specimen. After a burning period of 30 sec, all current is cut from the heating coil and spark electrodes, following which the time required for the flame to extinguish itself is measured.

MEETINGS

May 5-7: AIEE Great Lakes District Meeting
Michigan State University, East Lansing, Mich. Write to AIEE, 33 W. 39th St., N.Y. 18, N.Y.

May 5-7: PGMT&T National Symposium
Stanford University, Calif. Write to Dr. K. Tomiyasu, GE Microwave Lab., 601 California Ave., Palo Alto, Calif.

May 6-8: 12th Annual Frequency Control Symposium
Berkeley-Carteret Hotel, Asbury Park, N.J. Sponsored by the Frequency Control Division, U.S. Army Signal Engineering Labs. of Ft. Monmouth, N.J. Write to Dr. E. A. Gerber, Frequency Control Div., U.S. Army Signal Labs., Ft. Monmouth, N.J.

May 6-9: Western Joint Computer Conference
Ambassador Hotel, Los Angeles, Calif. For more information write David Parry, 6363 Wilshire Blvd., Los Angeles 48, Calif.

May 12-14: National Aeronautical and Navigational Electronics Conference
Biltmore Hotel, Dayton, Ohio. Contact Walter Fried, 1668 Wesleyan Rd., Dayton, Ohio.

May 13-14: Spring Assembly Meeting of the Radio Technical Commission for Marine Services
Benjamin Franklin Hotel, Philadelphia, Pa. Write to R. T. Brown, Radio Technical Commission for Marine Services, c/o Federal Communications Commission, Washington 25, D.C.

May 13-15: AIEE East Central District Meeting
Huntington, W. Va.

May 21-23: Joint Electronic Components Conference, AIEE, IRE, RETMA, WCEMA
Los Angeles, Calif.

May 26-27: Engineering Refresher (Electrical Engineering)
University of Wisconsin. Contact Mr. Robert A. Ratner, Director Engineering Institutes, University of Wisconsin Extension Div., Dept. of Engineering, Madison 6, Wis.

May 27-28: Maintainability of Electronic Equipment, 2nd EIA Conference
University of Pennsylvania, Philadelphia, Pa. For more information write J. A. Caffiaux, 650 Salmon Tower, 11 W. 42nd St., New York 36, N.Y.

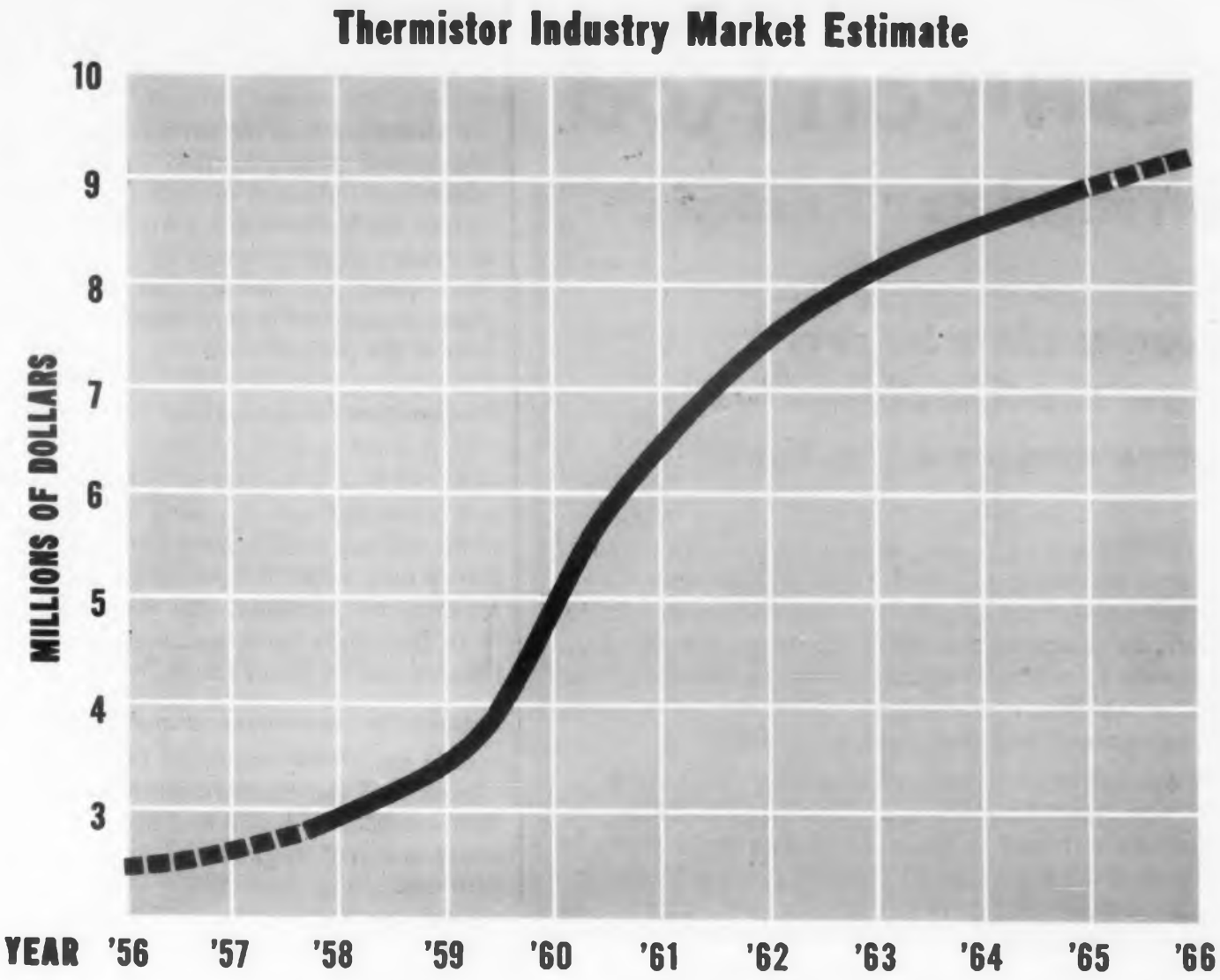
The Growing Thermistor Field

A. J. Gizzi
Manager, Specialty Resistor Project
Magnetic Materials Section
General Electric Co.
Edmore, Mich.

THE THERMISTOR, born some two decades ago in the laboratories of Western Electric, is now assuming full stature as a design component. Its unusual properties—extreme sensitivity, negative temperature coefficient, and high reliability make it an ideal component for modern electronic equipment. It is only in the last few years that manufacturers have taken up the challenge of providing the design engineer with reliable, standard, thermistor types. The versatility of thermistors is already reflected in a wide variety of applications, from medical temperature probes to missile-fuel sensing elements. Temperature measurement and control for instrumentation has become a major area of thermistor use.

The use of thermistors in transistor circuitry should prove of the greatest interest to designers. Thermistors are a good design choice for compensating transistor-circuits because they are of extremely small size, are very sensitive to temperature change, have indefinite life, are economical, and have very stable and reproducible characteristics within their design limits.

Active research is still being carried on and new thermistor types are being developed, such as special bolometer thermistors and ultra-low temperature thermistors. Research is also increasing the accuracy and reproducibility of thermistor types. Most present manufacture is still on the batch system, and continuous controlled production is an important goal. The evolution of a complete set of standard thermistor types is making the thermistor an invaluable tool for the designer.



Past, present, and future markets for the thermistor.

WHILE the thermistor is not a new product, nor even a new development, its commercial history is comparatively recent. With the increasing demand for small rugged components like the thermistor, that fit the growing technical complexity of circuits, some planning for the future was a necessity. In the summer of 1957, as a result, an extensive market survey was carried out by the General Electric Co.

For clarification, and for better visualization of types of applications, we might indicate subdivisions of typical applications of the three major branches:

Temperature compensation

Fluctuation in temperature will often affect many electrical and electronic systems or components, reflecting undesirable changes in resistance and general operating characteristics. In most cases a thermistor incorporated properly in the circuit will compensate for the expected temperature change. Some of the typical applications of this type of thermistor are:

a. Vertical deflection yoke on 110 degree television cathode-ray tubes.

b. Transistors and associated circuitry.

c. Fuel flow, in relation to ambient temperature fluctuations in a fuel injection system.

d. Delicate miniature or subminiature instrumentation, servomechanisms, missile components, or relays.

Temperature measurement and control

Thermistors have a high temperature coefficient of resistance, and can be effectively used to measure and control reasonable changes in temperature. With high resistance in a small mass, both rapid and accurate measurements are easy to obtain, even when the thermistor itself is spotted remotely from the measuring circuit. Some typical applications:

a. Indication of engine oil or water temperatures.

b. Oven roast-food probe.

c. Electric range surface and oven controls.

d. Indoor/outdoor temperature controls for home and industrial heating systems.

e. Indication and control of temperature in chemical reaction stills, kettles, or other industrial apparatus.

f. Replacement of thermocouples for temperatures ranging up to 400 C.

Time delay and inrush surge suppression

The thermistor's inherent thermal inertia delays current-rise through it, and through its associated circuitry. A thermistor prevents a large initial current surge caused by application of voltage to cold electrical components such as relays, tubes, transformers, or motors. Typical applications are:

a. Protection for longer life of TV and radio tubes by limitation of inrush currents.

b. Time delays required for many electrical or mechanical devices; one of these worth mentioning is the steadily growing adoption of home and industrial air-conditioning.

Major producers found it difficult to assess either present quantitative demand for thermistors or parameters for future potential. To efficiently predict trends or usage, and consequent effect upon production facilities, it was necessary to definitely determine the real areas of market growth.

To provide complete coverage, the survey was divided into two separate sections—a series of personal interviews and a direct-mail questionnaire. Based upon various informational sources, it is estimated that at least one-quarter of the total industry market was covered by the man-to-man interviews. Of the mailed question sheets, about 23 percent were filled out and returned to the checking source. Results of both surveys closely agreed, and it is felt that the voluminous data eventually compiled represents a good sampling of the thermistor market.

Over an extended period, based on final study of the paired surveys, the total industry market for all types of thermistors should be something like this:

1958	$3,000,000
1959	$3,500,000
1960	$5,000,000
1961	$6,500,000
1962	$7,500,000
1965	$9,000,000

These figures do not include "captive" industrial production.

Breaking down these totals into thermistor application areas, both for the known present and the expected future, we may expect:

Type of Application	1958	1965
Temperature compensation	40%	30%
Temperature measurement and control	40%	20%
Time delay, and inrush-surge suppression	20%	50%

Although in ratio the various types of uses may be expected to vary by 1965, its dollar value will increase as indicated in earlier pages. Although certain applications may narrow or widen, overall usage will grow. It may be of some interest to chart—using the survey results—some places where thermistors may be more broadly adopted than at the present time.

Temperature compensation

In general, both mechanical and electrical devices will tend to become more remotely operated and controlled, and also more automatic. In case of the military missile, more exact control is mandatory over wider temperature ranges. In these applications, certainly, the thermistor will be more frequently used, and more as a part of a planned system than as an individual item.

Temperature measurement and control

It is confidently expected that there will be extension of the effective temperature range of the thermistor. This will lead to a more simplified measurement of temperature, especially in remote locations.

Time, as a measurement of how food should be properly cooked, is being discarded in favor of using food temperature as a criterion. Already the thermistor is in use in this field, and recent design trends forecast an increasing growth.

Rigid control of home or industrial heating units, using thermistors, will provide a more uniform temperature. Individual-room control can be obtained, a special role for the thermistor.

Time delay, and initial-surge suppression

There is a large field for the thermistor in the protection of elaborate industrial lighting systems large inrush current. From a dollar viewpoint, this will increase lamp life and will reduce costly maintenance schedules.

Thermistors will be more widely used as a safeguard against faulty or erratic operation of relays or other control devices due to spurious currents.

As previously mentioned, the growing use of air-conditioning units, both domestic and industrial, will compound the problems of the utility companies. Initial inrush current to electric motors and sudden peak demand can be controlled by the thermistor. Of this last item, air-conditioning is only one of the fast-growing appliances that are appearing in the field of power consumption. The potential of this thermistor application prob-

ably is the largest of all, because of the variety of the end-products involved.

No attempt was made to list all or even part of the present or future application of the thermistor; the foregoing items are only indications of General Electric's belief that the market will continue to enlarge. Many other applications, of course, will be conceived by the design engineer as he learns more, and is able to design into his mechanisms the full potential of the thermistor. In line with this thinking, part of the survey study was made of present attitudes and needs of both the manufacturer and the present and potential users. Various questions were asked, and the general trade requirements were weighed against product improvements requested by present customers. The final tabulation is interesting, in that it defines both present limitations of the thermistor and the much greater possibilities that lie ahead:

1. Closer electrical tolerances.
2. Improved thermistor stability.
3. Higher operating temperatures, up to 1000 C.
4. Availability of differing resistances in the same geometrical shape.
5. Expansion of the temperature coefficient range, both negative and positive.
6. Greater current carrying capacity.

In the past, these requirements have been deterrents to many possible thermistor applications. It seems to be generally appreciated that the manufacturers are recognizing these demands, and are moving in the needed direction. With these design standards accomplished, the thermistor is even now being used where it had been ruled out in the past; obviously, more complete utilization cannot help but follow newer developments.

Although emphasis has traditionally been laid on refinement of volume production to provide the best attractive price, the survey points out that more and more basic studies are being conducted. Almost immediate technological advances should be forthcoming.

There is a definite need for standardization in the field. This includes both thermistor nomenclature, testing methods, and specifications in general. Lack of this basic standardization has led to confusion in the market. In many cases, the specifications for the thermistor are inadequate in that they improperly characterize the product itself.

In essence, the thermistor industry has just begun to grow. What has been a slow, steady pace should accelerate rapidly as the designers become fully aware of the thermistor's unique properties. With the development of even more advanced electrical and electronic equipment, the thermistor as an important component cannot be overlooked in system and circuit design.

This fresh approach to the design of thermistor temperature-compensating networks develops a simple three-step solution to network problems. The use of normalized curves and nomograms save laborious calculations. Curves and nomograms for two-resistor networks will be presented in a succeeding article.

Quick Design of Thermistor Compensation Networks

Bernard R. Schwartz
Radio Corp. of America
Defense Electronic Products
Camden, N. J.

THE USE of temperature compensat ng networks having thermistors as the active element has been steadily increasing the last few years. Among the many circuit applications which utilize such networks are those where transistors, deflection yokes, meters, and other components are to be exposed over a wide ambient temperature range. Other articles have indicated methods for the solution of these networks graphically (Refs. 1, 2) and for compensating copper-wound components (Ref. 3).

The approach taken here is that the designer has already made suitable tests to determine the resistance-temperature characteristic required. By selecting the desired performance from normalized temperature characteristic curves, a rapid solution of the circuit values is possible.

Temperature compensating networks (see Table I) involving one or two additional resistors together with a thermistor have been investigated. (Curves and nomograms for two-resistor networks will be presented in a succeeding article.) It was assumed that the resistors were temperature passive compared with the thermistor, which exhibits a negative temperature characteristic approximated by:

$$r_t = r_{t25}\, e\ (\text{exp.}) - \beta\left(\frac{1}{T_t} - \frac{1}{298}\right) \qquad (1)$$

The solution of circuit equations using the indicated nomenclature is as follows:

Type I(a)

$$R_t = \frac{R_1\, r_t}{R_1 + r_t} \qquad (2)$$

$$F = \frac{R_t}{R_{t25}} = \frac{r_t}{r_{t25}}\left(\frac{R_1 + r_{t25}}{R_1 + r_t}\right) = f\left(\frac{k_1 + 1}{k_1 + f}\right) \qquad (3)$$

Type I(b)

$$R_t = R_2 + r_t \qquad (4)$$

$$F = \frac{R_t}{R_{t25}} = \left(\frac{R_2 + r_t}{R_2 + r_{t25}}\right) = \left(\frac{k_2 + f}{k_2 + 1}\right) \qquad (5)$$

Type II(a)

$$R_t = \frac{R_3\,(R_2 + r_t)}{R_3 + R_2 + r_t} \qquad (6)$$

NOMENCLATURE

r_t:	dc resistance value of thermistor at temperature (t)°C; r_{t25} is dc resistance value of thermistor at 25°C
β:	thermistor material constant in exponential equation which approximates actual resistance-temperature response
R_t:	dc resistance value of network at temperature (t)°C; R_{t25} is dc resistance value of network at 25°C
$f = \frac{r_t}{r_{t25}}$:	normalized thermistor dc resistance value at temperature (t)°C with respect to its 25°C value
$F = \frac{R_t}{R_{t25}}$:	normalized network dc resistance value at temperature (t)°C with respect to its 25°C value
$k_n = \frac{R_n}{r_{t25}}$:	ratio of dc resistance value of temperature-passive circuit resistor ($R_n = R_1 \ldots R_4$) with respect to the thermistor's dc resistance value at 25°C

$$F = \frac{R_t}{R_{t25}} = \left(\frac{R_2 + r_t}{R_2 + r_{t25}}\right)\left(\frac{R_3 + R_2 + r_{t25}}{R_3 + R_2 + r_t}\right) = \left(\frac{k_2 + f}{k_2 + 1}\right)\left(\frac{k_3 + k_2 + 1}{k_3 + k_2 + f}\right) \qquad (7)$$

Type II(b)

$$R_t = \frac{R_4\,(R_1 + r_t) + R_1\, r_t}{R_1 + r_t} \qquad (8)$$

$$F = \frac{R_t}{R_{t25}} = \left(\frac{R_1 + r_{t25}}{R_1 + r_t}\right)\left(\frac{R_4\,(R_1 + r_t) + R_1\, r_t}{R_4\,(R_1 + r_{t25}) + R_1\, r_{t25}}\right) = \left(\frac{k_1 + 1}{k_1 + f}\right)\left(\frac{k_4\,(k_1 + f) + k_1\, f}{k_4\,(k_1 + 1) + k_1}\right) \qquad (9)$$

These equations can be solved for F by the substitution of appropriate values for f, k_1, k_2, k_3 and k_4. The following "k" values were substituted for individual calculations: 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10, 20, and 50.

The values of "f" used in these equations correspond to the resistance-temperature response of a specific thermistor material. Table II shows the various normalized values for this constant. Material f_1 was chosen as being the fastest response material available from most, if not all, of the thermistor sources. (Full sets of curves for another material, f_2, are not included in this article since such thermistors are available from only one manufacturer.)

The use of other materials for similar calculations would only require that their normalized

temperature response values be inserted in the equations. Little variation in the network temperature response was noticed for the different thermistor materials, especially for the Type II circuits. *Apparently the temperature-passive resistors so completely modify the thermistor's response that only extreme differences between thermistors can display significantly different network responses.*

Procedure

The designer selects the normalized dc resistance temperature response he desires from the various graphs. A particular curve is selected and the value of the "*k*" constant(s) noted. Interpolation between plotted curves is possible. With the noted "*k*" value(s), the appropriate nomogram quickly permits determination of the ohmic value(s) of the resistor(s) and the thermistor at 25 C. Note that the nomogram's scale for network resistance value at 25 C has a multiplier at 10x. The appropriate value of the thermistor's resistance would then be scaled by the same 10x multiplier.

Example No. 1

A network is desired which has the following resistance-temperature response:

Resistance (ohms)	Temp. (°C)
15,000	—40
13,200	—20
10,800	0
9,000	10
6,000	25
3,900	40
2,400	50
1,380	65

Step 1:

The network resistance value variation is then normalized with respect to the 25 C value.

F (norm. network resist.)	Temp. (°C)
2.5	—40
2.2	—20
1.8	0
1.5	10
1.0	25
0.65	40
0.40	50
0.23	65

Step 2:

An examination of the above table shows:

a. the required network should be fairly stabilized at the lower temperatures;

b. the required network continues to drop rapidly at temperatures near the high end of the temperature range.

These characteristics are indicative of shunt networks (see Figs. 1 and 2). Series networks (see Figs. 4 and 5) have characteristics which change

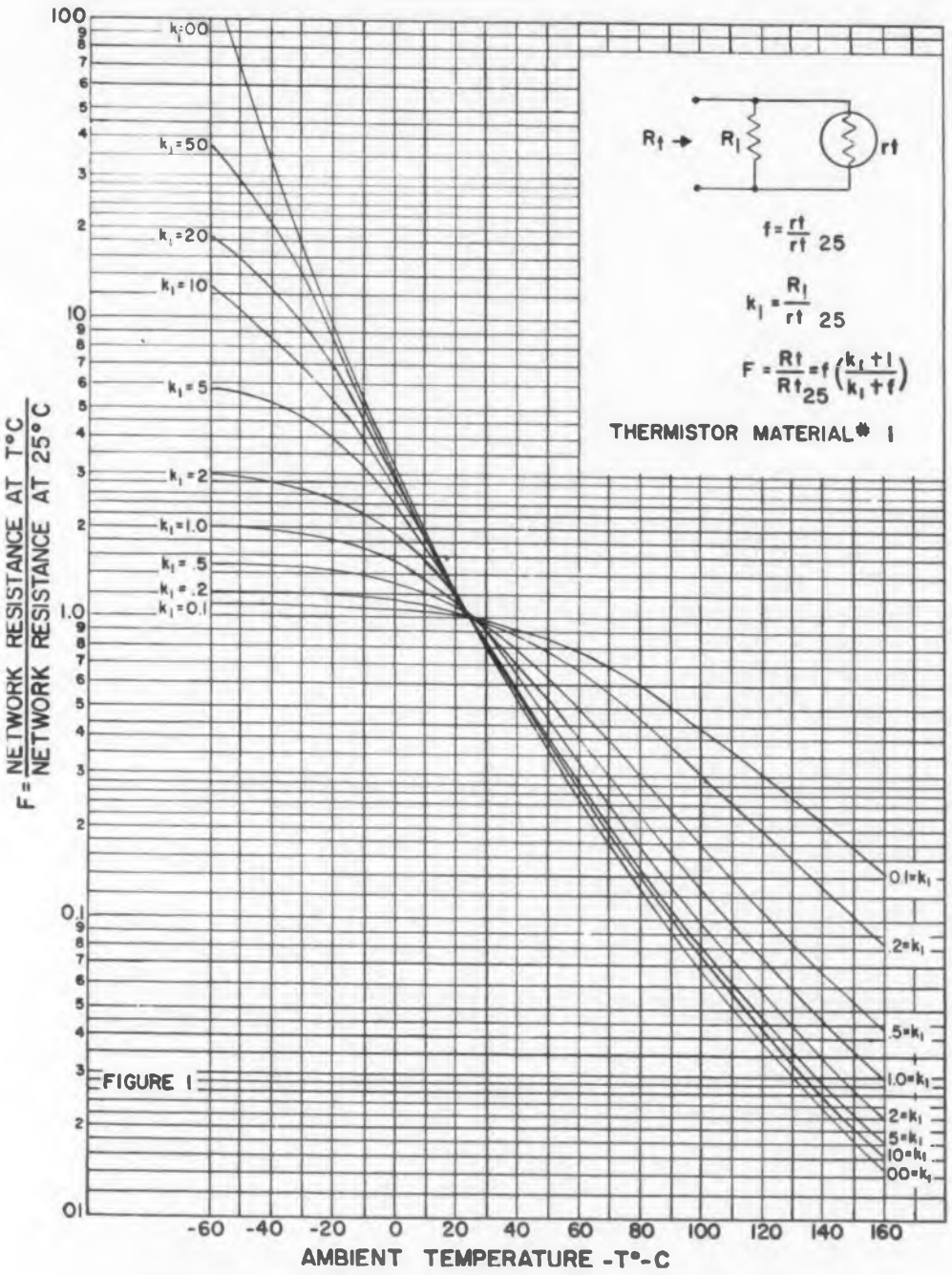


Fig. 1. Shunt network compensation circuit and characteristics for material No. 1 of Table II.

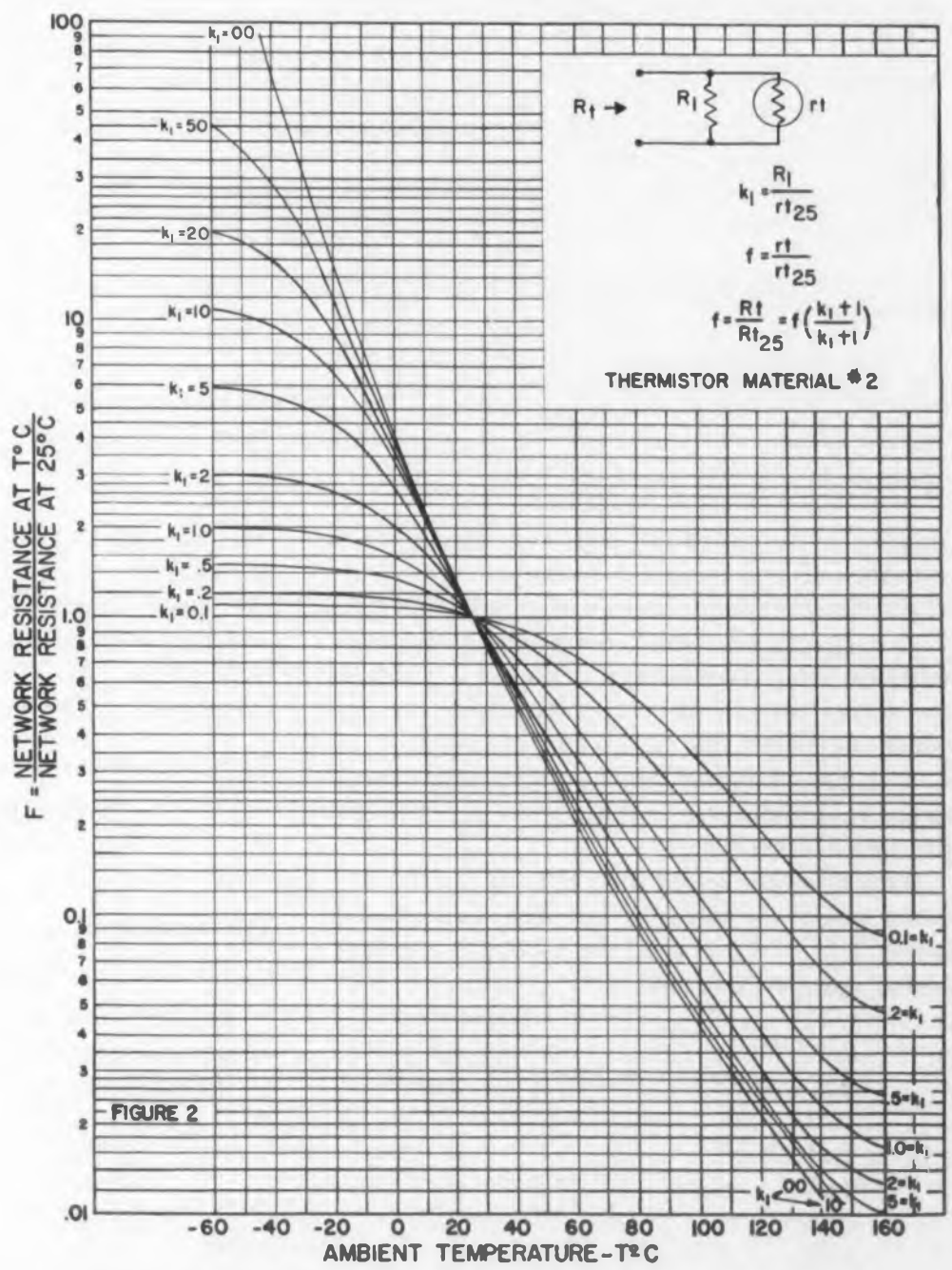


Fig. 2. Similar to shunt network compensation characteristics of Fig. 1 except material is Keystone Carbon type 150.

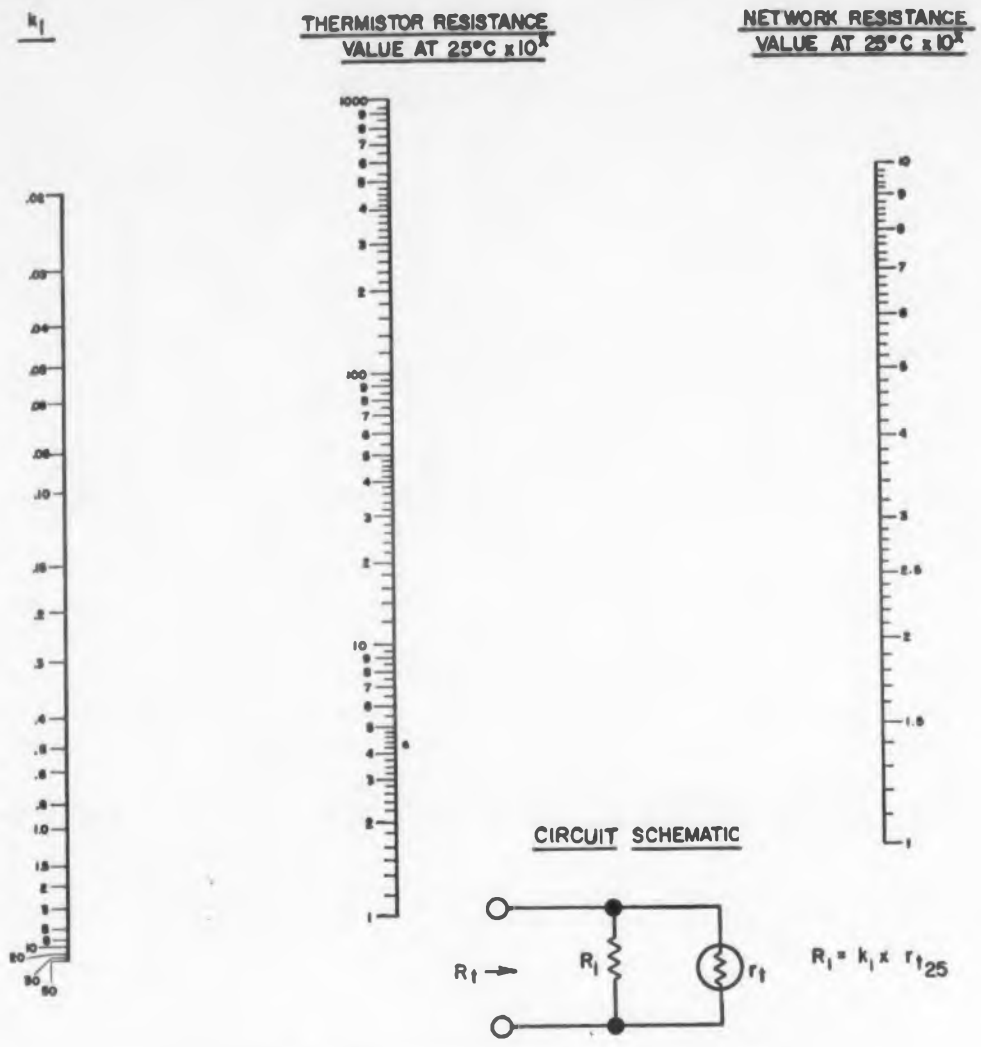


Fig. 3. Nomogram for solution of shunt circuit values.

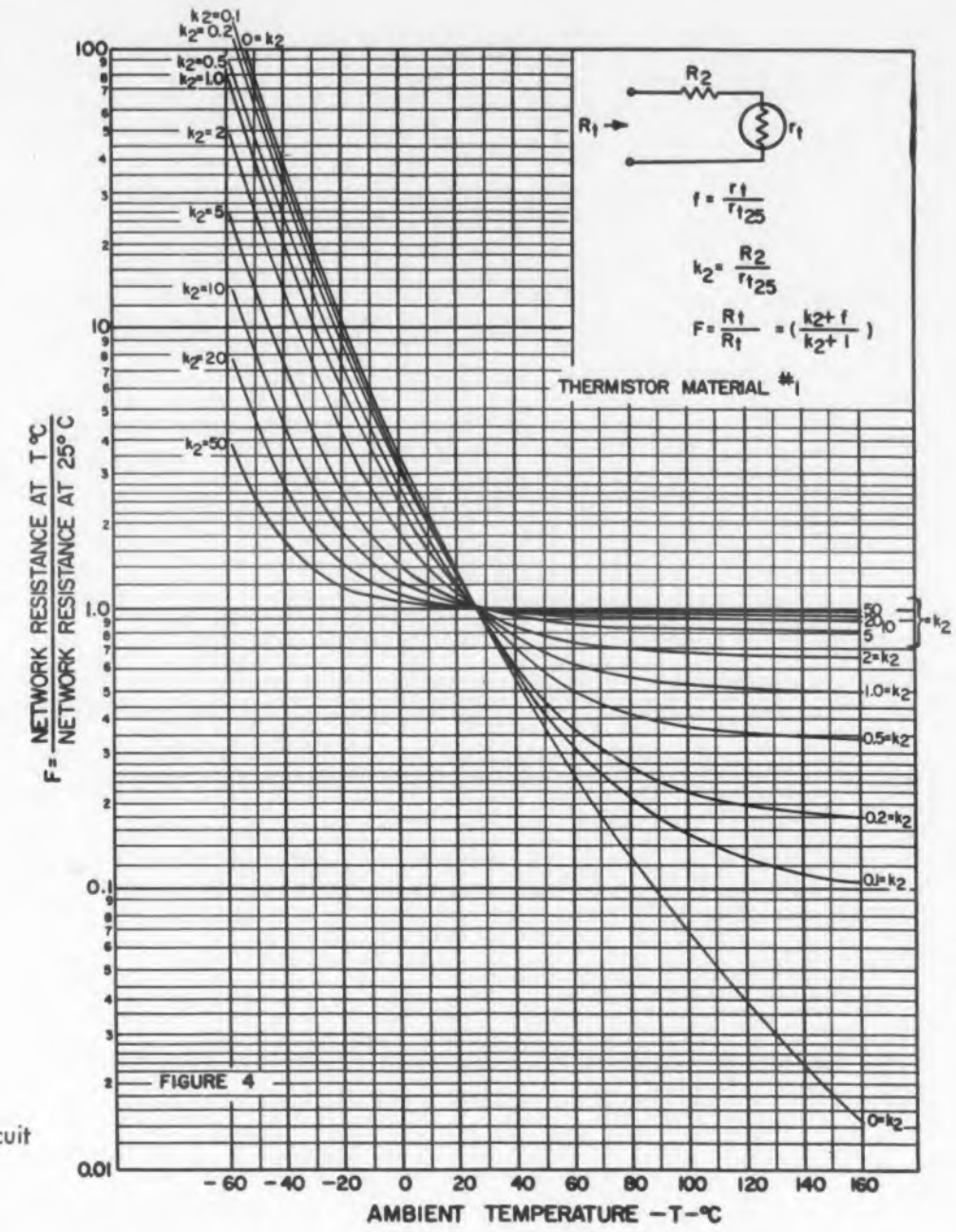


Fig. 4. Series network compensation circuit and characteristics, material No. 1.

rapidly or are relatively stable at the opposite extremes of this temperature range.

An examination of Figs. 1 and 2 will show that Fig. 2 has curves which more closely approximate the desired performance. If $k_1 = 2$ is chosen the actual curve will be slightly higher at temperatures below 25 C. If an interpolation of $k_1 = 1.5$ is attempted, the fit of the actual curve to the required curve will be better over the entire temperature range.

With no other application data available, this latter choice is made. When the interpolated curve of $k_1 = 1.5$ is used the following network performance is indicated.

F	Temp. (°C)
2.4	—40
2.2	—20
1.78	0
1.44	10
0.62	40
0.44	50
0.255	65

Step 3:

The appropriate nomogram for the shunt network is Fig. 3. A straight line is then drawn between the 1.5 point on the k_1 scale and the 6 on the network resistance value scale. This line intersects the thermistor resistance value scale at 10. Since the network scale is in thousands the same multiplier is used for the thermistor value scale. Thus, R_1 is equal to 1.5 times 10,000 or 15,000 ohms. The circuit appears as:

Example No. 2

A network is desired with the following resistance-temperature response within 5 per cent:

Resistance (ohms)	Temp. (°C)
19,500	—55
18,900	—25
18,500	0
16,000	25
11,100	50
7,700	80

Step 1:

Variation of network resistance value is first normalized with respect to its 25 C value:

F (Norm. network resistance)	Temp. (°C)
1.22	—55
1.18	—25
1.15	0
1.00	25
0.70	50
0.48	80

Step 2:

A brief examination of the above table shows that the desired response:

a. does not change rapidly at temperature excursions below room ambient, and

b. does fall rapidly between 50 C and 80 C.

An examination of the Fig. 1 shows that type I(a) circuits show this general trend, while type I(b) circuits, Fig. 4 show the opposite. That is, they tend to display rapid increases with temperature excursions below room ambient and do not fall rapidly at temperatures above room ambient.

Fig. 1 shows a curve having markedly similar response to the required one when $k_1 = 0.2$.

For $k_1 = 0.2$, the following network values are obtained: (These values meet the tolerance of the required response).

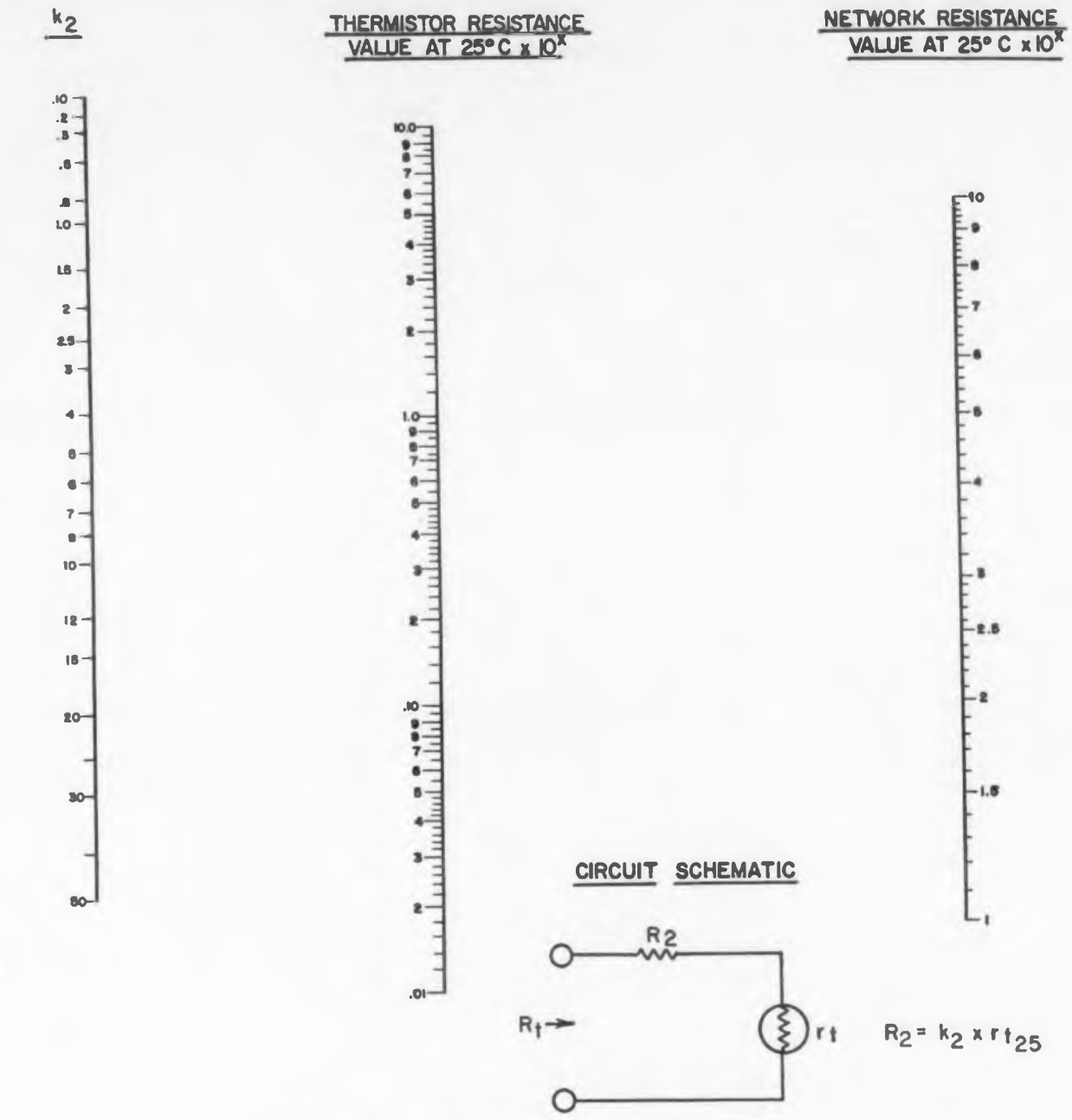
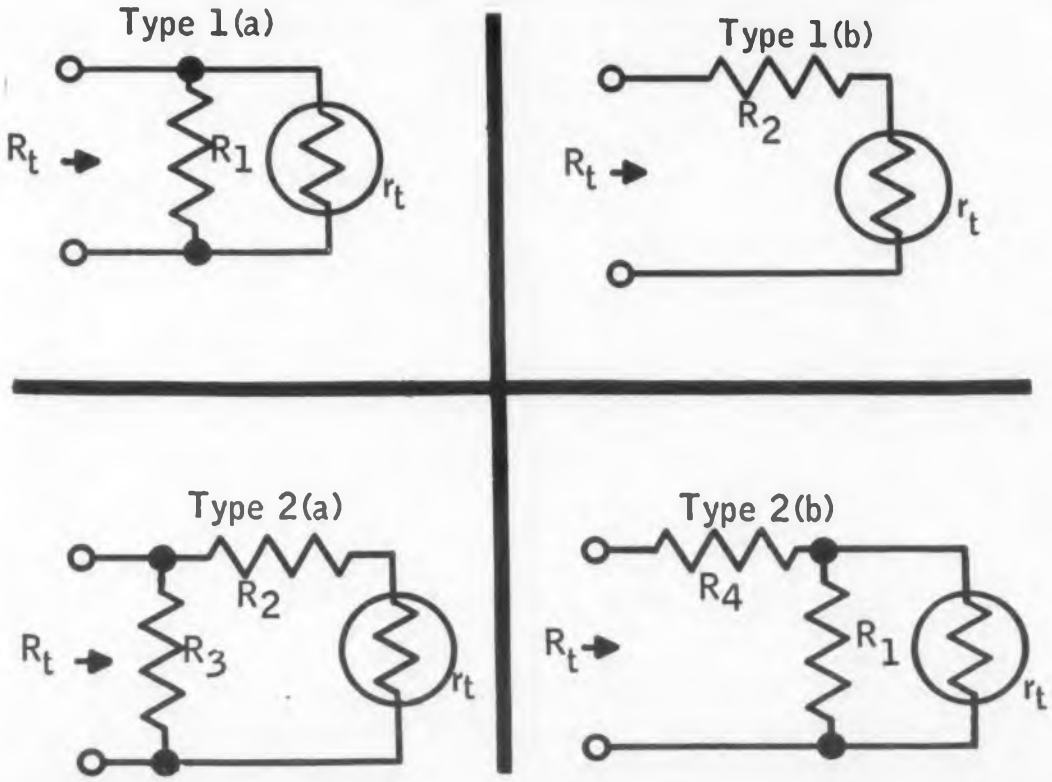


Fig. 5. Nomogram for solution of series circuit values.

Table I. Basic Temperature Compensation Networks



F	Temp. (°C)
1.20	—55
1.18	—25
1.14	0
1.00	25
.072	50
.046	80

Step 3:

Fig. 3 is the appropriate nomogram for circuit type I(a). A line is then drawn on Fig. 3 between the 0.2 point on the k_1 scale and the 1.6 point on the network resistance scale (16,000 x 10^{-4}, the specified resistance at 25 C). This line intersects the thermistor resistance scale at 9.6.

Step 4:

Since the 10^x scale factor of the network resistance value at 25 C scale is used, the same $x = 4$ is used for the thermistor resistance value at 25 C scale. The required thermistor is then obtained as 96,000 ohms at 25 C. R_1, then, is equal to k_1 (0.2) times 96,000 or 19,200 ohms. Beta is 3900 at ± 55 K.

For a reprint of this article turn to the Reader-Service card and circle **15.**

References

1. Designing Thermistor Temperature Correcting Networks Graphically, F. A. Bennett, *Control Engineering*, Nov., 1955.
2. Shaping the Characteristics of Temperature-Sensitive Elements, E. Keonjiian and J. S. Schaffner, *Electrical Engineering*, October, 1954.
3. Simplified Method for Selecting Thermistor Temperature Compensation Networks, ELECTRONIC DESIGN, December 15, 1956.

Acknowledgements: The author is indebted to Mr. J. Kimmel for his critical review and Mr. L. E. Harris for his efforts in the construction of the nomograms.

Table II.

Normalized Thermistor Resistance-Temperature Response Values

Temperature (°C)	Material #1	Material #2
—60	145.0	361.4
—40	34.3	64.3
—20	9.79	14.61
0	3.27	4.030
20	1.25	1.297
40	0.532	0.475
40	0.248	0.193
60	0.125	0.08561
80	0.0675	0.04103
100	0.0387	0.02092
120	0.0233	0.01128
140	0.0147	0.00843
160		
Vendors' Thermistor Material Type	Carborundum Corp. — Globar-type H; Fenwal Electronics-type No. 1; G. E.—Carboloy—Grade 1; Keystone Carbon—type 97; Thermistor Corp. of America (now Gulton)—type D; Victory Engrg. Corp.—type D	Keystone Carbon—type 150

Thermistor Data Chart

REPRESENTATIVE groups of thermistors made by major manufacturers are tabulated here. These are standard catalog items. Most manufacturers also produce special thermistors to customer specifications. Not included are the various thermistor assemblies produced for specific applications such as microwave power measurements, etc. Characteristics included in the table are described below.

Cold Resistance

The cold resistance, R_o, is the resistance value of a thermistor at a specified temperature when measured with zero electrical power dissipated in it. (For practical purposes, the resistance of thermistors is measured with test current sufficiently small to limit the rise in temperature of the unit to less than 0.01 d C above test temperature.)

Dissipation Constant

The dissipation constant, δ, is a constant of proportionality between the power dissipated and the resultant temperature rise in a thermistor at a specified temperature. Practically, this constant is the number of milliwatts which when dissipated by the unit will raise its temperature one degree Centigrade above that of its surroundings. Since the temperature rise of a thermistor due to dissipated power depends on the rate at which heat is transferred away from the unit, the dissipation constant depends on the method of mounting the unit as well as the medium or environment in which it is located.

The dissipation constants of a typical 2 in. long glass probe, when supported by its leads in still air, in still oil, or in still water are approximately 1, 3.5, and 5 milliwatts per degree Centigrade respectively.

Time Constant

The thermal time constant, τ, is the time required for a thermistor to change 63 per cent of the difference between its initial temperature value and that of its surroundings when no electrical power is being dissipated in it. With a bead element mounted in a glass envelope or bulb, a disc mounted on a plate, or one or more washer element bolted in a pile-up, the thermal time constant applies to the complete mounted unit rather than the thermistor element alone. It is also assumed that the thermistor element of such a unit is in thermal equilibrium with the remaining components of the unit (i.e., the thermistor element is not in a self-heated condition prior to the introduction of the change in temperature).

(Continued on page 25)

Thermistor Data Chart

Thermistor Number and Type		Resistance at 25°C	Temperature Coefficient %/°C	Dissipation Constant mw/°C	Time Constant (Seconds)
Carborundum Co., Globar Div. Niagara Falls, N. Y.					
759	rod	2.0	0.25	no data	
759	rod	3.5	0.25	available	
763	rod	5.0	0.25		
304	rod	10.0	0.28		
304	rod	100	0.35		
304	rod	1000	0.45		
304	rod	10000	0.49		
304	rod	100000	0.53		
997	rod	10	1.35		
997	rod	100	1.80		
997	rod	1000	2.00		
997	rod	10000	2.20		
997	rod	100000	2.25		
997	rod	1000K	2.35		
763	rod	4.5	1.25		
763	rod	10.0	1.60		
763	rod	25.0	1.70		
763	rod	50	1.80		
763	rod	100	1.90		
763	rod	500	2.05		
763	rod	1000	2.10		
763	rod	5000	2.15		
763	rod	10000	2.25		
763	rod	100000	2.40		
763	rod	1000K	2.50		
441	rod	10.0	1.70		
441	rod	100	2.00		
441	rod	1000	2.20		
441	rod	10000	2.25		
441	rod	100000	2.40		
763	rod	3150	3.40		
763	rod	5000	3.50		
763	rod	10000	3.90		
763	rod	50000	4.50		
763	rod	100000	4.75		
763	rod	500000	5.20		
763	rod	1000K	5.20		
416	disc	40	3.05		
416	disc	100	3.50		
416	disc	500	4.05		
416	disc	1000	4.40		
416	disc	10000	5.00		
479	disc	40	3.05		
479	disc	100	3.50		
479	disc	1000	4.40		
479	disc	10000	4.95		
343	washer	5.0	3.05		
343	washer	10	3.05		
343	washer	100	3.85		
343	washer	315	4.40		
343	washer	1500	5.20		

Thermistor Data Chart (cont.)

Thermistor Number and Type		Resistance at 25° C	Temperature Coefficient %/°C[2]	Dissipation[1] Constant mw/°C	Time[1] Constant (Seconds)
Fenwall Electronics, Inc., Framingham, Mass.					
GA51J1	bead	100000	10.3	0.7	2
GA51L1	bead	100000	10.3	0.7	2
GA51P8	probe	100000	10.3	1.0	25
GB32J1	bead	2000	7.3	0.7	2
GB32P8	probe	2000	7.3	1.0	25
GC32A1	bead	2000	5.6	0.1	1
GC32A2	bead	2000	5.6	0.1	1
GC32A3	bead	2000	5.6	0.1	1
GC32A4	bead	2000	6.0	0.4	1
GC32J1	bead	2000	5.6	0.1	1
GC32L1	bead	2000	5.6	0.1	1
KA31L1	disc	1000	9.1	6	20
KA31W1	disc	1000	9.1	125	4
KA34W1	disc	4000	9.1	45	15
KB23L1	disc	268	6.95	6	20
LA23W1	disc	300	9.1	240	9
LA27S1	disc	725	9.1	80	30
LA27W1	disc	700	9.1	105	20
LA28S1	disc	760	9.1	70	35
LA31J1	disc	1000	9.1	9	135
LA31S1	disc	1351	9.1	60	40
LA31W1	disc	1000	9.1	85	30
LB21J1	disc	100	6.95	8	135
LB21W1	disc	100	6.95	160	15
MA22S1	disc	228	9.1	200	20
QA51J1	rod	100000	9.1	2.5	20
RA43L1	rod	31500	9.1	4.0	70
RA51L1	rod	100000	9.1	6.0	90
RB33L1	rod	3150	7.1	4.0	70
RB36L1	rod	6300	7.1	4.0	70
RB38L1	rod	8000	7.1	4.0	70
RB41L1	rod	10000	7.1	6.0	90
WA21W1	washer	100	9.1	800	13
WA23W1	washer	315	9.1	350	18
WB11W1	washer	10	6.95	860	12
WB13W1	washer	31.5	6.95	500	16
General Electric Co., Carboloy Dept. Detroit, Mich.					
D101	disc	10000	no data	5.0	14.6[3]
D103	disc	5000	available	3.5	5
D201	disc	3000			
D203	disc	1000		7.0	4.2
D301	disc	3000		13.5	67
D303	disc	1000		8.0	11.7
D401	disc	1000		11.5	24
D403	disc	250		14.5	2.2
D501	disc	1000		19.0	64
D503	disc	500		16.0	14
D751	disc	250		25 5	
D753	disc	100		23.0	

1. Dissipation and time constants are based on units being suspended by their leads in still air.
2. Ratio $R_{..}$ @ 0°C / R_{0} @ 50°C
3. Time to reach 63% of applied voltage (seconds) for voltage of 48 v (for this Co.)

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Coil resistance: From .005 Ohms at .005 volts DC to 40,000 Ohms at 14.0 volts DC.

Nominal power required: Factory adjusted at .005 watts.

Contact rating: 1 amp resistive, .5 amps inductive at 115 volts AC or 26.5 volts DC.

Contact arrangement: SPDT only.

Advance type SV relays are ultra-sensitive, yet durable—dust-tight, yet fully adjustable. Contacts and all working parts are protected by a transparent molded plastic cover.

Sensitivity can be adjusted from the 5-milliwatt factory setting by turning the vernier screws. Use the type SV in any DC circuit where power consumption is limited to a few thousandths of a watt.

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Thermistor Data Chart (cont.)

Thermistor Number and Type		Resistance at 25° C	Temperature Coefficient %/°C	Dissipation Constant mw/°C	Time Constant[1] (Seconds)
General Electric Co., Carboloy Dept. (Cont.)					
D104	disc	500	no data	4.0	0.7
D202	disc	300	available		
D204	disc	100		8.0	<0.5
D302	disc	300		11.0	6.8
D304	disc	100		8.0	1.0[1]
D402	disc	100		13.0	
D404	disc	25		13.0	<0.5
D502	disc	100		17.5	4.6
D504	disc	50		22.5	1.2
D752	disc	25		22.5	
D754	disc	10		20.0	<0.5
D1002	disc	25		34.0	
D1004	disc	10		30.0	0.5
R051	rod	100000		4.5	
R111	rod	100000		14.0	
R113	rod	31500		7.5	
R171	rod	50000		24.5	
R173	rod	20000		11.0	
R052	rod	10000		4.0	11.4
R112	rod	10000		12.0	
R114	rod	4300		11.5	86
R116	rod	3150		10.0	32
R172	rod	5000		16.5	
R174	rod	2000		14.0	44
RF111	hi-temp rod	40000		7.5	
W751	washer	415		58	59
W753	washer	315		57	34
W755	washer	100		55	8.2
W752	washer	41.5		56	4.8
W754	washer	31.5		54	3.2
W756	washer	10.0		51	0.8
Gulton Industries Metuchen, N. J.					
11TE1	wafer	10	—3.9	7.9	23
12TE1	wafer	20	—3.9	4.7	16
15TE1	wafer	50	—3.9	3.2	11
21TE1	wafer	100	—3.9	2.5	7
21TD1	wafer	100	—4.4	7.8	16
22TD1	wafer	200	—4.4	4.0	12
25TD1	wafer	500	—4.4	3.0	7
31TD1	wafer	1000	—4.4	2.6	5
23TD11	wafer	270	—4.4	3.8	11
27MD1	wafer	725	—4.4	150[2]	35
28MD1	wafer	760	—4.4	150[2]	35
35TF1	wafer	5000	—4.9	4.3	12
45TG1	wafer	50K	—5.4	4.6	11
51TG1	wafer	100K	—5.4	4.2	7
61TM1	wafer	1 meg.	—6.8	5.3	13
36RR1	rod	6.3K	—3.9	4	70
36RR1	rod	6.3K	—3.9	4	70
41RR1	rod	10K	—3.9	6	95

1. Time to reach 63% of applied voltage (seconds) for voltage of 48 v (for this Co.)
2. With thermal sink

Thermistor Data Chart (cont.)

Thermistor Number and Type		Resistance at 25°C	Temperature Coefficient %/°C	Dissipation Constant mw/°C
Gulton Industries (Cont.)				
51RD2	rod	100K	—4.4	2.5
31CH1	bead	1000	—3.4	0.5
31CH2	bead	1000	—3.4	0.5
31CB1	bead	1000	—3.9	0.7
31CB2	bead	2000	—3.4	0.1
32CH1	bead	2000	—3.4	0.1
32CH3	bead	2000	—3.4	0.1
32CB1	bead	2000	—3.9	0.7
32CB2	bead	2000	—3.9	.07
32CB5[1]	bead	T2000	—3.9	
35CB1	bead	5000	—3.9	0.7
35CB2	bead	5000	—3.9	0.7
36CB2	bead	5700	—3.9	0.3
38CB2	bead	8000	—3.9	0.1
38CX2	bead	8000	—4.2	0.4
41CB1	bead	10000	—3.9	0.7
41CB2	bead	10000	—3.9	0.7
45CA1	bead	50000	—4.6	0.7
45CA2	bead	50000	—4.6	0.7
45CD3	bead	47000	—4.4	0.1
45CD5	bead	50000	—4.4	0.1
51CA1	bead	100000	—4.6	0.7
51CA2	bead	100000	—4.6	0.7
51CA3	bead	100000	—4.6	0.1
58CX2	bead	800000	—5.1	0.7
65CX2	bead	5.3 meg	—4.6	0.1
32PB1	bead probe	2000	—3.9	1
32PB2	bead probe	2000	—3.9	1
51PA1	bead, bulb	100000	—4.6	1
36BS1	bead, bulb	5700	—3.9	
65BS1	bead, bulb	5.3 meg	—4.6	
Keystone Carbon Co. St. Marys, Pa.				
L0503-1500-88	bead	2520	—4.1	no data
L0503-56K-125	bead	100000	—4.9	available
L0903-200-70	disc	316	—3.8	
L0903-1100-95	disc	1888	—4.3	
L0903-25K-140	disc	46700	—5.0	
L1204-48K-145	disc	89300	—5.1	
L1215-800-73	disc	1290	—3.9	
L1215-7.5K-107	disc	13400	—4.6	
L1215-33K-123	disc	60000	—4.8	
L1215-75K-131	disc	138000	—5.0	
L2110-45K-151	disc	85500	—5.2	
L2003-62-73	disc	99.6	—3.9	
L2005-95-70	disc	150	—3.8	
L2005-112-73	disc	180	—3.9	
L2005-156-97	disc	270	—4.4	
L2004-577-97	disc	1000	—4.4	
L2005-2.2K-111	disc	3800	—4.7	
L2005-7.1K-131	disc	13090	—5.0	
L2005-32K-152	disc	60600	—5.2	
L3004-20-73	disc	32.2	—3.9	

Time Constant (Seconds)
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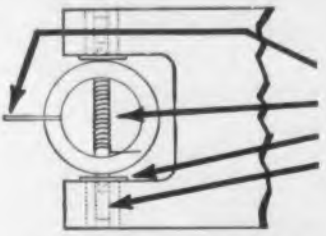

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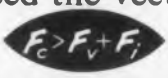
precision potentiometers

Long life is achieved by minimizing wear. Wear results from pressures or forces between contact assembly and winding. Total force consists of a dynamic force  due to vibration, acceleration and shock; an inertial force  acting on the contact assembly; and a static force resulting from contact pressure. For proper operation, contact force must exceed the vector sum of the dynamic forces 

The Kintronic contact assembly is *dynamically balanced* about a pivot  and therefore vibration, acceleration and shock forces cancel out. Inertial force on the contact assembly is minimized by making its mass and size small as possible. Reduction of these dynamic forces enable use of very low contact pressure.

Operational Results: total wear producing force is extremely small. 5,000,000 cycle life is achieved at maximum speeds of 3,425 r.p.m., under 2,000 cycle 30g vibration!

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Thermistor Data Chart (cont.)

Thermistor Number and Type		Resistance at 25° C	Temperature Coefficient %/°C[1]	Dissipation Constant mw/°C	Time Constant (Seconds)
Keystone Carbon Co. (Cont.)					
L3006-50-73	disc	80.4	—3.9	no data	44
L3006-120-89	disc	204	—4.2	available	44
L3006-450-97	disc	780	—4.4		44
L3006-1K-115	disc	1790	—4.7		44
L3006-10K-141	disc	18500	—5.0		44
L3804-30-73	disc	48.1	—3.9		50
L3806-100-81	disc	164	—4.1		64
L3806-1200-120	disc	2170	—4.8		64
L3806-4500-134	disc	8280	—5.0		64
L4010-577-97	disc	1000	—4.4		80
L4504-10-73	disc	16.8	—3.9		50
L4507-700-120	disc	1260	—4.8		78
L4507-10K-156	disc	19048	—5.2		78
L4715-100-79	disc	163	—4.0		110
L4715-300-97	disc	520	—4.4		110
L4715-1K-120	disc	1810	—4.8		110
L4715-5K-138	disc	9250	—5.0		110
L4715-20K-155	disc	38200	—5.2		110
L5505-3.3-59	disc	5.02	—3.5		90
L5507-100-100	disc	173.4	—4.4		96
L5507-500-120	disc	904	—4.8		96
L5507-2K-140	disc	3740	—5.0		96
L7606-15-85	disc	25.2	—4.1		
L8208-11-70	disc	17.39	—3.8		
L8212-150-108	disc	266	—4.6		
L10010-10-75[1]	disc	16.07	—3.9		
L10015-100-97	disc	174	—4.4		
L10012-260-92	disc	437	—4.3		
L060637-400-85	rod	674	—4.1		
L060637-43K-103	rod	74780	—4.5		
L060637-375K-125	rod	670000	—4.9		
5713-W29-100-85	washer	168	—4.1		
5726-W29-200-85	washer	336	—4.1		
7611-W28-1K-133	washer	1850	—5.0		
Victory Engineering Corp. Union, N. J.					
26A2	bead	528	5.6	0.5	3
31A3	bead	1000	7.3	0.7	2
32A1	bead probe	2000	7.3	1.0	25
32A5	bead	2000	5.6	0.1	1
32A11	bead	2000	7.3	1.0	25
32A16	bead	850	1.0	4.0	45
32A30	bead probe	2000	7.3	1.0	25
32A38	bead probe	2000	7.3	1.0	25
32A50	bead	2000	5.6	0.09	0.5
33C3	bead	3100	7.3	0.4	2
35A1	bead	5000	7.3	0.7	2
35A11	bead probe	5000	7.3	1.0	25
37A3	bead	7000	7.3		
41A2	bead	10000	7.5	0.7	2

1. Ratio $R_{\text{}}$ @ 0°C / R_o @ 50°C

Thermistor Data Chart (cont.)

Thermistor Number and Type		Resistance at 25° C	Temperature Coefficient %/°C[1]	Dissipation Constant mw/°C	Time Constant[1] (Seconds)
Victory Engineering Corp. (Cont.)					
43A4	bead	30000	7.3	0.7	2
44A1	bead	35000	4.5		
45A2	bead	50000	9.1	0.7	2
45B3	bead	50000	9.1	0.5	
46A2	bead	60500	4.5		
49A1	bead	85000	4.5		
51A10	bead	100000	10.3	0.6	2
51A22	bead	100000	10.3	0.09	0.5
55A2	bead	500000	11.5	0.7	2
61A1	bead probe	1000K	12.7	1.0	25
61A11	bead probe	1000K	12.7	1.0	25
71A2	bead rod	12000K	20.0	1.0	25
05E1	disc	5	6.95	12	200
21D1	disc	100	9.1	800	13
21E3	disc	100	6.95	8	140
23D2	disc	300	9.1	250	9
23E3	disc	310	6.95	6	20
25E2	disc	500	6.95	3	10
28D2	disc	760	9.1	100	25
31D2	disc	1000	9.1	100	4
31D7	disc	1200	9.1	6	20
31E1	disc	1000	6.95	30	2
33D4	disc	2500	9.1	20	4
35D1	disc	5000	9.1	130	2
11X1	washer	10	6.95	850	13
21W1	washer	100	9.1	800	13
22X1	washer	150	6.95	130	4
33S1	rod	3150	7.1	4.0	70
41S1	rod	10000	7.1	6.0	95

1. Ratio R_o @ 0°C/R_{50} @ 50°C

Since the time required for the thermistor to change its temperature by a specified amount depends on the rate of heat transfer between the thermistor and its surroundings, the thermal time constant depends upon the method of mounting the unit as well as the medium of environment in which it is located. For example, the thermal time constants of a typical 0.4 in. diameter disc, when supported by its leads in still air, in moving air (1000 ft/min), still oil, or moving oil (200 ft/min), are approximately 100, 30, 20, and 5 seconds respectively.

The thermal time constants for a typical 2 in. long glass probe thermistor, when supported by its leads in still air, in still oil, or in still water are approximately 25, 2, and 1 second respectively.

The thermal time constants of a thermistor with leads is usually specified for the unit supported by its leads in still air. For a thermistor which does not have leads, the thermal time constant is specified for the unit mounted in intimate contact with a good thermal sink.

Temperature Coefficient

The temperature coefficient of resistance, α, is the ratio of the rate of change of resistance with temperature to the resistance of the thermistor at a specified temperature. It is commonly specified in per cent per degree, or ohms/ohm/degree and may be expressed mathematically as:

$$\alpha(T) = [1/R_o(T)]\,[dR_o(T)/dT]$$

Since the resistance versus temperature characteristic of a thermistor is nonlinear, alpha varies with temperature. In general, alpha increases as the temperature decreases and vice versa.

ELECTRONIC ENGINEERS

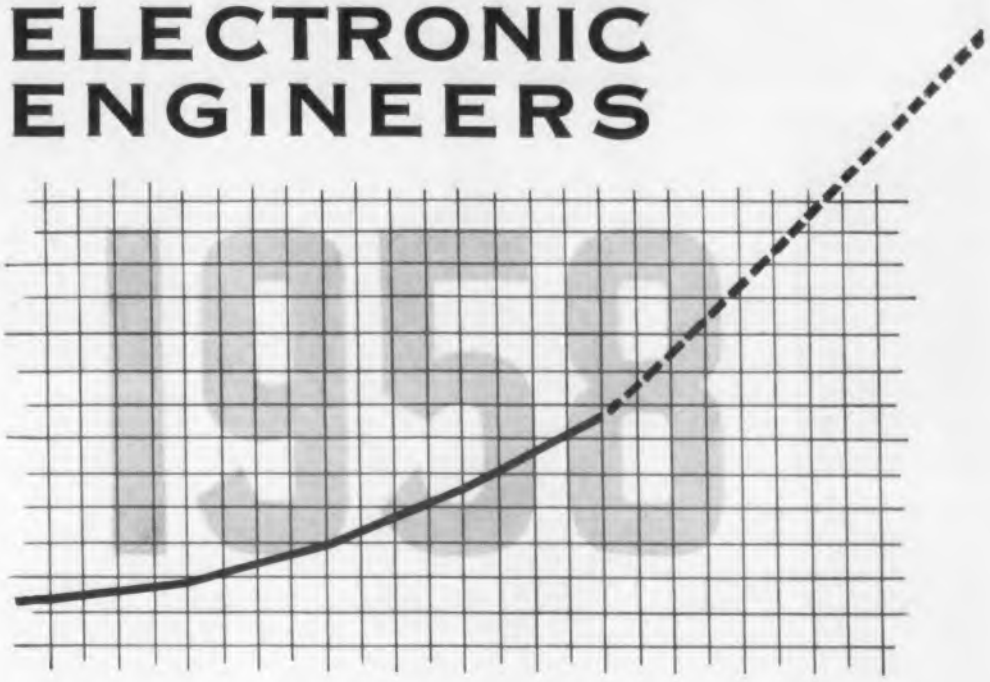

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Plate voltage, max.	4000 volts	Grid-Screen Mu	5

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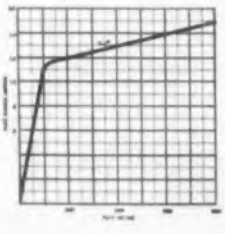

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Microwave Applications of Thermistors

Leonard I. Kent

Chief Microwave Engineer
The Narda Microwave Corp.
Mineola, N.Y.

A thermal sensitive resistor, the thermistor, is finding wide application in measuring microwave power. Among the topics of importance are thermistor characteristics, thermistor mounts, dc characteristics, broadband mounts, and coaxial mounts. Part II will discuss waveguide thermistor mounts, and measuring techniques.

Part I

(a)

Cartridge Type

(b)

Enlarged Miniature Cartridge

Fig. 2. Thermistor Mounts.

THERE ARE many devices which are sensitive, with varying degree, to thermal or temperature changes. The thermistor, a thermal sensitive resistor with a negative temperature coefficient of resistance, is one of the more sensitive devices. When a thermistor is subjected to a temperature change, as occurs when it is exposed to electromagnetic energy, it undergoes a very large change in resistance. If the thermistor is small compared to a wavelength, and its resistivity sufficiently great that high-frequency currents are forced to flow throughout the volume of the element, rather than on the surface; the temperature gradients within the volume of the element, and the exchange of heat with the surrounding area, will be almost identical for direct current, audio and microwave frequencies. Since this implies that equal quantities of dc, af, or rf power absorbed by the thermistor heat it to the same temperature and effect the same resistance change, this principle can be used to measure any of these powers by substitution methods. Of particular interest here is the measurement of rf or microwave power.

Primary equipment needed for the measurement of microwave power are an efficient thermistor mount matched to the transmission line in which it will be used, and a Wheatstone bridge circuit, preferably one which is self-balancing. When a power substitution method is used, the

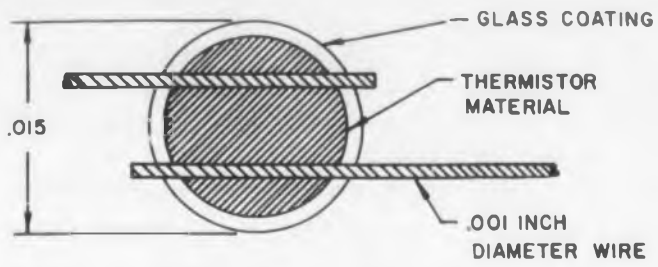

Fig. 1. Thermistor bead construction. The finished bead is a hard ceramic material enveloped in a thin glass coating.

bridge should be capable of biasing the thermistor to at least the amount of power to be measured, and the thermistor must be capable of withstanding that amount of power. For the measurement of power greater than the element can handle, additional equipment can be used.

Characteristics of Thermistors

Thermistors used for microwave power measurements are ceramic semiconductor beads which consist of various mixtures of the oxides of manganese, nickel, cobalt, copper, uranium, iron, zinc, titanium, and magnesium.[1] The materials are mixed in proper proportion to obtain the required specific resistance and temperature coefficient of resistance. To form the bead, two taut platinum alloy wires, 0.001 inches in diameter, are stretched parallel to each other with an accurately controlled spacing between them. The thermistor material in paste form is placed across the gap. Surface tension molds the paste into an approximate sphere with a diameter of 0.015 inches. The sphere is air-dried and sintered under accurately controlled atmospheric and temperature conditions. The leads become embedded tightly in the material, making good electrical contact to it. The finished bead is a hard ceramic material which is enveloped in a thin glass coating protecting it from further oxidation at high temperatures. This coating also greatly aids in the ruggedness and electrical stability of the bead. Diagonally opposite lead wires are cut and the bead cross-section is then as shown in Fig. 1.

Preliminary Mounting of the Thermistors

The bare thermistor element can be placed in a mount to which its impedance is matched and then used for microwave power measurements. Although this would serve the purpose, it is not the easiest assembly task to achieve. The extremely small size of the element makes it necessary for a skilled technician to do the assembling. In addition, when the bead has to be replaced, the user must acquire another bead and endure the hardship of soldering the new bead in the mount, or else send the unit back to the manufacturer for the replacement of the thermistor. The

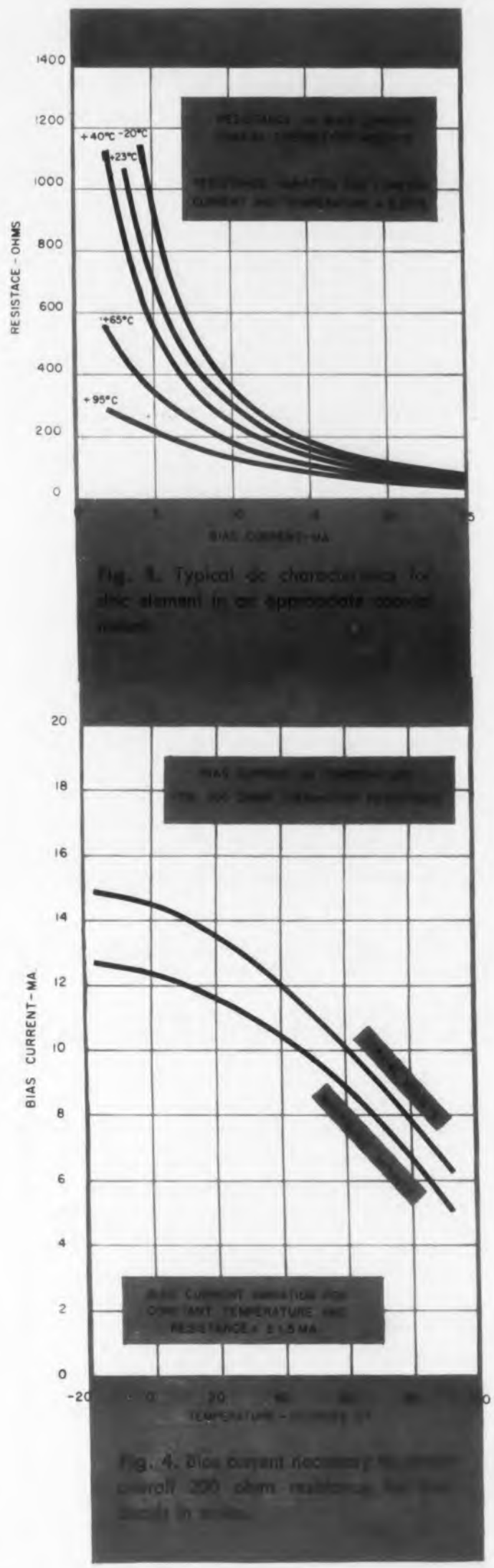

Fig. 3. Typical dc characteristics for disc element in an appropriate coaxial mount.

Fig. 4. Bias current necessary to obtain overall 200 ohm resistance for two beads in series.

logical approach, then, is to put the thermistor element into a form which is conveniently replaceable.

Figs. 2(a), 2(b), & Fig. 5 show appropriate forms in which thermistors can be placed so that they can be easily handled and readily replaced. The element shown in Fig. 5 is a mica disc, upon which two thermistors are mounted. This unit is specifically designed for use in a mount which can be used to measure power in a coaxial transmission line. Fig. 2(a) shows a cartridge which is similar in shape to the body of a 1N21 and 1N23 crystal. One or two thermistor beads can be mounted in this unit, dependent upon its application. This element is primarily used in mounts which measure power in waveguide systems. Fig. 2(b) shows a miniature version of the Fig. 2(a) unit. This is used in waveguide mounts for the higher frequency ranges. Further details of the construction of these elements are discussed in subsequent paragraphs.

DC Characteristics

Typical curves of the dc characteristics of the thermistor units are shown in Fig. 3. This curve is typical for the disc element in an appropriate coaxial mount and the cartridge units in a representative waveguide mount. The data variation among elements or mounts stated in the curves are due primarily to two factors. One is the difference in characteristics among thermistor beads and the other is the difference in the immediate surroundings within the mounts in which the elements are placed. The length of the 0.001-inch diameter leads and the effect of conductive and convective heat losses affect the dc characteristics appreciably. By keeping the leads uniform in length for the particular types of elements, some of the variational effects are reduced. Each mount, though, will still present at least a slightly different environment to the element, so that the dc characteristic can not be absolutely uniform among mounts designed for various frequency ranges. The variations of the dc characteristics are particularly important if a self-balancing bridge circuit is not used for the power measurements.

Experience has shown that these thermistor elements should operate within the range of 100 to 300 ohms in order to obtain the optimum conditions of good bridge sensitivity, ease of impedance-matching the thermistor to the mount, and protection from overload or burnout of the beads.[2] Therefore, when a single-bead thermistor is used, it is usually biased to 200 ohms, and two beads in series are biased to 100 ohms each. The latter, of course, requires a larger bias current to obtain necessary resistance. This is advantageous in the substitution method of measuring microwave power, since a greater amount of rf power can now be substituted for the power that biases

the element than if a single bead were used. Fig. 4 shows the bias current as a function of temperature necessary to obtain the overall 200 ohms for the beads connected in series in waveguide and coaxial mounts.

Broadband Thermistor Mounts

One of the most important items required for microwave power measurements is a mount whose impedance is matched to the thermistor it houses, and is also matched to the transmission line in which it will be used. To be completely versatile, the thermistor mount should be well-matched over as large a frequency range as possible with no tuning necessary. It should also be able to maintain a good match with any of the same type of elements that may readily be placed in it. Not only would this mount need no adjustments by the user, but no factory adjustments would be required by the manufacturer.

By matching the thermistor mount to the transmission line over a broad frequency range, the error due to the loss of power by reflection is minimized. Another factor requiring attention, however, is inefficiencies in the mount. There must be no microwave power leaking from or into the mount, and no sources of power dissipation other than the thermistor beads must exist. Lossy tuning devices and defective electrical contacts must be completely avoided. With these points in mind, excellent coaxial and waveguide thermistor mounts can be designed.

In Fig. 5, the internal construction of a broadband coaxial thermistor mount is shown. Also shown is the construction of a mica disc thermistor element. The element contains sprayed silver electrodes upon which two thermistor beads are mounted. The principles by which the mount and element operate can be described with the aid of the equivalent circuit of Fig. 6. The two beads are placed in series for the external bias circuit and in shunt across a 50-ohm coaxial line. When the beads are biased to present a resistance of 200 ohms to the external bridge circuit, each bead is biased to 100 ohms. To the rf line, the two beads are in parallel, thereby presenting a thermistor rf resistance of 50 ohms. Bias connections are provided by one end of a thermistor bead being isolated from the outer coaxial conductor by means of an rf by-pass capacitor, and the end of the other bead connected to the outer conductor, which is ground for the external circuit. An rf blocking capacitor isolates the center point between the two beads from the center conductor of the rf coaxial line. Both capacitors are in the form of silvered circular electrodes on a thin mica insulator. The undercut of the center conductor of the mount in Fig. 5 provides a series inductance to match any reactance of the thermistor beads, as well as the fringing capacity caused by the sudden termination of the coaxial center conductor. The center conductor bead support shown in the figure has been designed to give negligible reflections over the operating range.

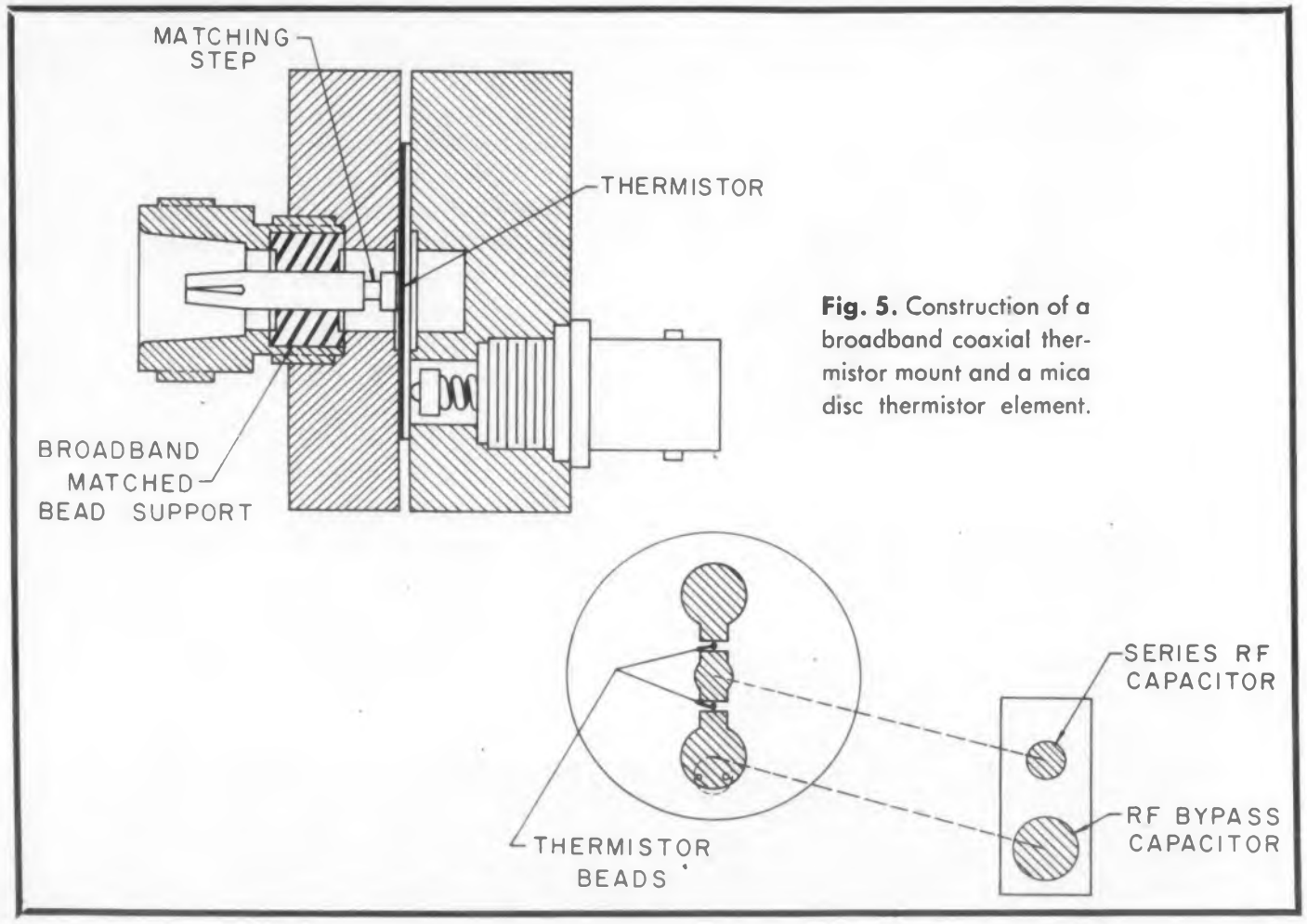

Fig. 5. Construction of a broadband coaxial thermistor mount and a mica disc thermistor element.

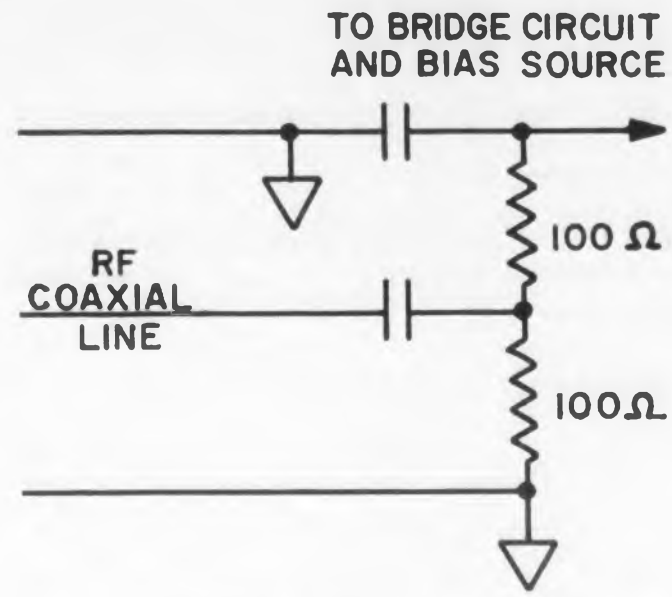

Fig. 6. Equivalent dc circuit of broadband coaxial thermistor mount.

Fig. 7. Photograph of coaxial mount opened to replace the element. It can be used with disc bolometer elements.

Fig. 8. Coaxial thermistor mount using two replaceable cartridge thermistor elements. Blocking capacitors are built into the mount.

The coaxial thermistor mount is designed to operate over the frequency range from 500 to 10,000 mc. The vswr of the mount over this range is always less than 1.50. This corresponds to a power reflection loss less than 0.2 db. Operation below the lowest frequency is limited by the blocking capacitor, while at the highest frequency, the coaxial connector limits the operation. The disc thermistor element is capable of measuring power levels from 0.01 to 10 mw. The design of this element embodies the considerations given it for ease of handling and replacement of a damaged element. Uniformity is maintained very closely in its manufacture so that the replacement of a thermistor element does not adversely affect the broadband characteristics of the mount. A photograph of the coaxial mount is shown in Fig. 7, and how it appears when opened to replace an element. As an incidental feature, besides being used as a thermistor mount, this unit can be used with various disc bolometer elements which are available. The principles of operation for bolometers in this mount are similar to those described for the thermistors. This mount offers a broadband match (vswr < 1.50) to four types of bolometers that require bias currents of 4.5, 8.75, or 35 ma. The arrangement of the locating pin in the descriptive nameplate makes it possible to change elements rapidly, and to determine at a glance which type of element is in the mount and its bias requirements.

Another type of coaxial thermistor mount (see Fig. 8) can be briefly mentioned here. This fixed tuned mount makes use of two replaceable cartridge thermistor elements as shown in Fig. 2(b), each containing a single thermistor bead. As with the disc's thermistor beads for the 561 coaxial mount, the two cartridges are placed in series for dc, and in parallel for rf. The parallel combination is again similarly made to present a 50-ohm impedance to the input coaxial line. Necessary blocking capacitors are built into the mount. This coaxial mount can be used over the frequency range from 20 to 1500 mc with a vswr less than 1.20. Similar to the 561 thermistor mount, this mount can also give equal performance with the appropriate cartridge type 100-ohm bolometers which are available. (This is the first of two articles on Microwave Applications of Thermistors.)

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Design Data for Ultra Low Temperature Thermistors

Herbert B. Sachse
Keystone Carbon Co.
St. Marys, Pa.

LOW-TEMPERATURE thermistors are very useful to measure temperatures of missile fuel components. New low-temperature types have been designed which work in liquid oxygen, nitrogen, and hydrogen. Thermistors are desirable replacements for helium gas and platinum resistance thermometers because they are less expensive, much less breakable, and much more sensitive. The gas thermometer has additional shortcomings in that it does not produce electrical signals directly and cannot be easily miniaturized.

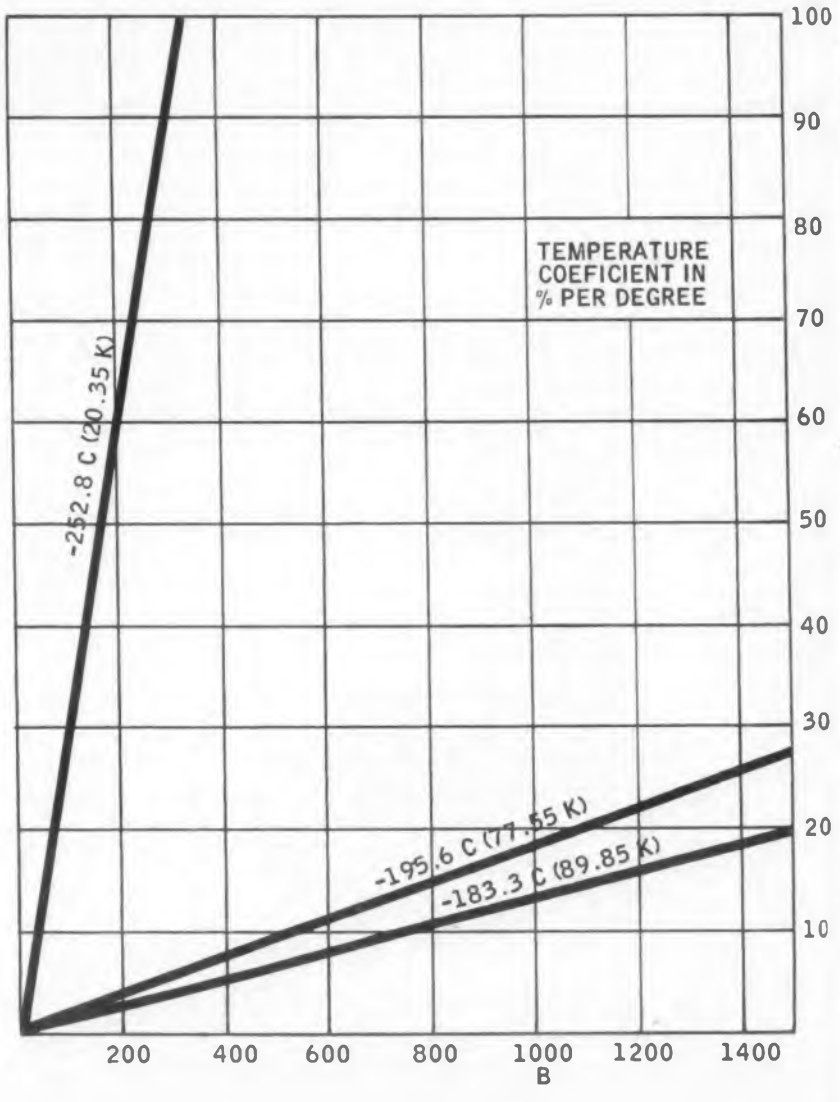

Fig. 1. Temperature coefficient in % per degree C as a function of B for —183.3, —195.6, and —252.8 C. B is calculated from the resistance ratio: R —183.3 C/ R + 20 C.

The usual commercial thermistors with negative temperature coefficients between 2 and 8 per cent per degree at room temperature cannot be used for very low temperatures. In liquid oxygen (—183.3 C) the resistance would be increased to values above 10 megohms, which are inconvenient for electronic circuitry. The new types of thermistors developed for applications at such low temperatures are described in this article.[1,2] Data on wattage rating, time constant, and reliability estimates are given.

Resistance

Various resistance materials have been developed to cover the temperature range between liquid oxygen and liquid hydrogen with resistance values which are practical for normal circuitry. "Large" temperature coefficient materials can only be used down to —220 C, while "small" temperature coefficient materials were developed for applications down to —255 C. The classification "large" and "small" temperature coefficient is arbitrary and refers to the behavior of the materials in liquid oxygen. At room temperature both materials have a very low temperature coefficient. On the other hand, in liquid hydrogen, the "low" temperature coefficient would increase to 50 to 75 per cent per degree. See Table 1.

Further variations, though only to a lesser degree, can be made by changing the geometrical dimensions of these units. By producing thermistor units either in disk or rod type, a resistance range of more than one decade can be covered by the same material. Simultaneously, the self-heating and wattage rating of these units, which are determined by the values of their mass and surface, can be varied within certain limits. The same holds true for their response to temperature changes (time constant).

The gap between "large" and "small" temperature coefficient thermistors is expected to be closed soon by new thermistor types.

The exponential increase of the resistivity of thermistors with decreasing temperature is expressed in first approximation by the formula:

$$log \quad \frac{\rho 1}{\rho 2} = \frac{B\,(T_2 - T_1)}{2.303 \cdot T_1\,T_2}$$

in which $\rho 1$ and $\rho 2$ represent resistivities at the respective absolute temperatures T_1 and T_2 in degree Kelvin (degree K = degree C + 273.15). For a given temperature interval ($T_2 - T_1$) the constant B is a linear function of the Briggs logarithm of the resistivity ratio between T_1 and T_2. On the other hand, B, Fig. 1, is truly constant only for smaller temperature intervals. It has its own temperature dependence, which however is small and tends to decrease the B value itself and correspondingly the resistivity ratio, thus extending the application range of these thermistors to lower temperatures.

Table 1. Thermistor Resistance and Temperature Coefficient

Characteristic	Large temperature coefficient	Small temperature coefficient
TEMPERATURE RANGE	+20 to —220 C	+ 20 to —255 C
RESISTANCE RANGE (ohms)		
at —183.3 C (liquid oxygen)	240 to 30 K[1]	90 to 10 K[1]
at —195.6 C (liquid nitrogen)	1600 to 260 K[1]	150 to 20 K[1]
—252.75 (liquid hydrogen)		100 K to 100 Meg[2]
RESISTANCE RATIO		
—183.3 C/+20 C	2500 to 14,000[1]	18 to 300[1]
—195.6 C/—183.3 C	6.6 to 9.0[1]	1.4 to 2.0[1]
—252 C/—195.6 C		850 to 100,000[2,3]
TEMPERATURE COEFFICIENT		
in liquid oxygen	14 to 17% per deg C[4]	2.6 to 3.7% per deg C[1]
in liquid nitrogen	19 to 26% per deg C[4]	3.3 to 5.3/ per deg C[4]
in liquid hydrogen		58 to 130% per deg C[4]

[1] in tolerance bands of ±10%
[2] no standardized tolerance.
[3] only values below 2000 are of practical interest because of high resistance values involved.
[4] depending on B or the ratio group: See Fig. 1.

Note that the range of possible resistance values at temperatures below —183.3 C becomes larger.

This effect is most welcome for ultra low temperatures in the order of —253 C (20 deg K) where it helps to shift the limit of application 3 to 4 degrees lower. For a truly constant B the resistivity would be a linear function of $1/T$, the reciprocal absolute temperature in degree Kelvin.

In Fig. 2 the resistivity versus temperature characteristics of various thermistor types are compared with that of carbon resistors which during the past few years have been recommended for temperature measurements below 4 deg K. From the illustration, four facts are evident.

- The resistivity of commercial thermistors is sky high in the liquid oxygen range.
- The practical low temperature limit for "large" temperature coefficient thermistors is of the order of —220 C (53 deg K).
- The resistivity versus temperature slope tends to decrease with falling temperatures as mentioned before.
- Carbon resistors are impractical as a temperature sensing element above 20 deg K. Below this temperature they require individual calibration.

Wattage Rating, Time Constant

Wattage rating and time constants are mainly determined by the absolute values of mass and surface and their ratio. A second contributing

Table 2. Physical Data on Ultra Low Temperature Thermistors

Type	Code No.	Diameter in inch	Length in inch	Weight in milligram	Contact
MIDGET DISKS	L0904	.09±.01	.04±.004	20	Fine silver wire .007 in. dia., 2 in. long.
STANDARD DISKS	L2505	.245±.02	.048±.005	200	Fine silver wire .014 in. dia., 2 in. long.
MIDGET ROD	L050533	.052±.003 square	.33±.01	50	Tinned copper wire .01 in. dia., 1.75 in. long.
STANDARD ROD	L1440	.140±0.04	.400±.020	380	Tinned copper wire .019 in. dia., 1.75 in. long.

This types listed above are not available in all materials and resistance values. Disk types are preferred for "small" temperature coefficient materials, but by no means restricted to them. On the other hand, standard rods are normally made of "large" temperature coefficient materials, as are also midget rods. The latter have played a minor role in electronic design till now.

factor is the heat conduction of the lead wires. Economical considerations impose some restrictions on the variety of types with regard to the physical dimensions and the contact leads. Table 2 describes these features for the principal types.

Wattage rating. The wattage which can be applied to these thermistors without changing their value beyond certain limits by self-heating is influenced not only by their geometrical dimensions and their mass, but also by their temperature coefficient and the heat dissipation into the surrounding medium. Heat capacity, viscosity, and, for liquid gases, pressure and heat of evaporation, will determine the dissipation. Table 3 refers to thermistors immersed in liquid oxygen at its boiling temperature. The per cent resistance decrease for various thermistor wattage ratings is shown.

Table 3. Reversible resistance decrease and wattage for disk and rod type thermistors.

Type	*5*	*10*	*30*	*100*	*300 mw*
Midget disk	0.2	0.6	1	2	3%
Standard disk	0.1	0.3	0.6	1	2 "
Standard rod	1	2	3	6	8 "

Table 4. Time constant of Various Thermistors (From +20 C in air to —183.3 C in liquid oxygen)

Type	*Time Constant*
Midget disk	2 ±0.2 sec.
Standard disk	6 ±0.3 "
Midget rod	2.5 ±0.5 "
Standard rod	9 ±1 "

The relatively high resistance change for standard rods compared to disks shown in Table 3 evidently results from the large temperature coefficient material normally used for this type. The temperature increase for 100 mw corresponds to 0.5, 0.25, and 0.35 C, respectively.

Time constant. The time which is necessary to reach 63 per cent of the final value when submerging a thermistor of room temperature into liquid oxygen is listed for several types in Table 4.

Under equal cooling conditions the time constant should be in first approximation proportional to the heat capacity or the mass respectively of the unit. However, the data of Table 4, by no means, reflect the decrease in mass from standard to midget size.

The formation of gas bubbles, though only transient, during the dipping of the units into the boiling oxygen apparently distorts the cooling conditions and obscures the true time con-

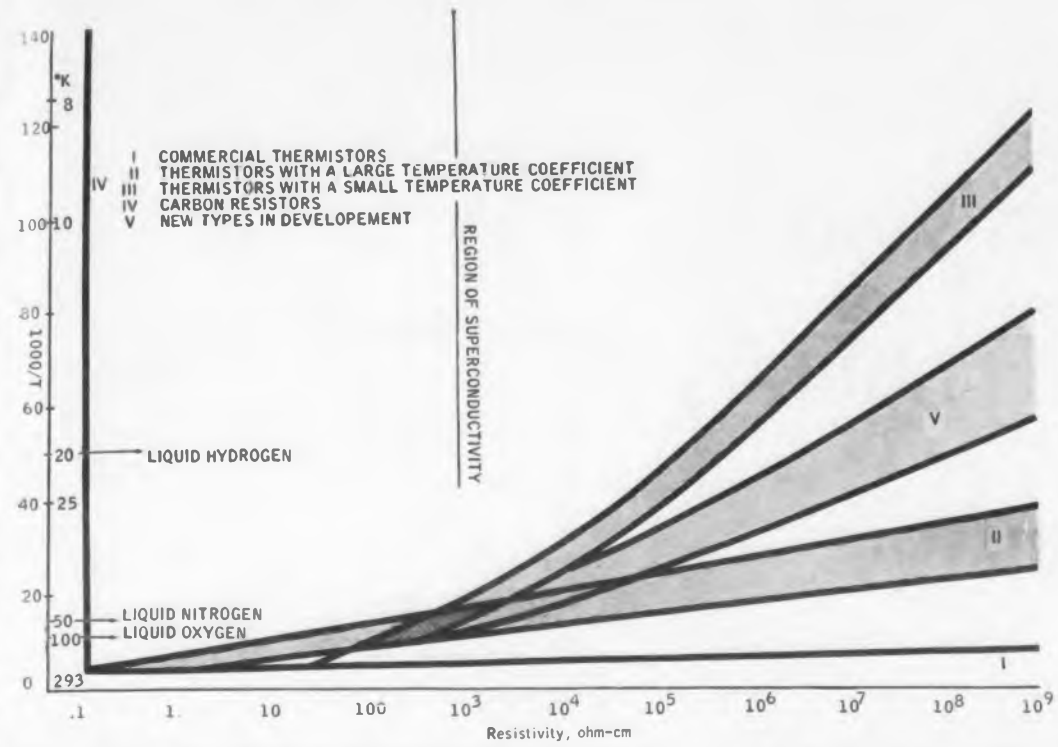

Fig. 2. Resistivity versus temperature characteristics for various thermistor types. Types III and V show up as best for extreme low temperatures. Two ordinate scales are shown. For plotting, the 1000/T scales are used. For reading, the direct reading absolute temperature scale is more convenient.

stant. A similar effect is observed when water is dropped onto a red hot steel plate. The water does not evaporate explosively, but a few water drops "swim" a few seconds on a heat insulating cushion of water vapor (Leidenfrost phenomenon). The true time constant of these units measured without formation of gas bubbles, e.g., non-evaporating media, will be smaller. In order to provide some data for the calculation of temperature adaptation processes, the approximate specific heat in cal/gram of these materials is given: +20 C = 0.15; −200 C = 0.08; −230 C = 0.04.

For temperatures below −230 C the specific heat will drop further at an increased rate, thus decreasing the time constant. This effect is most welcome insofar as it opens the possibility to apply larger and more rugged thermistors at very low temperatures (< 30 deg K). In other words, larger units behave as if they had a smaller mass.

Reliability. Life tests were carried out in two different ways.

Long term life tests: Consecutive cooling cycles from room temperature to −183.3 C and back were made with storage periods at ambient temperature between the cooling cycles;

Short term life tests: Repetitive cycles were made either between room temperature and liquid oxygen or between liquid oxygen and liquid nitrogen temperature.

Since resistance changes alone are not conclusive enough because of the different temperature coefficients for various types and ratio groups, it is more informative to express reliability data as possible temperature errors produced by resistance deviations with time.

Possible temperature error:

- in long term life tests (1000 hours and more) ±2 C or better;
- in short term life tests ±0.2 C.

It is obvious that the electrical stability of these thermistors is in some degree dependent upon the cooling rate. The life test cycles were always made by direct quenching in liquid gases and reheating in air of ambient temperature. The thermal shock during quenching in the liquid is exceptionally rough. It can be compared to the quenching of other electronic components from 200 C in air into ice water, a test which normally is not applied.

Since certain applications call for a better long term stability, higher quality grades can be obtained by proper classification and treatment. However, as usual, quality requirements and economy will have to be matched by the designer.

Protective coatings. The high insulation resistance of liquid gases and their chemical indifference makes it superfluous to apply insulating or protective coatings. Furthermore, many of the conventional coating materials such as plastic films become very brittle at low temperatures and do not withstand consecutive quenchings. Nevertheless, special coatings have been investigated which hold promise of being satisfactory in this temperature range.

Acknowledgement: The author wishes to thank Mr. G. W. Vollmer for his assistance and Keystone Carbon Co. for granting permission to publish this information.

References

First basic facts on low temperature thermistors were published in:

1. Low Resistance Thermistors As Ultra-Cold Thermometers by H. B. Sachse, *Tele Tech & Electronic Industries*, Jan., 1957, pp. 55.
2. Temperature measurements Near Absolute Zero by H. B. Sachse, *Tele Tech & Electronic Industries*, Sept. 1957, pp. 58.

Specifying Military Thermistors

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The increasing use of thermistors has made adequate military specifications a necessity. As yet no standardization efforts have been made by the Armed Services or by industry. This general specification for procurement of thermistors was prepared by R.C.A. for military airborne equipment. It has enabled the purchase of reliable thermistors for the past few years.

THERMISTORS are being utilized in increasing numbers in new military equipments. The versatility of this part is evidenced by its many applications: temperature compensation of transistor circuitry and instruments; measurement of true air speeds; indication of liquid levels; control of cabin temperature; stabilization of oscillator frequency; and many other ingenious designs.

However, there remains the problem of specifying thermistors for military applications. There has been no standardization efforts for this part by the usual sources, the Electronic Industries Association, the Aircraft Industries Association, or any of the Armed Services. This article describes a general specification for procurement of thermistors prepared by Radio Corporation of America for military airborne equipments.

The most widely known characteristic of thermistors is its variation of dc resistance value with temperature. This property is not quite the same thing as "temperature coefficient of resistance" for resistors. The resistance-temperature characteristic can be closely described by:

$$R_t = R_o\, \epsilon^{-\beta\left(\frac{1}{T_t} - \frac{1}{T_o}\right)} \qquad (1)$$

where: T_o and T_t are the references and test temperatures, respectively, in degrees Kelvin.
β—material constant

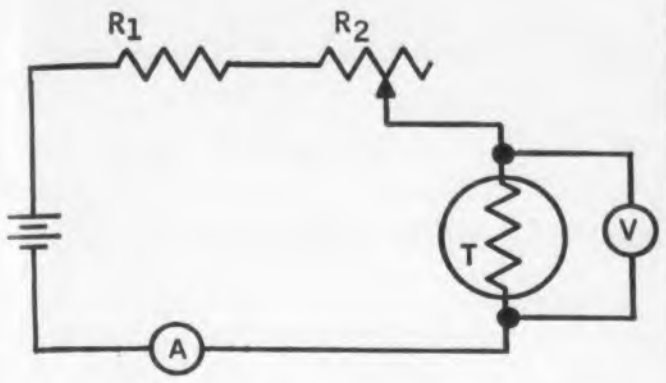
Since thermistors exhibit relatively large changes in dc resistance with small temperature swings, the specification should carefully indicate the test procedure for evaluation.

Resistance-Temperature Characteristic

Thermistors should be mounted at least one inch apart on suitable mounting strips. Three temperature baths should be available to provide controlled temperature environment over an extended period of time. The temperatures should be controlled within ±0.05 degrees C and should consist of one of the group options listed below:

OPTION I	OPTION II	OPTION III
0°C	−21.5°C	37.8°C
25°C	25.0°C	25.0°C
50°C	37.8°C	104.4°C

The thermistors should have their dc resistance value measured at the listed temperatures, in the order shown, with a Wheatstone bridge which is accurate to ±0.05 per cent. The resistance values measured at the low and high temperatures shown above (0°C and 50°C, −21.5°C, and 37.8°C, or 37.8°C and 104.4°C, respectively) should be used to calculate the material constant (beta or "b") of each sample for comparison with subsequent measurements. The 25°C resistance measurements should be only to initially check



Schematic circuit for voltage-current characteristic test.

Table I. Current Values for Voltage-Current Characteristic Test

Sequence	Current Value (% nom. 25°C current rating)
(a)	10
(b)	25
(c)	50
(d)	100

Table II. Qualification Test Procedure

Test Group I (All Specimens)
Resistance-Temperature Characteristic

Test Group II (Ten Specimens)
Low Temperature Exposure
Temperature Cycling
Moisture Resistance
Terminal Strength (Applicable only to Rod Thermistors)
Effect of Soldering
Body Strength (Applicable only to Rod Thermistors)

Test Group III (Ten Specimens)
Load Life

Test Group IV (Four Specimens)
Voltage-Current Characteristic
Vibration
Shock

the commonly-specified 25°C resistance tolerance. The following formulas should be used in the material constant calculations with Options I, II, and III, respectively:
Material Constant = Beta =

$$4061 \log \frac{R_{0°c}}{R_{50°c}};\ 3036 \log \frac{R_{-21.5°c}}{R_{37.8°c}};\ \text{or } 4056 \log \frac{R_{37.8°c}}{R_{104.4°c}}$$

Voltage-Current Characteristic

This characteristic is extremely important in many thermistor applications where self-heating is an integral part of the circuit design. Thus, the test procedure should be carefully stated so that the desired performance is indicated.

The thermistors should be mounted with the leads soldered 1-1/2 ±1/8 inch (effective length)

Specifying Military Thermistors *continued*

from the body and in still air at 25°C. The test circuit should be that shown in Figure 1. The series-limiting resistors (R_1 and R_2) shall be such that initially the circuit current will not cause self-heating in the thermistor sample. The circuit current should then be increased in the sequence shown in Table I and the corresponding voltage measurements should be made. A stabilization period, not to exceed 15 minutes, should be allowed at each sequence prior to recording values. The nominal 25°C current rating should be calculated as:

$$I_{(\text{nom. 25°C rating})} = \left(\frac{P_{(\text{nom. 25°C rating})}}{R_{(\text{nom. 150°C value})}} \right)^{\frac{1}{2}}$$

Qualification Tests

As a condition for granting engineering approval a group of specimens should be submitted to a qualification test procedure designed to determine whether they meet minimum acceptable quality levels. The determination of those limits should be the result of an initial study of thermistor performances when subjected to the usual military specification environmental tests. A study of this nature has been completed by the Radio Corporation of America, Camden, N.J. The qualification test procedure, as used by RCA, Defense Electronic Products, is in Table II.

Adequate precautions should be taken during tests to prevent moisture condensation on specimens, except during the Moisture Resistance and Temperature Cycling Tests.

Failure of a single thermistor in one or more tests of a test group should be charged as a single failure. One failure should be permitted in each test group but no more than two should be permitted for all test groups combined.

When thermistors as a group fail a specified average percent-change requirement, only one failure should be charged; however, a failure should be charged for each thermistor of the group which exceeds the maximum percent-change requirement, and these thermistors should not be considered in computing that average. It is intended to permit one average percent-change failure to be charged for the material constant requirement and an additional failure for the resistance change requirement.

The Resistance-Temperature and Voltage-Current Characteristic Tests have already been described.

Low Temperature Exposure

After a 24 hour exposure at —80°F (+2°F, 0°F) the resistance-temperature characteristic should again be performed.

The average change in the material constant for a group of specimens should not exceed ±0.5 per cent, nor should an individual specimen have a material constant change greater than ±1.0 per cent. The average change in the resistance value for a group of specimens at 0°C, —21.5°C or 37.8°C should not exceed ±3.0 per cent, nor should any individual specimen have a resistance change (from initial 37.8°C, 0°C or —21.5°C value) greater than ±5.0 per cent.

Temperature Cycling

Specimens should be subjected to the Method 102, MIL-STD-202, condition A test. No subsequent measurements should be required. Mounting should be as specified in the Resistance-Temperature Characteristic Test.

The specimens should be inspected for evidence of mechanical damage and discoloration of the color coding which renders it unrecognizable from the specimen background color.

Moisture Resistance

Specimens should be subjected to the Method 106, MIL-STD-202 test. Mounting should be as specified in the Resistance-Temperature Characteristic Test. No load or polarizing potential should be applied to the specimens during the test. Final measurements should be made after the 24 hour room ambient conditioning following the tenth cycle. The Resistance-Temperature Characteristic Test should be performed. Per cent change of resistance value at 0°C, 37.8°C, or —21.5°C and material constant (β) should be calculated.

The average change in the material constant for a group of specimens should not exceed ±5.0 per cent, nor should an individual specimen have a material constant change greater than ±10 per cent. The average change in the resistance value for a group of specimens at 0°C, —21.5°C or 37.8°C should not exceed ±10 per cent, nor should an individual specimen have a resistance change (from initial 37.8°C, 0°C or —21.5°C value) greater than ±12 per cent. Evidence of galvanic action within a specimen should be considered as cause for rejection as a defective specimen.

Terminal Strength (applicable to rod thermistors only)

Thermistors should be held by a terminal and tensile force should be gradually applied to the

other terminal in the direction of the longitudinal axis until the applied load reaches 3 pounds. Each wire lead should be bent through 90° at a point 0.25 inch from the body of the thermistor, and rotated through 360° in alternating directions for five cycles, at the rate of approximately 5 seconds for each complete cycle.

Terminals should withstand a direct pull of 3 pounds and the five twist cycles without evidence of mechanical failure.

Effects of Soldering

Thermistor terminals should be immersed individually for $3 \pm 1/2$ seconds in a pot of molten solder at a temperature of 350 ± 10°C to a point one-eighth to three-sixteenths inch from the thermistor body.

There should be no evidence of mechanical damage, loosening of terminals or discoloration of color coding beyond ability to distinguish from the specimen background body color.

Body Strength (applicable to rod thermistors only)

Specimens should be supported one-eighth inch from each end, and should then be subjected to a transverse load of not less than 4 pounds. The load should be applied at the center of the thermistor through a fulcrum having a radius of not less than 0.25 inch.

There should be no evidence of mechanical damage, breaking, or splitting of the specimen's body.

Load Life

The thermistors should be mounted on terminal strips with terminals spaced two inches apart, so that the effective lead length (including the height of the terminal post) is not greater than 1 inch.

Thermistors should be placed in an oven whose temperature is then brought to 125°C ± 2°C within two hours from room temperature. A current equivalent to 10 per cent of the nominal 25°C current value should be drawn by each thermistor for 1000 (+0, −8) hours. The power

supply should then be disconnected and the doors of the oven may be opened so as to allow the oven temperature to return to room conditions in not less than two hours. Final measurements of Resistance-Temperature Characteristic should be made and per cent change of resistance value at 0°C, 37.8°C or —21.5°C and material constant should be calculated.

The average change in the material constant for a group of specimens should not exceed ±1.0 per cent, nor should individual specimen have a material constant change greater than ±3.0 per cent. The average change in resistance value for a group of specimens at 37.8°C, 0°C or —21.5°C should not exceed ±3.0 per cent, nor should any individual specimen have a resistance charge (from initial 37.8°C, 0°C or —21.5°C value) greater than ±5.0 per cent.

Vibration

With the component mounted rigidly as intended, vibrate according to the following information noting all resonant frequencies:

Frequency range: 5 to 500 cps. 5 to 500 and back to 5 in 15 minutes.
Repeat 8 times (2 hours) for modes 1, 2, and 3, below.

Total excursion or acceleration: 0.01 in. or ±5g, whichever is maximum.

Mode (1) Horizontal-parallel to major axis.

Mode (2) Horizontal-perpendicular to major axis.

Mode (3) Vertical.

Resonance running time: 30 minutes at each noted resonant frequency.

If any mounting bracket resonance occurs below or at 55 cps, run for 30 minutes at that frequency with total excursion of 0.60 inch.

There should be no evidence of mechanical damage to the wire leads, breaking or splitting of the specimen's body.

Shock

Subject the part to 30 impact shocks which have an amplitude of 30 times the acceleration of gravity, each shock impulse having a time duration of 11 ±1 millisecond. The shocks should be applied in the following directions:

Horizontally, parallel to the major axis, five shocks in each direction.

Horizontally, perpendicular to the major axis, five shocks in each direction.

Vertically, five shocks in each direction.

There should be no evidence of mechanical damage to the wire leads, breaking or splitting of the specimen's body.

The procurement drawing covering the above tests and requirements has permitted RCA to buy reliable thermistors during the past few years. It is expected that a future evaluation of the qualification test results will permit reduction of allowable change levels.

Thermistor Bridges

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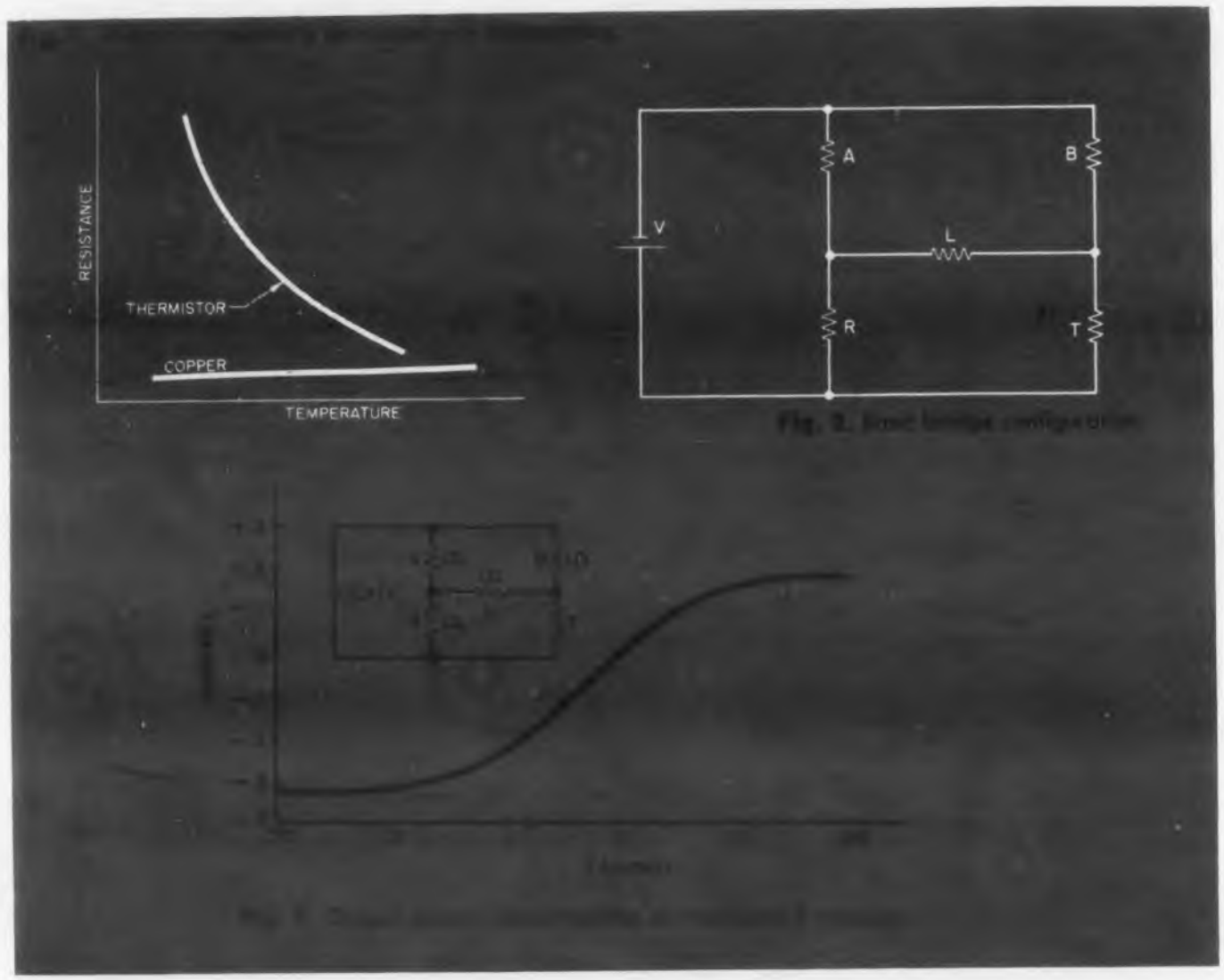
Significant advantages can be obtained from the relatively large outputs rendered by thermistor bridges. Temperature sensing circuits become quite involved because of the inherently low outputs from most transducers. A basic sensing circuit with a reasonably high output offers important savings and increased reliability. Three thermistor bridges with relatively large outputs are compared with those of several types of a more familiar device, the thermocouple.



Thermistor Self-Heating

Before proceeding directly to bridges there is one further item that must be thoroughly understood. Since thermistors are basically resistors, they will heat up appreciably if sufficient current is passed through them. The resultant temperature change should be accounted for.

For instance, suppose that it were required to measure the temperature of water flowing through a large pipe at a varying rate. Further, suppose the thermistor, which of course is the sensing element, is heated so that its temperature is three degrees above that of the water when the water is flowing slowly. When the water speeds up it will not draw off more heat from the thermistor than before. If it is assumed the increased flow cools the thermistor so that it is now only two degrees above the water temperature, a one degree temperature change has been introduced in the measurement, and the water, for all practical purposes, has not changed temperature at all.

How is this change eliminated? Simply keep the power dissipation in the thermistor low

Fundamentals

Thermistors in general have very high negative temperature coefficients, that is, they drop drastically in resistance as the temperature rises and vice versa. This function is depicted graphically in Fig. 1.

Thermistors presently are available in resistance values from a matter of a few ohms to tens of megohms. Since they are very temperature sensitive, a reference point of 25 C (77 F) is usually assumed as the temperature at which they are measured. For instance, a thermistor which is purchased as a one thousand ohm unit has been tested to within its specified tolerance at exactly 25 C. For values of resistance at other temperatures there is a graph or table of values usually covering the range of about —50 to 300 C. For those who may wish to calculate the values, the following approximate formula may be applied:

$$R_1 = R_2\, e^{\beta\left(\frac{1}{T_1}-\frac{1}{T_2}\right)} \qquad (1)$$

where:

R_1 = Thermistor resistance at temperature T_1
R_2 = Thermistor resistance at temperature T_2
e = Naperian base . . . 2.713
β = Material Constant ($_0K$)
T_1 = Reference temperature ($_0K$) of thermistor
T_2 = Another thermistor temperature ($_0K$)

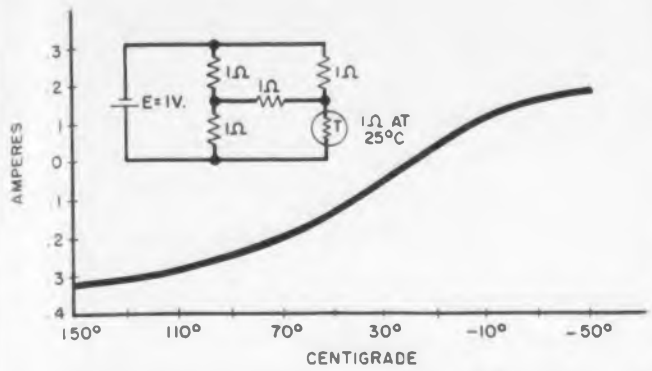


Fig. 4. Output current as a function of thermistor resistance change with temperature.

enough so that its temperature rise is less than the desired accuracy of measurement. For, if it is desired to measure a temperature accurately to one degree F, the thermistor temperature rise due to electrical current flow must be kept less than one degree.

Each unit's heating capacity is described as a dissipation constant which states the number of watts or milliwatts required to heat up a particular thermistor one degree Centigrade. If a unit were to have a dissipation constant of say two milliwatts per degree Centigrade, ten milliwatts of power would cause the thermistor to rise approximately five degrees above its surrounding medium. When the thermistor is dissipating a negligible (for the problem in question) amount of power, it is said to be non-self heated. In contradistinction, if the unit is heated appreciably above its medium, it is said to be self-heated. Incidentally, many applications require this latter condition.

Simple Bridge

Fig. 2 is the simplest bridge configuration possible. All further discussion will be based on use of this rather familiar circuit.

Assuming an equilateral bridge, one in which all legs are initially equal, $A = B = R = T$. The power source V may be in any form desired such as a battery, voltage regulator tube or transformer. Note that alternating currents may be applied as easily as direct currents.

If the only element in the bridge to vary is T, and the output load L is matched to the bridge for maximum power transfer; i.e. $L = A = B = R$, then the curve in Fig. 3 will describe the output current characteristics where all the aforementioned elements are one ohm and the applied potential is one volt.

If a thermistor is placed in position T, the curve of current output that will now be derived as the thermistor changes resistance with temperature is shown in Fig. 4.

Note the relatively wide range of temperature over which good linearity is obtained. This range runs from about 10 C to 60 C, or 50 F to 140 F, a span of room temperatures any section of

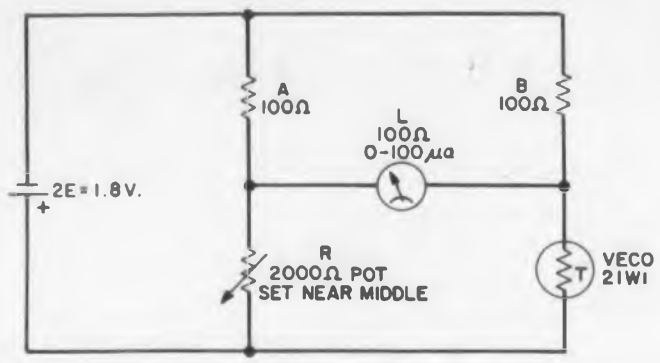


Fig. 5. Practical bridge for temperature measurement over one degree centigrade.

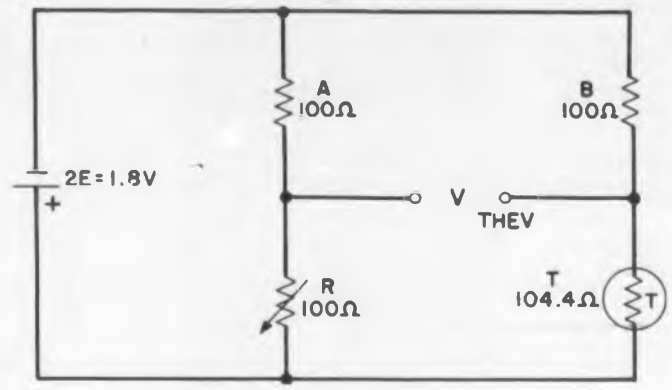


Fig. 6. Approximate output current is calculated from Thevenin's theorem. See Fig. 7.

which will plot out on a meter scale as practically a linearly divided arc.

For a practical case, the problem of temperature measurement over only a one degree Centigrade span will be examined. Suppose that in particular a plate of copper is varying between 25 and 24 C. An approach to this rather difficult problem is to construct a bridge as shown in Fig. 5. From the meter's scale we wish to read off temperature divisions of .01 degrees C. Obviously this can be done only if the thermistor has the sensitivity to deflect the meter at least to full scale.

The thermistor indicated is a Veco washer type 21W1 and is approximately 0.77 in. in diameter by 0.048 in. in thickness. It has a convenient mounting hole with approximately a 0.28 in. diameter by which it may be screwed or bolted directly to the copper plate and is specified as 100 ohms ±10 per cent at 25 C. Data from the Veco catalog indicates also that this unit has a dissipation constant of approximately 800 mw per degree C. If the requirements demand that the thermistor contribute no more than 0.01 degree C error, this means that no more than 8 milliwatts can be dissipated in the unit. Using formula (2),

$$E = \sqrt{PR} \qquad (2)$$

where E = Thermistor voltage
P = Power allowed in thermistor
R = Thermistor resistance

the required bridge voltage ($2E$) is found to limit the thermistor to 8 milliwatts. The necessary bridge voltage is approximately 1.8 volts as shown in Fig. 5.

Data further reveals that the 21W1 thermistor changes about —4.4 per cent/°C at 25 C. With this knowledge, an approximation can be made of the output meter current. This shall be done by employing Thevenin's Theorem. With the meter out of the circuit the output bridge voltage is derived from divider relations in Fig. 6. This is now the Thevenin voltage of the circuit when the thermistor changes from 25 C to 24 C or 100 ohms to 104.4 ohms. Since the Thevenin resistance of the circuit is relatively unchanged by this small leg shift, we shall simply approximate it as 101 ohms. Therefore, the complete Thevenin circuit of our bridge is as shown in Fig. 7.

When the meter is connected into the bridge, the calculation of its current is quite simple:

$$I_M = \frac{V_T}{R_T + L} = \frac{0.0216}{101 + 100} = 107\ \mu a \qquad (3)$$

It is seen that the meter can be driven well off scale by the small change in temperature of only one degree.

For the next bridge example, a relatively high resistance thermistor is utilized since the object will be to develop a high voltage output from the bridge. The unit employed will be the Veco type 71A2. It is a bead in a glass rod and has a shape very similar to a standard one watt size carbon resistor with axial leads. The ratings of the 71A2 are:

Resistance at 25 C	= 12 Megohms ±20%
Dissipation Constant	= 5 mw/°C in water
Maximum Power	= 0.1 watt
Temperature Coefficient	= —5.8%/°C @ 25°C
Maximum Temperature	= Approx. 500°C

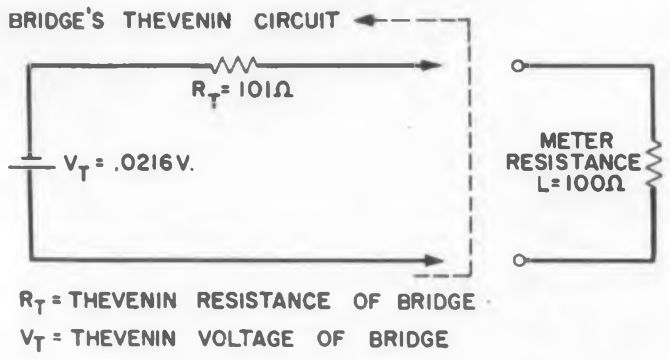


Fig. 7. Thevenin circuit for temperature bridge of Fig. 5.

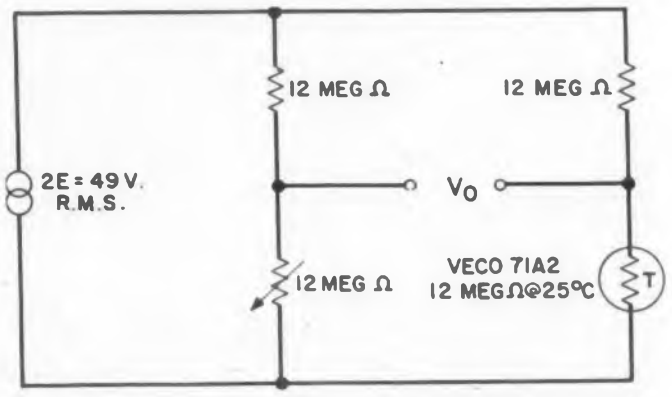


Fig. 8. Thermistor and bridge for high output voltage.

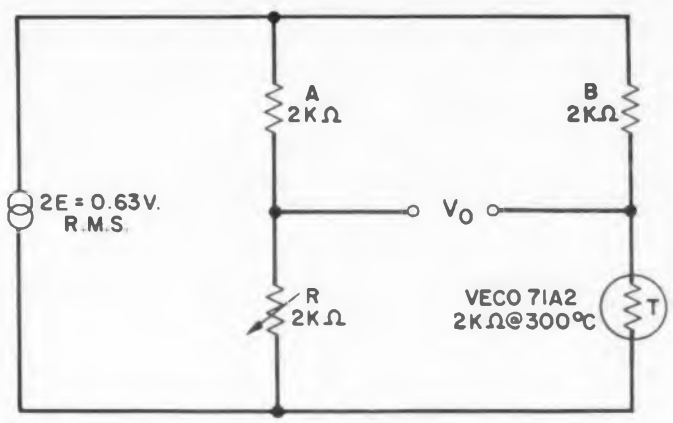


Fig. 9. Bridge for measurement in 300 C range.

Let us now construct another equilateral bridge using the 71A2 and check its output for a single degree change with less than 0.01 degree C self-heating. From formula (2) we find

$$E = (PR)^{\frac{1}{2}} = (0.00005 \times 12{,}000{,}000)^{\frac{1}{2}}$$
$$= 24.5 \text{ volts across thermistor}$$

Therefore the bridge voltage (2E) is 49 volts. If the 71A2 is changed to 24 C its resistance will rise to approximately 12.7 megohms. Using formula (4) we find the output (V_0) to be:

$$V_o = \left(\frac{T}{T+B} - \frac{1}{2}\right)(2E) = \left(\frac{12.7}{12.7+12.0} - \frac{1}{2}\right)49$$
$$= 0.686 \text{ volts output} \qquad (4)$$

Now by simply placing another 71A2 in leg A of the bridge, the output may be more than doubled, thus rendering a total output of over 1.4 volts for only a one degree change! Of course this bridge is unloaded and has a very

high Thevenin resistance. However, it does serve to demonstrate that large outputs can be approached by this type of circuit.

The examples given so far have been for room ambients. At elevated temperatures the outputs though less, are still extremely large compared to similarly used components such as thermocouples. The upper temperature limit of commercial thermistors in use today is approximately 500 C (932 F). Thermistors have been used at higher temperatures, but for good stability it is recommended that they be used below 500 C.

For use around 300 C the type 71A2 would be approximately 2000 ohms. Assume now construction of a 2000 ohm bridge using a 71A2 at 300 C.

At this temperature the thermistor's coefficient is about 1.5 per cent degree C. Using formula (2) again and keeping the allowable self-heating to 0.01 degrees C:

$$E = (PR)^{\frac{1}{2}} = (0.0005 \times 2000)^{\frac{1}{2}}$$
$$= 0.316 \text{ volt across thermistor}$$

Therefore the applied bridge voltage should be 0.63 volts (either ac or dc as the application may warrant). Using formula (4) to find the output:

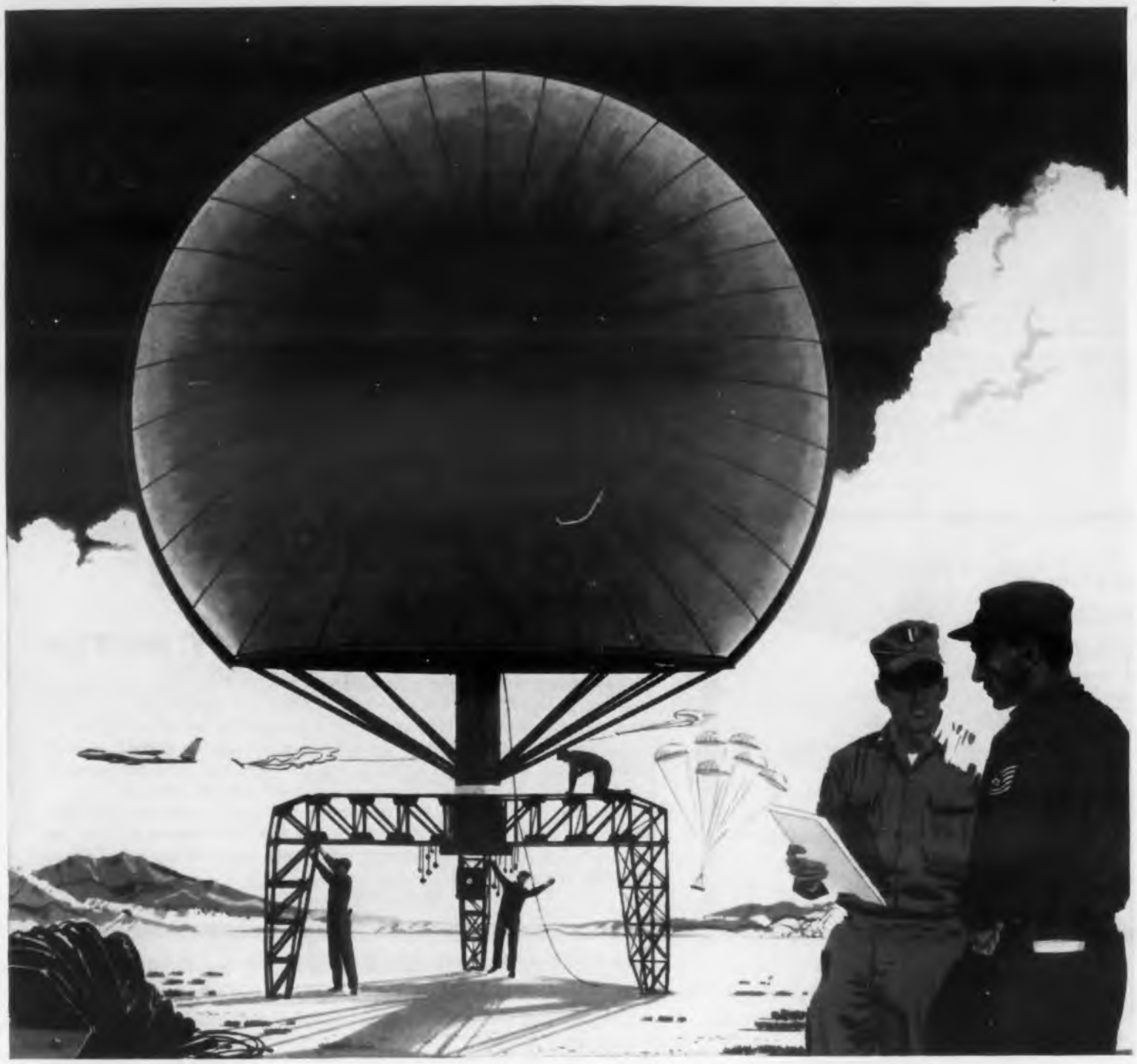
$$V_o = \left(\frac{T}{T+B} - \frac{1}{2}\right)(2E) = \left(\frac{2030}{2030+2000} - \frac{1}{2}\right)0.63$$
$$= 2.52 \text{ mv}$$

Several added advantages are inherently present in thermistor bridges. For example, the thermistor may be located at remote distances from the bridge itself since extension lead resistance can be made negligible compared to the thermistor resistance. Some other advantages are the absences of cold junction compensation and polarity observation which are always present with the use of thermocouples.

A table will now be constructed showing comparative outputs of the thermistor bridges developed versus some of the more commonly used thermocouples.

Bridge or Thermocouple	Microvolt outputs per Degree Centigrade at 25 C	at 300 C
Bridge Fig. 6	10,700	
Bridge Fig. 8	1,570,000	
Bridge Fig. 9		2520
Copper/Constantan	40	60
Iron/Constantan	50	55
Chromel/Alumel	40	40
Plat/Plat-10% Rhodium	6	9
Plat/Plat-13% Rhodium	6	10

The thermistor bridge outputs indicated are comparatively very high. However, the figures shown are perhaps even more impressive when it is recalled that they are drastically reduced by the severe restriction that was placed on them to achieve a readout accuracy of 0.01 degrees C.



Have Radar—Will Travel

"Paraballoon" antenna folds up, flies to the fight. It's magnesium light.

Take a high-powered radar installation, and design it with magnesium so it can be assembled and disassembled easily, and toted around from place to place.

That's just what Westinghouse did when it developed the "Paraballoon" antenna for the Air Force. This highly mobile radar unit weighs just 1,730 lbs. compared to 10,000 lbs. for its comparable heavy metal counterpart. It can be taken apart by its crew in minutes, packed in 200-lb. containers, airlifted to a new location and put into action immediately.

Wondering why the "Paraballoon" antenna can do such a big job, yet weigh so little? The unit is constructed almost entirely of lightweight, rugged magnesium alloy. The reflector platform is magnesium sheet and extruded channels. The turning tube is a magnesium sand casting and the tripod is welded magnesium tubing. The radar reflector is a fully deflatable fiber glass balloon.

The "Paraballoon" antenna is one of the many examples of how the high strength-to-weight ratio of magnesium pays off in terms of saved weight in electronic equipment. For more information on magnesium in electronics contact the nearest Dow Sales Office or write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Department MA 1416M.

YOU CAN DEPEND ON DOW

CIRCLE 34 ON READER-SERVICE CARD

Making Thermistors

THERMISTORS consist of a mixture of metallic oxides held together with a binder. All types of configurations are made from these mixtures. Discs and washers are formed on a pill press, rods on an extruder, and beads on special frames. Each forming operation is followed by firing or sintering to insure mechanical rigidity. A permanent crystal structure is formed. Photographs are courtesy of Fenwal Electronics, Inc.

Beads are made by placing exact drops of mix on two parallel platinum wires, above. Surface tension forms drops into little spheres which become beads when fired in a furnace, below. Mixture, shape of bead and spacing between beads determines characteristics.

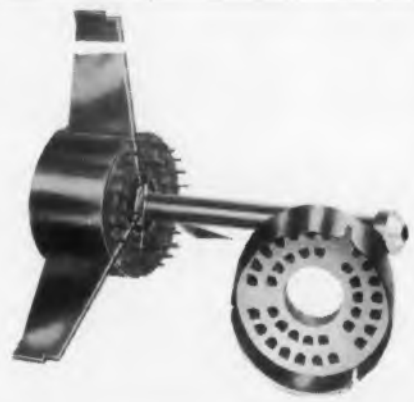
Discs and washers are formed on automatic pill presses, above. Density and dimensions are accurately controlled. After forming and sintering, discs and washers are lapped to exact dimensions to get desired electrical characteristics, immediately below, and then sprayed with silver paint, bottom, to assure uniform distribution of current over their surface.

DESIGN ACHIEVEMENTS WITH **SUPRAMICA*** CERAMOPLASTICS

OPTICALLY FLAT CAPACITY COMMUTATOR PLATE|SUPRAMICA 500

HIGH-TEMPERATURE AIRCRAFT TERMINAL BLOCK|SUPRAMICA 560

HIGH-TEMPERATURE A-N CONNECTOR |SUPRAMICA 560



RADIATION RESISTANT AIRCRAFT ENGINE CONNECTOR|SUPRAMICA 555

HIGH TEMPERATURE FIREWALL THERMOCOUPLE|SUPRAMICA 555

ORGANIC VAPOR FREE HIGH TEMPERATURE SEALED RELAY|SUPRAMICA 555

HIGH TEMPERATURE ceramoplastic INSULATION

SUPRAMICA ceramoplastics provide broader design scope for product engineers

Increased thermal endurance . . . total, permanent dimensional stability . . . better electrical properties . . . lower density and improved machineability of SUPRAMICA ceramoplastics bridge the design gap between organic plastics and conventional ceramics. The world's most nearly perfect insulation, SUPRAMICA ceramoplastics allow product engineers to meet the requirements of today's thermal problems.

There is no possibility of shrinkage, growth or age polymerization since the materials are completely inorganic, made with SYNTHAMICA* synthetic mica. Metal inserts molded in SUPRAMICA ceramoplastics cannot loosen during thermal cycling because coefficients of expansion are closely matched. Other desirable properties are high dielectric strength, radiation and arc resistance, low electrical loss, resistance to moisture, oil and organic solvents. In thousands of military and critical industrial applications, SUPRAMICA ceramoplastics are contributing to better, safer, more reliable operation of electrical and electronic equipment.

Write for complete technical information.

SUPRAMICA* 560 — for temperatures over 500°C (932°F)
SUPRAMICA* 555 — for temperatures up to 650°F
SUPRAMICA* 500 — sheet and rod material for machining

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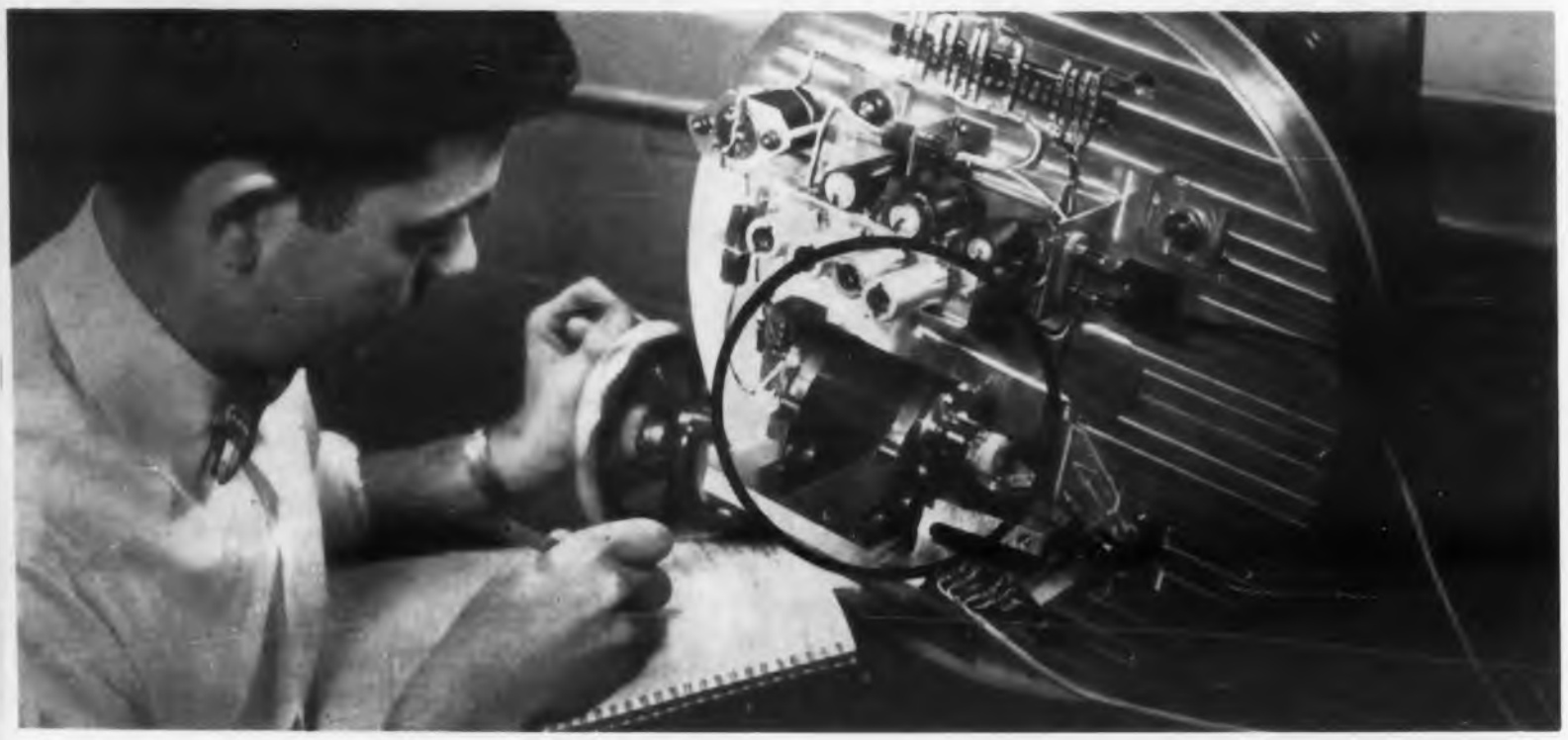
WORLD'S LARGEST MANUFACTURER OF GLASS-BONDED MICA AND CERAMOPLASTIC PRODUCTS.

CIRCLE 35 ON READER-SERVICE CARD

NEW PRODUCTS

To provide a complete coverage of ALL new products generally specified when designing electronic original equipment, the New Product section has been extended. To include the larger number of items, products which are best suited to a brief description have been noted at the end of the section.



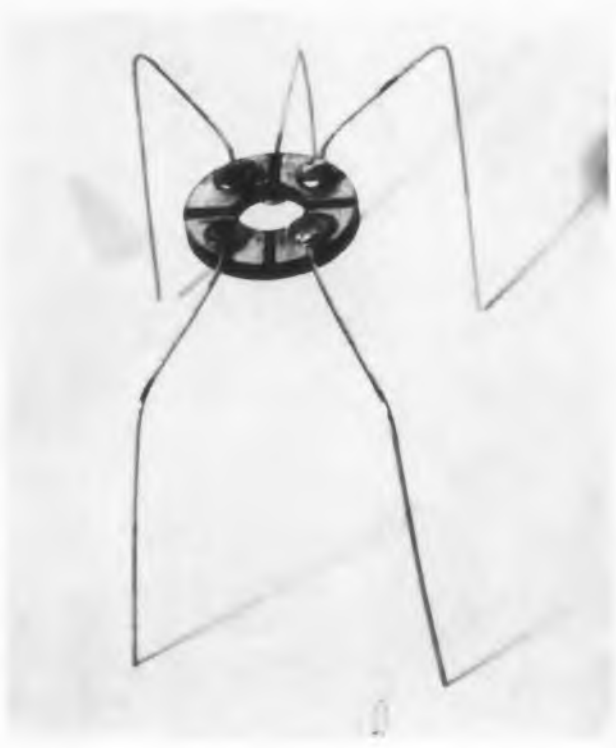
ACCELEROMETER

A fluid immersed sensing element moving precisely in a straight line makes possible the high accuracy of this accelerometer. Threshold sensitivity is better than 10^{-5} *g*. This means that when the accelerometer (circled) is attached to the index table shown, it has the ability to detect the gravity force produced by tilting its sensitive axis as little as 2 seconds of arc.

Three small metal cylinders are the basic elements of the device. The smallest internal cylinder is the acceleration sensitive element. This is immersed in a silicone fluid inside the next larger cylinder, which in turn is supported by bearings within the outer shell or case. The middle cylinder is caused to spin at 1000 rpm by a small external motor. This rotates the silicone fluid as well, and produces hydrostatic forces that exactly center the inner sensor away from adjoining walls, thus eliminating the need for bearings. Because no static friction is present, the slightest component of acceleration along the longitudinal axis is measured accurately.

Sperry Gyroscope Co., Dept. ED, Great Neck, N.Y.

CIRCLE 36 ON READER-SERVICE CARD



THERMISTORS

Tapped resistance values give these thermistors added versatility. Called Tap-A-Therm, the thermistors are available in a variety of tapped values, and resemble standard types except for the addition of extra leads to permit in circuit design changes or adjustments. There are nine types, covering the range from 100 to 100,000 ohms. Each unit has from four to seven terminals providing 100 or 200 ohm steps.

Victory Engineering Corp., Dept. ED, P.O. Box 573, Union, N.J.

CIRCLE 37 ON READER-SERVICE CARD

KERR CELL

Exposure time of 0.01 μsec has been achieved with this Kerr cell electro-optical shutter, which features an improved pulse generator circuit. The complete shutter has been redesigned into a 12 x 12 x 5 in. package, which includes the pulse generator and a spark gap to provide the required driving signal.

Avco Manufacturing Corp., Research & Advanced Development Div., Dept. ED, 20 S. Union St., Lawrence, Mass.

CIRCLE 38 ON READER-SERVICE CARD

TRANSISTORS

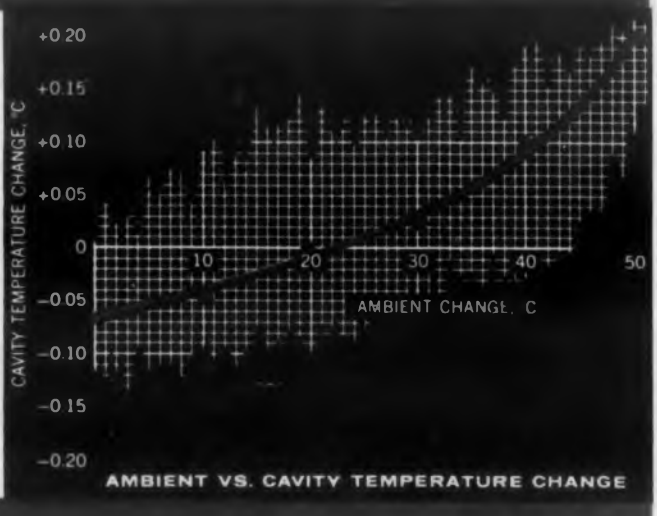
Very high stability over long storage periods is obtainable in this line of four pnp medium speed switching transistors. The units have less than a twenty per cent change in h_{fe} and I_{co} after four-thousand hours storage at 100 C. Designated types 2N394, 2N395, 2N396, and 2N397, the transistors have minimum dc current gain ratings of 20, 25, 30, and 30 respectively at a collector current of 10 ma.

General Electric Co., Semiconductor Products Dept., Dept. ED, Syracuse, N.Y.

CIRCLE 39 ON READER-SERVICE CARD

HIGH PRECISION

CHANGE OF STATE CRYSTAL OVEN



AMBIENT VS. CAVITY TEMPERATURE CHANGE

SPECIFICATIONS

[illegible]

Approximately 30 minutes

AMBIENT TEMPERATURE
RANGE: Operating 0° to +50°C
Storage +65°C maximum

ELECTRICAL

[illegible]

6.3 volts A.C. or D.C. ± 5%

[illegible]

5 watts max. during warm-up
2 watts max. after warm-up

[illegible]

6.7 volts

[illegible]

1-7/16" x 1-7/8" x 4 3/16" seated height

[illegible]

Approximately 8.5 oz.

APPLICATIONS

[illegible] requiring precise temperature control may be mounted within the oven cavity. Applications include: *Crystal Oscillator Circuits* — exacting frequency control employed in communications, computers, frequency standards and marker circuits for radar and precision test equipment. *Temperature sensitive components* such as zener diodes, thermocouple reference junctions and transistorized oscillator circuits.

Complete information upon request. Ask for Technical Bulletin RF-584

[illegible]

CIRCLE 41 ON READER-SERVICE CARD

NEW PRODUCTS

Coaxial TR Tubes

For low frequency high power use

Designed for low frequency high power transmit-receive purposes, the TR860 utilizes a large metal-to-ceramic seal. Measuring 9 in. diam, the coaxial TR tube is cylindrical in shape with smaller window and seal areas than previous low frequency waveguide TR's. The reduction in size of these areas, plus substitution of ceramic for glass in the window, is stated to result in a more rugged yet lighter and smaller tube than conventional types.

Sylvania Electric Products, Inc., Dept. ED, Woburn, Mass.

CIRCLE 42 ON READER-SERVICE CARD

Bolometer-Thermistor Mounts

Instantly replaceable

Both bolometers and thermistors may be replaced instantly in this series of matched bolometer-thermistor mounts. Replacement elements, available from stock, simply plug in without the use of tools, and require no adjustments.

The mounts feature low vswr of 1.5, without tuning, over the full waveguide band. Models 533 and 536 cover C to L band frequencies and may be used with both bolometers and thermistors. For frequencies from 5.4 to 10.0 kmc, models 531 and 532 are designed for use with bolometers, and models 541 and 542 for thermistors.

Narda Microwave Corp., Dept. ED, Mineola, N.Y.

CIRCLE 43 ON READER-SERVICE CARD

Control Cable

Features high flexibility

This 42 conductor, no. 24 gauge, vinyl insulated cable is color coded and has a nylon braided jacket. In meeting a flexibility test in which a four foot sample had to be pulled through a 4-in. ring with a pulling load of no more than 4 lb, this cable passed with average pull being between 3/4 to 1-1/4 lb.

Rex Corp., Dept. ED, W. Acton, Mass.

CIRCLE 45 ON READER-SERVICE CARD

Connectors

Provide true hermetic sealing

Designed to give hermetic sealing against high g forces, heat and cold extremes, pressure and atmospheric variations, vibration and corrosion, these two series of miniature electrical receptacles are designated DM5600 and DM 5606.

The units withstand mechanical shock of 100 g, thermal shock from —100 deg to 500 deg F, temperatures up to 1000 deg F, operating pressures up to 100 psi, and high potentials over 2000 v.

The hermetic seal is obtained when special alloy conductor pins are fused in a furnace with compression glass insulation into a specially designed steel shell.

The Deutsch Co., Dept. ED, 7000 Avalon Blvd., Los Angeles 3, Calif.

CIRCLE 46 ON READER-SERVICE CARD
CIRCLE 47 ON READER-SERVICE CARD ➤

NEW PRODUCTS

Component Solver

Lightweight computer device

From inputs in polar coordinate form, this component solver produces outputs in X and Y cartesian coordinates. All inputs and outputs are in the form of shaft rotations. The mechanism, which weighs 3 lbs, is designed for use in lightweight electro-mechanical and mechanical analog computers.

Belock Instrument Corp., Dept. ED, 111-01 14th Ave., College Point, N.Y.

CIRCLE 49 ON READER-SERVICE CARD

4PDT Relay

High resistance to shock

The CH-12D relay features a balanced armature and contact section affording higher resistance to shock and vibration. Specifications are as follows: contact rating of 10 amp resistive, 8 amp inductive, at 29 v dc or 115 v ac 400 cps; vibration of 5 to 55 cps at 0.5 in. double amplitude, 55 to 2000 cps at 30 g units; shock of 100 g; temperature range of −65 to +125 C; weight of 5.3 oz; dielectric of 1500 v rms at sea level; and contact resistance of 0.1 ohm max initial.

Allied Control Co., Inc., Dept. ED, 2 East End Ave., New York 21, N.Y.

CIRCLE 50 ON READER-SERVICE CARD

Binary Counter

Uses magnetic core transformers

The Model 301-D binary counter has plug-in type magnetic cores which may be replaced easily, if necessary. Designed primarily for use with television synchronizing generators, the unit measures 7-3/4 x 3-1/4 x 3-7/8 in. An entire synchronizing generator, model 1005-A2, is also available mounted in a portable carrying case which may also be rack mounted.

Telechrome Mfg. Corp., Dept. ED, 28 Ranick Dr., Amityville, N.Y.

CIRCLE 51 ON READER-SERVICE CARD

Discriminator

Switch controlled

Model GMD-1, switchable discriminator for use in fm/fm telemetry data systems, is a compact 20-channel ground-based subcarrier assembly. Individual push buttons actuate a solenoid-operated 20-position rotary switch which selects all bandpass and output filter components to tune the discriminator to any standard IRIG telemetry channel.

Selector switches permit monitoring of either input or output signals and feed output connectors for driving a counter, voltmeter, penmotor, or galvanometer.

Data-Control Systems, Inc., Dept. ED, 39 Rose St., Danbury, Conn.

CIRCLE 52 ON READER-SERVICE CARD

CIRCLE 53 ON READER-SERVICE CARD ➤

NEW PRODUCTS

Digital-Voltage Converter

Accuracies to 0.01 per cent available

Series D high-speed transistorized Multiverters generate a voltage that is the product of a digital number and a fixed or varying reference voltage. If the reference is a fixed voltage, the d units operate as conventional digital to voltage converters. Accuracies up to 0.01 per cent are available and, by sacrificing accuracy, conversion speeds up to 0.5 μsec are possible.

Packard-Bell Computer Corp., Dept. ED, 11766 W. Pico Blvd., Los Angeles 64, Calif.

CIRCLE 55 ON READER-SERVICE CARD

TWT Amplifier

For C band application

Model 506 traveling wave tube amplifier has a power output of 1/2 watt or more from 4 to 8 k mc, and 1 w from 3.5 to 7.5 k mc. This amplifier is particularly suitable for antenna range work. Small signal gain is 32 db or more. By optimizing helix voltage, gain may be increased to 35 db over a substantial part of the frequency range. All r-f connections are made with type N connectors.

Alfred Electronics, Dept. ED, 897 Commercial St., Palo Alto, Calif.

CIRCLE 56 ON READER-SERVICE CARD

Wirewound Resistors

Bobbinless construction

Designed for printed circuit boards, and subminiature assemblies for airborne and missile applications, these resistors, style R-2, have a resistance range of 0.1 ohms to 750 kilohms. The

units have a max length of 26/64 in., max diam of 17/64 in., and a lead length of 1 in. max.

Operating voltage is 250 v dc, and the bobbinless construction eliminates strain and stress on wire under extreme environmental conditions.

General Transistor Corp., Dept. ED, 91-27 138th Place, Jamaica 35, N.Y.

CIRCLE 57 ON READER-SERVICE CARD

Silicon Diode Series

750 ma at 50 C, with up to 400 piv

Comprised of types 1N536 through 1N540, this series is rated at 750 ma at 50 C, and 250 ma at 150 C ambient, with piv ratings of 50, 100, 200, 300, and 400 v respectively. Maximum full load average voltage drop is 0.5 v. Maximum leakage current is 0.4 ma.

International Rectifier Corp., Dept. ED, 1521 Grand Ave., El Segundo, Calif.

CIRCLE 58 ON READER-SERVICE CARD

PC Coil Forms

Are not threaded internally

This line of ceramic printed circuit coil forms (types 2525, 2530, 2540, 2550) are available with four terminals for printed circuit mounting. Made completely of class H materials, the units are equipped with the Perma-Torq locking device. The forms are not internally threaded. Instead, the tuning core is affixed to the form through a brass housing at one end; a design which results in a more precise element and finer tuning.

Cambridge Thermionic Corp., Dept. ED, 445 Concord Ave., Cambridge 38, Mass.

CIRCLE 59 ON READER-SERVICE CARD

NEW PRODUCTS

Power Supply

High resolution and stability permits use as standard

Two mv resolution and directly calibrated controls enable model 407 power supply to calibrate panel meters and multimeters. Regulation of model 407 against line or load changes is 0.01 per cent. Long term stability is better than 0.05 per cent. In addition to the 0-555 v dc 300 ma range, two 6.3 v ac 5 amp filament windings, two variable bias outputs (0-25 v dc and 0-225 v dc are available.

John Fluke Mfg. Co., Inc., Dept. ED, 1111 W. Nickerson St., Seattle 99, Wash.

CIRCLE 63 ON READER-SERVICE CARD

Transistor Test Set

Tests basic characteristics

Model 210-A ascertains the basic characteristics of all types of small transistors. With the addition of a laboratory oscillator and a-c voltmeter, the a-c operated and completely self-contained test set can make alpha cut-off, beta cut-off, collector capacitance and other high frequency measurements. The performance of any given circuit can then be predicted with respect to voltage and power gain, matching impedances, and frequency response.

The instrument operates on a frequency of 1.5 kc with emitter supply impedance of approximately 200 K and collector supply impedance of approximately 5 ohms. Weighing 18 lb, Model 210-A measures 15 x 13 x 4 in.

Owen Lab., Inc., Dept. ED, 55 Beacon Pl., Pasadena, Calif.

CIRCLE 64 ON READER-SERVICE CARD

Potentiometer

Linearity of ±0.3 per cent in production quantities

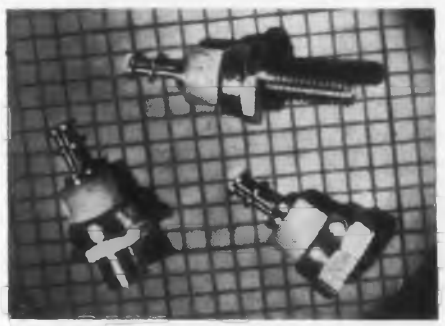
Model 087 size 9 potentiometers are available with linearity accuracies to ±0.3 per cent in production quantities. Non-linear functions can be furnished. Specifications include a resistance range of 20 K, resistance tolerance of 2 per cent, and a standard electrical angle of 340 deg ±2 deg.

George Rattray Co., Dept. ED, 116-08 Myrtle Ave., Richmond Hill 18, N.Y.

CIRCLE 65 ON READER-SERVICE CARD

Printed Circuit Connectors

Bifurcation provides larger contact surface



The Bellows Action contact for printed circuit connectors provides a redundant circuit, with two independent spring leaf contact actions for greater reliability. Coil spring action grip of the bifurcated contact clasps the printed circuit board over its entire contact area. A gold plated phosphor bronze spring retains tension when used with either undersized or oversized tolerance boards. The contact resistance is rated at less than 20 mv at 5 amp.

Wiring styles include eyelet lug for soldering, solderless wire wrap lug, taper tab solderless wiring, and contacts for dip soldering.

Dejur-Amsco Corp., Electronic Sales Div., Dept. ED, 45-01 Northern Blvd., Long Island City 1, N.Y.

CIRCLE 66 ON READER-SERVICE CARD

CIRCLE 67 ON READER-SERVICE CARD ➤

NEW PRODUCTS

Recorder Amplifiers

Isolated differential input

DC μv signals as low as 20 μv can produce full scale deflection of a high speed 12 in. chart potentiometer in 1/4 sec or less with the Model 2HLA-7 preamplifier. This preamplifier has an isolated differential input, 20 cps frequency response, 1 μv recorded noise and drift, and gains as high as 100,000.

Applications for the preamplifier-recorder combination include low level thermocouple and differential thermocouple measurements, strain gage analysis, measurement of low output photocells, other processes where low level signals could be traced on a recording potentiometer.

Minneapolis-Honeywell, Boston Div., Dept. ED, 1400 Soldiers Field Rd., Boston, Mass.

CIRCLE 68 ON READER-SERVICE CARD

Differential Transformer

Explosion-proof model for 500 F use

This Atcotran differential transformer is explosion-proof and permits operation in temperatures up to 500 F. The unit measures 2-1/8 in. long by 1-1/4 in. od. Range is ±0.15 in. with a sensitivity of 0.5 mv output per 0.001 in. displacement per volt input at 400 cps. For a 20 v 400 cps input, the output is 0.001 amp to 500 ohm load for 0.05 in. armature motion.

Automatic Timing & Controls, Inc., Dept. ED, King of Prussia, Pa.

CIRCLE 69 ON READER-SERVICE CARD

Rate Meter

Fast quantitative analysis

Model 412, a premium log and linear multirange rate meter, is extremely useful for fast quantitative analysis. Applicable in high-speed scintillation and proportional counting systems, the unit simultaneously provides logarithmic and precision linear displays.

The five-decade logarithmic scale allows continuous accurate monitoring of activity levels varying over the widest ranges normally encountered.

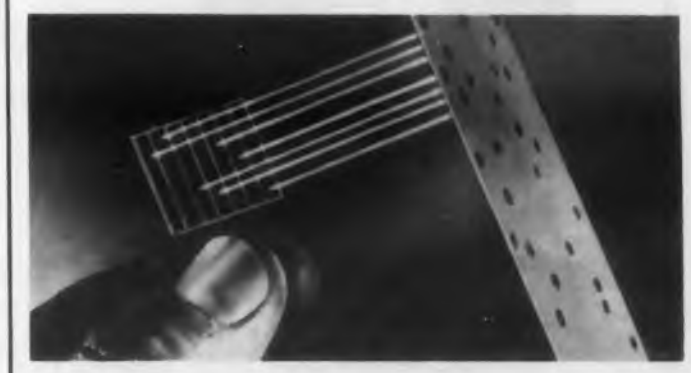
Model 412 will drive any standard potentiometer or galvanometer-type recorders from both linear and log scales. Selectable by a ten-position front panel switch, the linear scale has ranges of 0 to 30 cpm and 0 to 1,000,000 cpm. A special five-cycle log scale provides a logarithmic range of 10 to 1,000,000 cpm.

Baird-Atomic, Inc., Dept. ED, 33 University Rd., Cambridge 38, Mass.

CIRCLE 71 ON READER-SERVICE CARD

Photo-Voltaic Cells

Silicon types with 20 μsec response



This series of silicon photo-voltaic cells has a response time of less than 20 μsec and very high lifetime expectancy. The cells operate, with no appreciable loss in efficiency, through a temperature range from —65 to +175 C, with an effective spectrol response range from 3000 to 8000 angstroms. Applications include punched tape and card readouts, programming controls, pinhole detection, remote switching controls, infrared sensing, and automatic counting.

Hoffman Electronics Corp., Semiconductor Div., Dept. ED, 930 Pitner Ave., Evanston, Ill.

CIRCLE 72 ON READER-SERVICE CARD

NEW PRODUCTS

Temperature Control

Utilizes magnetic amplifiers

Use of bi-stable magnetic amplifiers in place of relays in this temperature control extends operational life. Potting is used to bond together the entire unit. Proportional pulse modulation permits small deadbands in a high response system with good stability. When an error is detected at the edge of the deadband, short duration, full power pulses are applied to an actuator or valve motor. As the magnitude of the error increases, the power pulses are of longer duration until finally power is applied to the actuator continuously.

The Garrett Corp., Dept. ED, 9851 Sepulveda Blvd., Los Angeles 45, Calif.

CIRCLE 74 ON READER-SERVICE CARD

Heat Dissipator

Press fitted over transistor

Designed to fit the JETEC-30 package, this device permits efficient heat dissipation for transistors. The finned jacket is made of black anodized aluminum alloy and can be press fitted over the transistor case without interfering with operation or servicing. Type 3AL-635 maintains a dissipation coefficient of Kr 0.28°C/mw.

The Birtcher Corp., Dept. ED, 4371 Valley Blvd., Los Angeles 32, Calif.

CIRCLE 75 ON READER-SERVICE CARD

Coaxial Cable

Highly stable to 200 C

Teflon jacketed, this low capacity, high temperature, miniature coaxial cable has a capacitance stability of 2 per cent from —65 to 200 C. Nominal outside diameter of the cable is 0.185 in.

The cable has a capacity of 10 μμf per ft at 1 mc with 125 ohms at 1 mc characteristic impedance. Velocity of propagation is 81 per cent. Other electrical properties show attenuation of 10 db per 100 ft at 250 mc, and 16.5 db per 100 ft at 400 mc.

The Rex Corp., Dept. ED, Hayward Rd., West Acton, Mass.

CIRCLE 76 ON READER-SERVICE CARD

Galvanometer Amplifier

60 ma output

System D is a 4-channel galvanometer amplifier package including power supply. It is suited for use with wire strain gages and other transducers, and will drive low-sensitivity, high frequency galvanometers. Features include a balanced input, high output of ±60 ma, phase sensitivity, high stability, low noise level, overload indicator and protector, and no operational delay when overloaded.

Allegany Instrument Co., Inc., Dept. ED, 1091 Willis Mountain, Cumberland, Md.

CIRCLE 77 ON READER-SERVICE CARD

Potentiometers

High resolution

Designed in 1-7/16 in. and 1-3/4 in. sizes, these potentiometers feature the availability of a wide range of special electrical features. Standard resolution for Model 1437 (1-7/16 in.) is 3900 wires, with a resistance range from 100 to 160,000 ohms. Model 1750 (1-3/4 in.) is available with resolution to 5000 wires, and with resistance ranging from 100 to 300,000 ohms. The standard linearity range for both units is 0.5 per cent to 0.1 per cent.

G. M. Giannini & Co., Inc., Dept. ED, Pasadena, Calif.

CIRCLE 78 ON READER-SERVICE CARD

NEW PRODUCTS

High Power Loads

Both coaxial and waveguide types

This line of high power loads in both coaxial line and waveguide is stated to take more than 75 per cent of the full power capabilities of the line size used. Examples of power handling capabilities offered as follows: X-band 900 w average power, overall length 9 in.; 1-5/8-in. coaxial line size, 1000 w average power, 12-1/2 in. length, and a 7/8-in. line size, 1000 w average power, 18 in. overall length.

Douglas Microwave Co., Inc., Dept. ED, 252 E. Third St., Mount Vernon, N.Y.

CIRCLE 81 ON READER-SERVICE CARD

Scaler

Counts pulses from nuclear instruments

Model 762 high speed scaler consists of an input pulse height discriminator, a fast scale of 10, three slow-speed counter decades and a six-digit electromechanical register. The fast scale uses a Burroughs beam switching tube capable of counts in excess of 1 million counts per sec. Slow-speed decades are dekatron counter tubes capable of 5000 counts per sec.

The scaler permits counting pulses from nuclear instruments at high rates with low coincidence loss.

Victoreen Instrument Co., Dept. ED, 5806 Hough Ave., Cleveland 3, Ohio.

CIRCLE 82 ON READER-SERVICE CARD

← CIRCLE 80 ON READER-SERVICE CARD

Stepping Motor

Provides high accuracy

The stepping motor is designed to rotate an external shaft and connected load through any specified angle up to 36 deg in response to a pulsed electric input signal. The unit will accept consecutive command pulses from either of two independent sources in any order. Resulting successive shaft steps may be continuously clockwise or counter-clockwise, or any random combination of the two directions.

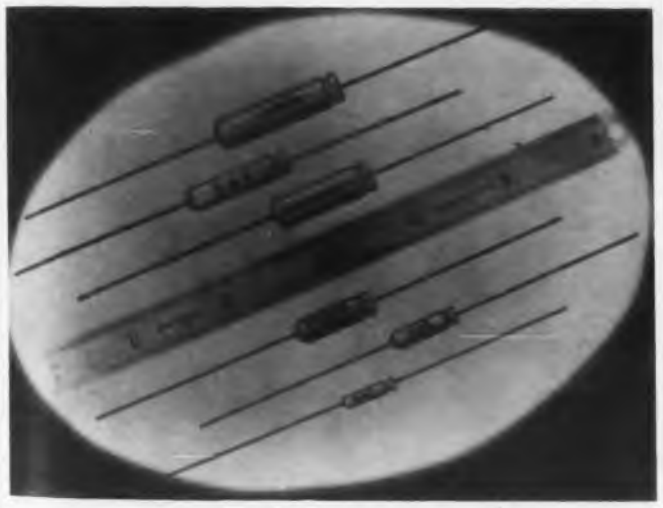
Designed for standard servo mounting, size 15, the stepping motor will operate at any altitude and at temperatures ranging from —65 to +160 F.

Clary Dynamics, Dept. ED, 408 Junipero St., San Gabriel, Calif.

CIRCLE 83 ON READER-SERVICE CARD

Tantalum Capacitors

Ratings up to 150 wvdc



These low voltage tantalum foil capacitors consist of 15 sizes of both etched and plain foil tantalums, 0.125 od x 5/16 in. long to 0.375 od x 2-12/16 in. long. Voltage ratings are available from 3 wvdc to 150 wvdc and capacities from less than one μf to 6000 at 3 wvdc.

The units operate in the temperature range of —55 to +125 C. Featuring a solid cathode end construction, the capacitors are cased in silver or silver plate.

International Electronics Industries, Inc., Dept. E[illegible] Nashville, Tenn.

CIRCLE 84 ON READER-SERVICE CARD

NEW PRODUCTS

VSWR Amplifier

Battery-powered, transistorized unit

Battery-operated Model 441 is completely independent of line voltage deviations, and provides complete portability.

The unit features full sensitivity over the expanded vswr scale and eliminates the need for switching attenuation range when going from normal to expanded scale. The noise level, less than 0.02 μv equivalent, and amplifier gain remain the same in the expanded position. Sensitivity is 0.1 μv at 200 ohms, over the full scale.

Narda Microwave Corp., Dept. ED, Mineola, N.Y.

CIRCLE 87 ON READER-SERVICE CARD

Vibration Test Accessory

Pinpoints cause of failure

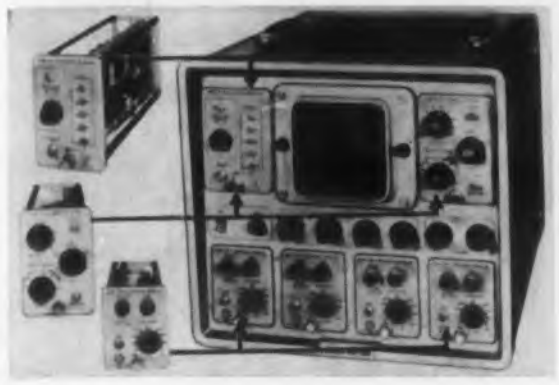
Designated Slip-Sync, this vibration test accessory automatically adjusts the flashing rate of stroboscopic lights to match the frequency of electromagnetic shakers in aircraft and missile testing. The vibrating component is watched in still or slow motion as it vibrates through the various frequencies to which it is subjected.

Chadwick-Helmuth Co., Dept. ED, Monrovia, Calif.

CIRCLE 88 ON READER-SERVICE CARD

Oscilloscope

Plug-in 4-channel instrument



Through the use of plug-in features for individual pre-amplifiers, sweep generators, and marker-calibrator, this wide-band oscilloscope combines the advantages of true four-channel oscillography. Known as ETC Model K-470, the instrument handles oscilloscope applications from dc to 5 mc.

Five pre-amplifiers form an integral part of the instrument and may be used in any combination on each of the four channels. The ETC Model K-470 is one of the first scopes to use a special square face, four-gun cathode ray tube.

Electronic Tube Corp., Dept. ED, 1200 E. Mermaid Lane, Philadelphia 18, Pa.

CIRCLE 89 ON READER-SERVICE CARD

Pulsed Oscillator

Stable high power output

Model PG-650 is a variable frequency pulse modulated r-f source for applications requiring high power output as well as stability. The principal use is in measuring various parameters of ultrasonic delay lines, whose high initial insertion loss and operation at low impedance levels usually present difficulties.

The output of a delay line (60 db into 50 ohms) can be shown at r-f using only the vertical amplifier of an oscilloscope. A second feature is that it can cascade two delay lines without an intermediate amplifier.

Arenberg Ultrasonic Lab., Inc., Dept. ED, 94 Green St., Jamaica Plain 30, Mass.

CIRCLE 90 ON READER-SERVICE CARD

NEW PRODUCTS

Hydrogen Thyratrons

High reliability, long life

For radar and other high-power pulse modulators, Genalex hydrogen thyratrons offer more reliable operation and greatly increased life through a new replenisher system, controlled by an integral barretter and thermistor. The replenisher generates hydrogen by means of a heater surrounding titanium hydride pellets and prevents tube failure due to gas clean-up.

A barretter in series with the replenisher heater keeps the gas pressure constant. A thermistor in parallel with the heater maintains constant replenisher temperature over an ambient range of −25 deg C to +70 deg C and reduces warm-up time and anode delay time drift.

British Industries Corp., Dept. ED, Port Washington, N.Y.

CIRCLE 93 ON READER-SERVICE CARD

Pulsed Oscillator

Miniature high power unit

The A-12 miniaturized high power 2 kw output pulsed oscillator cavity is designed for aircraft, beacon, and missile applications. The unit measures 5.75 in. in the tunable model and only 4.9 in. in the fixed frequency version while only 1.75 in. in diameter.

Designed to sustain rugged treatment utilizing the GL 6442 ceramic triode, the A-12 can be tuned in excess of 200 mc in the S band.

Atomitron, Inc., Dept. ED, 168-25 Hillside Ave., Jamaica, N.Y.

CIRCLE 94 ON READER-SERVICE CARD

Microwave Circulator

Compact broadband unit

Model RX 810 C is a broadband, compact, four port circulator utilizing the principle of Faraday rotation of the plane of polarization of microwave energy.

The unit is 4-15/16 in. long and operates over the band 8.4-10.2 kmc with a minimum of 13 db isolation and 0.35 db insertion loss. The circulator can be pressurized to 30 psig.

Rantec Corp., Dept. ED, Calabasas, Calif.

CIRCLE 95 ON READER-SERVICE CARD

Chokes

Encapsulated types for 125 C use

A family of epoxy encapsulated chokes, covering a range of inductances from .01 μh to 200 mh is available in various configurations. One popular type features a flat side for mounting on printed wiring boards with axial leads. Additional leads are provided for mechanically securing heavier components.

Waters Mfg., Inc., Dept. ED, Boston Post Rd., Wayland, Mass.

CIRCLE 96 ON READER-SERVICE CARD

Word Generator

PRF of up to 250 kc

This equipment is designed to create a selected 16-bit word for testing digital recording techniques and circuits. The word formed may be set up by the sixteen switches on the front panel. A trigger input establishes the pulse repetition frequency which may be as high as 250 kc.

Systems Research Labs,, Dept. ED, 300 Woods Dr., Dayton 32, Ohio.

CIRCLE 200 ON READER-SERVICE CARD

NEW PRODUCTS

Waveguides

Thin walled

This process for producing irregular thin walled waveguide shapes features weight reduction, close tolerances, and smooth inner surfaces at reduced cost.

The method makes possible hollow, seamless one piece configurations in aluminum, silver, copper and other metals which usually require casting or electroforming.

Gorham Mfg. Co., Dept. ED, Providence 7, R. I.

CIRCLE 99 ON READER-SERVICE CARD

Flat Cable

Can be solder dipped

A lightweight, flexible, multi-conductor flat cable called Polystrip is available. Insulation is a polyester which can be quickly stripped and the cable solder dipped. The cable is rated at 85 C continuously, and is available in widths up to 51 conductors. Each conductor is conservatively rated at 1 amp in free air at 25 C.

International Resistance Co., Dept. ED, 401 North Broad St., Philadelphia 8, Pa.

CIRCLE 101 ON READER-SERVICE CARD

Remote Control System

Combines accuracy with high torque

The Electrolink model 60 is a closed-loop remote positioner designed specifically for industrial applications requiring fast response, high output torque, and high accuracy. The unit consists of a combined controller-amplifier and a servo drive.

The output shaft, driven by the high-response powder clutch, follows movement of the manual control with accuracies better than 0.25 deg. At maximum excitation, servo output torque is 250 in. lb. High gain and low-inertia drive permit the system to reach maximum speed in 0.020 sec.

Installation problems are simplified by modular construction, permitting the control to be panel-mounted away from the amplifier.

Lear, Inc., Dept. ED, P.O. Box 688, Grand Rapids, Mich.

CIRCLE 102 ON READER-SERVICE CARD

High-Pot Programmer

Applies voltages at controlled rate

The function of model 1102 is to program the line voltage fed to a high-pot tester, thus producing a system in which test voltages are applied to components under test at a uniform controlled rate. The programmer prevents equipment damage due to accidental output surges, and assures that each component is given an identical, precisely controlled test.

Jackson Electronic and Mfg. Co., Dept. ED, 695 Johnston St., Akron 6, Ohio.

CIRCLE 209 ON READER-SERVICE CARD

NEW PRODUCTS

Nylon Jack

Self-locking into chassis

The Pushlock molded nylon-tip jack requires no threads, nuts or lock washers. When the fluted nylon body is pushed through a 1/4 in. chassis hole, the flutes compress, then expand to provide positive holding action that requires approximately a 50-lb pull to release. Contact pressure and low resistance are provided by a heat-treated, silver-plated beryllium copper contact.

Whitso, Inc., Dept. ED, 9330 Byron St., Schiller Park, Ill.

CIRCLE 104 ON READER-SERVICE CARD

Relay

Rotary action

The HG-2SMP series relay is a plug-in unit with an asbestos filled melamine socket designed specifically for performance exceeding standard socket units. Rotary action and rugged construction make this relay suitable for reliability and rapid interchangeability.

Contacts are rated up to 5 a and 250 v with coil operating voltages of 6 to 115 v ac or dc. Contact arrangement is 1 or 2 pole double throw.

Sockets are available with several types of gold plated terminals to mount above or below the chassis.

Hi-G, Inc., Dept. ED, Bradley Field, Windsor Locks, Conn.

CIRCLE 105 ON READER-SERVICE CARD

Ferrite Isolator

Rated at 5 megawatts

Rated at 5 megawatts for large S-band radars, this air-cooled ferrit isolator is six in. long, or half the length of previous watercooled designs of lesser power rating.

By effecting a minimum 10 db one-way isolation in the transmission waveguide, the isolator protects high-power tubes from load impedances.

Sperry Gyroscope Co., Microwave Electronics Div., Dept. ED, Great Neck, N. Y.

CIRCLE 106 ON READER-SERVICE CARD

Silicon Rectifiers

Reverse polarity types

Reverse polarity types in a variety of ratings and mounting styles are the features of these hermetically sealed, all-welded units. The series is rated at 45 to 150 amp (half-wave) with piv ratings from 50 to 800 v. Reverse polarity types are offered in each rating and mounting style.

International Rectifier Corp., Dept. ED, 1521 E. Grand Ave., El Segundo, Calif.

CIRCLE 107 ON READER-SERVICE CARD

Strip Recorder

Amplifiers have 2 mv/mm sensitivity

The ER-20 two channel recorder features direct-coupled amplifiers which give a sensitivity of 2 mv/mm. Stylus deflection on each channel is 40 mm, with an accuracy of 2 per cent. Electro-sensitive paper eliminates the need for any inking system. Easy paper loading and an electrically controlled two-speed chart drive make operation simple.

Mandrel Industrial Instruments, Dept. ED, 5134 Glenmont Dr., Houston, Tex.

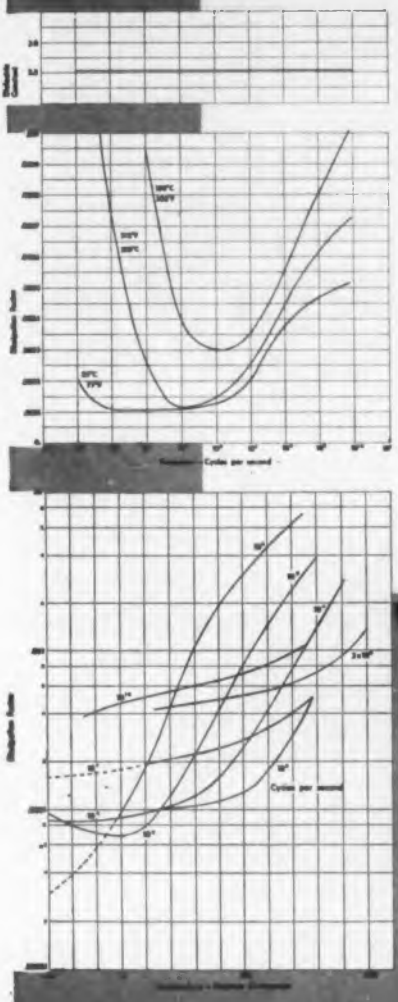
CIRCLE 210 ON READER-SERVICE CARD

For Ultra High Frequency Insulation

REXOLITE 1422

In cast rods of diameters to 6" and plates up to 36" x 36", from .031" to 1½" thickness.

REXOLITE 1422 CHARACTERISTICS



- Withstands high temperatures — to 400° F.
- Does not exhibit cold flow.
- Has low dielectric constant and power factor.
- Specific gravity of 1.045-1.050.
- Is strong and rigid with good tensile and impact strengths.
- Unusual chemical inertness permits its use where others fail.
- Readily machinable to close tolerances.

WHERE PERFORMANCE PLUS PRICE IS A FACTOR

REXOLITE 2200

UHF insulation in thermosetting sheets 36"x36",.031"-.125" thick

- Has good punching properties.
- High impact strength.
- Good machinability.
- Dielectric constant 10-10,000mc, 2.77.

Send for complete technical data and samples

The REX CORPORATION
Electronics Division

210 Hayward Rd. West Acton, Mass.

CIRCLE 109 ON READER-SERVICE CARD

NEW PRODUCTS

Bondable Wire

For high temperatures

Wires and cables insulated with Teflon are available with the surface of the insulation treated so that it can be bonded to various impregnants. Magnet wire, lead wire, and cable jackets treated in this manner can be supplied. Individual wires inside cables can also be provided with a bondable surface.

American Super-Temperature Wires, Inc., Dept. ED, Winooski, Vt.

CIRCLE 110 ON READER-SERVICE CARD

Power Meter

Calorimetric type for low r-f

A calorimetric power meter for low r-f power measurements between dc to 10 kmc has been announced. Full scale measurements range is 5 w. Resolution is 50 mw per division on 4-1/2 in. meter.

This power meter is a simplified calorimeter which uses an accurate metering pump of the gear type driven by an over powered synchronous motor to keep the fluid flow constant.

Electro Impulse Lab., Dept. ED, 208 River St., Red Bank, N.J.

CIRCLE 111 ON READER-SERVICE CARD

Electrolytic Capacitors

High voltage and capacity ratings

For high μf applications such as bulk capacitance requirements, these Alumalytic capacitors are rated from 30,000 μf at 10 v dc to 1000 μf at 450 v dc and will operate from —20 to +65 C. The capacitors are manufactured with diameters of 1, 1-3/8, 2, and 3 in., and with a length of 4-1/8 in. The 1 and 1-3/8 in. diameter units are available in case lengths of 2, 2-1/2, 3, 3-1/2 in.

The principal construction feature of this capacitor is the use of 99.99 per cent pure aluminum foil anodes in every rating. This type of pure aluminum permits increased shelf and operating life and reduces leakage current.

General Electric Co., Dept. ED, Schenectady 5, N.Y.

CIRCLE 211 ON READER-SERVICE CARD

CLUTCH-BRAKE.—Added to the company's line of miniature units, Model MBB duplex clutch-brake is a standard line of 4 sizes in 3 shaft alternates featuring zero back lash, zero end play, no slip rings, fast response, and maximum efficiency per unit size.

Autotronics Inc., Dept. ED, Box 812, Rt. 1, Florissant, Mo.

CIRCLE 114 ON READER-SERVICE CARD

COAXIAL COMPONENTS.—Consist of attenuators with a precision of ±0.5 db, and impedance matching pads having a low loss. Dimensions of both are ⅜ in. diam x 2 in. length.

Electro-Physics Labs., Dept. ED, 2065 Huntington Dr., San Marino, Calif.

CIRCLE 115 ON READER-SERVICE CARD

TRANSFORMER.—This 25 w, 400 cycle transformer is available in voltage ratings up to 1000 v. Small size and low heat rise are featured.

Advance Industries, Inc., Dept. ED, Cambridge, Mass.

CIRCLE 116 ON READER-SERVICE CARD

DELAY LINE.—Smaller and lighter than previous units, these are especially designed for radar and computer applications for which a nominal repetition frequency of 360 cps is required.

Andersen Laboratories, Inc., Dept. ED, 501 New Park Ave., West Hartford, Conn.

CIRCLE 117 ON READER-SERVICE CARD

RELAY.—Having a hydrogen annealed magnetic structure and more contact pressure, Series AA telephone-type relays offers increased efficiency of operation.

Automation Controls Corp., Dept. ED, 5737 West 98th St., Los Angeles 45, Calif.

CIRCLE 195 ON READER-SERVICE CARD

MOTOR-GENERATOR.—The generator portion produces an exact frequency of 400 cps. Single phase and rated at 1100 w, the unit is self-regulated with voltage change kept within 5 per cent from no load to full load.

Kato Engineering Co., Dept. ED, Mankato, Minn.

CIRCLE 196 ON READER-SERVICE CARD

TERMINAL KIT.—Contains eight basic types of stand-off and feed thru terminals insulated with Teflon in a complete range of sizes.

Taurus Corp., Dept., ED, 8 Coryell St., Lambertville, N. J.

CIRCLE 197 ON READER-SERVICE CARD

CONNECTORS.—Identical to models DM9606-197 P/S and DM9700-197 P/S, except that the grommet is designed for four No. 12 or No. 14 wires and three No. 20 or No. 24 wires.

The Deutsch Co., Dept. ED, 7000 Avalon Blvd., Los Angeles 3, Calif.

CIRCLE 198 ON READER-SERVICE CARD

AHEAD AGAIN...

U. S. Radium's Newest Instrument Dial

A current problem in integral instrument lighting is that of obtaining, at reasonable cost, a dial for a particular unit which will light within the brightness ratio spec of MIL-L-25467A. Since different instruments will have different lighting systems and will require different dial configurations and indicia, the dial contractor must be able to vary the opacity of his dials in order that the finished instrument assemblies will light to MIL spec, regardless of the internal light levels and the number and position of the lights.

U. S. Radium's new production process for MIL-L-25467A dials permits the variation of the opacity factors of the background and indicia within wide limits, to provide a compatible instrument-dial assembly. It also allows piece-to-piece uniformity which excels conventional methods for meeting this spec, and at lower unit cost. These advantages, plus the availability of U. S. Radium's light engineering service during the formative stages of light housing design, provide a foolproof working method for eliminating light engineering headaches, cutting costs and speeding delivery.

For information, contact Department D4

USRADIUM

UNITED STATES RADIUM CORPORATION

MORRISTOWN, N. J. | Offices: Chicago, Illinois and No. Hollywood, Calif. Affiliates: Radelin-Kirk, Ltd., Toronto, Canada and United States Radium Corp. (Europe), Geneva, Switzerland

CIRCLE 199 ON READER-SERVICE CARD

Magnet Calibration

MODEL 1295
DIRECT READING

Gaussmeter

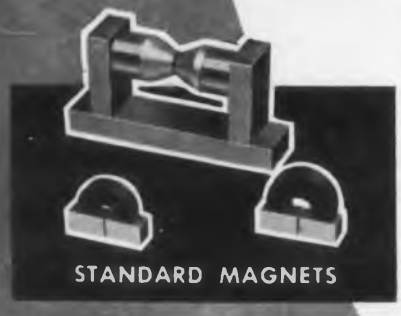
measures magnetic flux density ACCURATELY

This stable, all transistorized Gaussmeter operates on the Hall effect and provides a conservative accuracy of ±3% over nine full-scale ranges: 0-100, 200, 500, 1 K, 2 K, 5 K, 10 K, 20 K and 20 K + gausses, using a single probe. Two standard Alnico V reference magnets having ¾% accuracy are supplied. Unit is housed in an aluminum case, weighs 12 lbs. and operates from 115-volt, 50-400 cps line. Price $420.

MODEL 889A

Magnetreater®

Model 889A de-magnetizes saturated magnets to any desired level of flux. Provides a precisely controlled method for rapidly treating permanent magnets, including the new core-type instrument mechanisms. Used with Model 206A Booster Unit or Model 107A Magnet Charger. Over-all size is 8" x 10" x 7". Weight 24 lbs. Price $163.



STANDARD MAGNETS

Standard Magnets

Laboratory standard fixed gap reference magnets having flux densities from 100 to as high as 20,000 gausses are now available. These units are fully stabilized magnetically, mechanically and thermally and are used to calibrate fluxmeters and gaussmeters for engineering or production testing. Certification supplied for each magnet.

Performance of all models is rigidly guaranteed. Prices are net f.o.b. Boonton, N.J. and subject to change without notice.

WE CAN HELP YOU

13 years' magnet charging experience is yours for the asking—send for illustrated data sheets.

RFL **Radio Frequency LABORATORIES, INC.**
Boonton, New Jersey, U.S.A.

CIRCLE 118 ON READER-SERVICE CARD

NEW LITERATURE

Slip Ring Assemblies 119

"Design Considerations for Miniature Slip Ring and Brush Assemblies" is a 32-page pamphlet. Photographs and drawings are included. Poly-Scientific Corp., Blacksburg, Va.

Coaxial Terminations 120

This illustrated bulletin sheet describes a line of coaxial terminations with type BNC or TNC, male or female connectors. Stoddart Aircraft Radio Co., Inc., 6644 Santa Monica Blvd., Hollywood 38, Calif.

Wirewound Resistors 121

Bulletin CB-3 describes and illustrates a line of axial, radial, and lug type precision wirewound resistors. Winding techniques, wattage range and temperature range are included. Kelvin Electric Co., 5907 Noble Ave., Van Nuys, Calif.

Microwave Components 122

This 48-page catalog describes over 300 different types of microwave waveguide components, test equipment, and pressure windows. Designated Catalog 58CP, it includes operating characteristics, performance curves, application data, outline drawings, dimensions, and prices of components in the 1.12 kmc to 90.0 kmc frequency range. Photographs of each product type are included. Microwave Associates, Inc., Burlington, Mass.

Aircraft and Missile Testers 123

This catalog describes a line of aeronautical and missile testing equipment. Featured in addition to a line of hydraulic system testers are many electrical devices. These include power supplies, generator testers, panel meters, and other equipment to test almost any electrical assembly that flies. Sun Electric Corp., Harlem and Avondale, Chicago 31, Ill.

Synchros 124

This catalog sheet presents the salient characteristics of synchros, servomotors, resolvers, motor tachometers, and tachometer generators in production. The information is arranged for easy reference, and forms a useful key to the more detailed information contained in the sheet. Muirhead Instruments Inc., 677 Fifth Ave., New York, N.Y.

R-F Filters 127

This 4-page catalog lists custom r-f filters. Variations in size, shape, voltage, and current ratings are allowed without extra cost for this custom order service. All-Tronics, Inc., 45 Bond St., Westbury, N.Y.

Impregnated Fibre 128

Bulletin V-58 is a 4-page folder describing a low-cost intermediate insulation material made of resin impregnated vulcanized fibre for use in many electrical and bearing applications. Typical applications are given for the material, which is available in the larger 43 x 76 in. sheet size. Tables and charts give mechanical and dielectric strength compared with those of other materials normally used for high-volume electrical and structural applications, together with physical properties. Continental-Diamond Fibre Corp., a subsidiary of the Budd Co., Newark, Del.

Circuit Analysis 129

This brochure titled "Modern Testing Methods" describes how this company's analyzing equipment can be utilized by various manufacturers to test wiring systems in all phases of production. It points out how this same testing system, as used by the manufacturer, may be passed on to the military as support equipment to test electrical systems of aircraft, missiles, etc., at maintenance and overhaul bases, thus allowing the manufacturer and the military to standardize on like test equipment. DIT-MCO, Inc., 911 Broadway, Kansas City, Mo.

Film Capacitors 130

Polystyrene, polyethylene, teflon, and Mylar dielectric capacitors appear in a 6-page illustrated catalog. The folder also lists a line of high voltage packaged power supplies. Electrical characteristic data, physical specifications, related part numbers, and prices are shown for all types listed. Film Capacitors, Inc., 3400 Park Ave., New York 56, N.Y.

Digital Voltmeter 131

The operation, features, and specifications of a dc digital voltmeter are discussed in the four pages of Bulletin 19-2. Also described are accessories that may be added to permit the measurement of ac, ohms, and ratios, to allow scanning multiple inputs, or to drive typewriter and punched tape units. Kin Tel, Div. of Cohu Electronics, Inc., 5725 Kearny Villa Rd., San Diego 11, Calif.

Torque as low as 0.003 ounce inches achieved by Giannini in MICROTORQUE® and MINITORQUE® Precision Potentiometers

For extremely sensitive instrument applications where minimum torque is essential, specify Giannini Microtorque and Minitorque precision potentiometers. Highly reliable performance under the most rugged operating conditions is assured by Giannini's care for detail and production crafting.

By using sapphire jewel bearings... and precision ball bearings in certain Minitorque models, these 1 inch diameter instruments effect an unusually low coefficient of friction.

Available in 12 standard linear wiring types, the potentiometer output can, on special order, be designed to perform to a wide range of natural or empirical functions. All models employ non-corrosive precious metal windings and contacts... thereby permitting light brush pressures and ensuring long noise-free life.

Dependability, reliability, and ten years proven application success are your benefits, when you use Giannini Microtorque and Minitorque potentiometers—precision instruments "crafted with care."

For additional information, please write for Bulletins 85111 and 85151.

SPECIFICATIONS:

Torque	0.003 to 0.008 oz. in. depending on resistance and wiring type. (Sleeve bushing Minitorque 0.025 oz. in.)
Resistance Range	100 to 100,000 ohms.
Linearity	±0.5% (±0.25% on special order)
Power Rating	1.63 watts @ 25°C.
Shaft Diameter	Microtorque, 0.031 in., Minitorque, 0.125 in.

Giannini

G. M. GIANNINI & CO., INC., 918 EAST GREEN STREET, PASADENA, CALIFORNIA

CIRCLE 132 ON READER-SERVICE CARD

NEW LITERATURE

Ceramics and Ferrites 135

A 6-page bulletin describes industrial ceramics, ferrites, and custom services. Covered are services for producing precision, electronic, and metallized ceramics and ceramic-to-metal assemblies. Among the ferrites discussed are low loss ferrites for frequencies up to 100 mc, microwave ferrites, and square hysteresis loop ferrites for computer applications. Thermo Materials, Inc., 4040 Campbell Ave., Menlo Park, Calif.

Accelerometers 136

Now available is a 32-page catalog which describes a line of more than 40 accelerometers, high temperature strain gages and associated electronic equipment. A series of engineering drawings, tables and graphs are employed to give specifications and performance characteristics in terms of sensitivities, natural frequencies, acceleration and temperature ranges for the accelerometers along with the gage factors, resistances, drift rates, temperature ranges and card sizes of the strain gages. Columbia Research Labs., MacDade Blvd. and Bullens Lane, Woodlyn, Pa.

Residual Stresses 201

"Residual Stresses in Cold Finished Steel Bars and Their Effect on Manufactured Parts" is an illustrated condensation of a paper which E. S. Nachtman presented at a semi-annual meeting of the ASME. Available as Data Book 16, a pocket-size booklet of 32 pages, the article covers specific subjects ranging from residual stresses in cold drawn, ground turned, and heat treated steels to discussions of fatigue cracking, machinability, tolerances, and corrosion. LaSalle Steel Co., 1420 150th St., Hammond, Ind.

Coil Winder 202

An automatic coil winder with wire guides at the rear is featured in a one page illustrated catalog sheet. Dimensions, types of windings, maximum coil OD and width, and wire sizes are listed along with other details. Geo. Stevens Mfg. Co., Inc., Pulaski Rd. at Peterson, Chicago 30, Ill.

Flight Simulator 203

A description of a three-dimensional flight simulator system and its applications are included in this 24-page illustrated bulletin. Bendix Aviation Corp., Bendix Computer Div., 5630 Arbor Vitae St., Los Angeles 45, Calif.

Printed Circuit Etching 141

In Bulletin 90 a process for etching printed circuits with a solution of ammonium persulfate is described. The 7-page text outlines the advantages of the persulfate bath over ferric chloride and gives instructions for preparing the solution, processing, after-treatment, and disposing of the waste solution. Food Machinery and Chemical Corp., Becco Chemical Div., Station B, Buffalo 7, N.Y.

Plug-In Servo Systems 142

Plug-in servo repeater systems and subminiature servo amplifiers are among the "Micromation" products appearing in a recent file folder. In addition to specification sheets, the folder contains a discussion of "Micromation". Waldorf Instrument Co., Huntington Station, N.Y.

Capacitors 143

A 2-page engineering bulletin on microminiature molded thermoplastic metallized-paper capacitors has been issued. It contains complete specifications, size and capacitance tables, and insulation resistance tables. Photographs illustrate the bulletin. Aerovox Corp., Application Engineering Dept., New Bedford, Mass.

NEW LITERATURE

Precision Potentiometer Table 148

A handy precision potentiometers table in 8-1/2 x 11 in. page size to fit the data file or loose-leaf binder, is available. The table lists seven single-turn and one multi-turn types, with dimensions, resistance values, tolerances, resolution, ratings, rotation, tandem groupings, torque, taps, weight, bearings, and other data. At a glance the designer or engineer can select the precision potentiometer that best meets his particular requirements. Clarostat Mfg. Co., Inc., Dover, N.H.

Digital Pulse Decoder 149

A 12-page engineering manual has been issued to describe a digital pulse decoder and its several applications. With diagrams, the text explains the use of the selector in both ac and dc circuits. It specifically discusses remote supervisory control, telephone, telegraph printer, and mobile radio applications. Photographs and a list of specifications round out a description of the instrument itself; and operation, code settings, and installation are separately discussed. Electrical Communications, Inc., 765 Clementina St., San Francisco 3, Calif.

Time Rate Indicator 204

Bulletin 501A-B discusses the applications of a 10 mc time-rate indicator which measures frequency, the interval between pulses and period or averaging period, determines the ratio between two frequencies, and counts pulses per unit time. The 4-page illustrated brochure explains the features, functions, and advantages of the unit as it is used in various types of electronic circuits. Laboratory for Electronics, Inc., 75 Pitts St., Boston 14, Mass.

Batteries 205

This 20-page three color catalog illustrates and presents information on all types of a company's dry cell batteries. Specification charts list each type of battery on separate pages. Also included, on fold-out page, is a cross reference chart of "Comparative and Interchangeable Numbers by Brands." Marathon Battery Co., Wausau, Wis.

Potentiometer 206

Details of the series 7600 precision potentiometer are covered in Data Sheet 1273. In addition to dimensional drawings and descriptive text about the 10-turn, 1-13/16 in. diam potentiometer, the four-page data sheet now includes a table of coil characteristics for resistance values ranging from 350 to 450,000 ohms. Beckman/Helipot Corp., Newport Beach, Calif.

Research Activities 153

The activities and fundamental research program are described in a 12 page booklet just released. Subjects covered include the SAGE system, heavy radar, memory devices, transistorized digital computers, scatter communications, AEW, and systems analysis. M.I.T. Lincoln Laboratory, Box 24, Lexington, Mass.

Polyethylene Sheath 154

The bulletin, describes the advantages of polyethylene sheathing compound, its specifications, and applications. Rating, scope of use, conductor construction, insulations, and shielding of available sheathed cables are detailed. The sheathing material passed industry (IPCEA) tests for ac and dc voltage and corona level.

Tables show the insulation and sheath thicknesses for 5001-9000 v (single conductor, grounded neutral), 3001-5000 v (single conductor, grounded or ungrounded), 5000-9000 v (single conductor, ungrounded neutral), and 15,000 v (single conductor, ungrounded neutral). AWG or MCM wire size, standing and nominal od in inches are also given in each table.

The four page bulletin, 8-1/2 by 11 in., is punched for notebook insertion. Rome Cable Corp., Rome, N.Y.

Machlett ML-6544

A New Forced-Air Cooled Triode

For Use As Switch Tube in Hard-Tube Pulse Modulators

For Radar Applications

Machlett Laboratories, Inc. offers the designer a new forced-air-cooled, shielded grid triode designed primarily to operate as a switch tube in hard-tube pulse modulators in radar applications. Ruggedly constructed electrodes of the ML-6544 are of such a design as to provide electron beaming essential in keeping grid current to a minimum. This, in addition to the increased heat dissipation capabilities of the rugged control-grid structure, reduces grid emission to a negligible quantity.

The following tentative ratings apply:

Electrical Characteristics	
Filament Voltage	6.0 Volts
Filament Current	60 Amps
Maximum Ratings	
Peak Plate Voltage	25 kv
D-C Plate Voltage	20 kv
D-C Grid Voltage	—600 Volts
Peak Positive Grid Voltage	1500 Volts
Peak Cathode Current	75 Amps
D.C. Plate Current	100 mA
Grid Dissipation	45 watts*
Plate Dissipation (150 cfm @ 0.8" water)	1000 watts

*Sufficient air cooling must be provided to keep glass seal temperatures no more than 175°C under all conditions of operation.

For full technical data on this or any other Machlett tube type, write:

Machlett Laboratories, Inc., 1063 Hope Street, Springdale, Connecticut

CIRCLE 156 ON READER-SERVICE CARD

TELEMETERING TEST OSCILLATOR

MODEL TO-258 **$425.00**

PUSH-BUTTON SELECTION OF FREQUENCY

Standard model provides accurate and convenient calibration for telemetering systems. Also ideal for production testing and other applications. Models can be supplied with any 20 frequencies from 20 cycles to 100 KC.

Standard FM/FM frequencies from 400 cycles to 70 KC. Calibrated deviation control ±15% of center frequency. Distortion less than 1% to 21 ma. rms. Less than 1% frequency error.

Full size module of TLI Modular Instrumentation System.

TELETRONICS LABORATORY, INC.

54 KINKEL STREET WESTBURY, L. I., N. Y.

CIRCLE 157 ON READER-SERVICE CARD

NEW LITERATURE

Coaxial Components 160

Coaxial components are cataloged in a 28-page booklet. Attenuators, filters, terminations, power dividers, crystal mounts, stub tuners, and miniaturized components are among the items listed. The catalog covers the operation theory of each product. It also presents application and performance data and mechanical and electrical specifications. Microlab, 71 Okner Pkwy., Livingston, N.J.

Insulating Tubing 161

A selector card for insulating tubing and sleeving has been issued. It has a size gage and more than 40 tubing samples. Technical data on the 8-1/2 x 11 in. card includes dielectric strengths; temperature ratings; applicable NEMA, ASTM, and MIL specifications; flammability; oil resistance; flexibility; abrasion resistance; and resistance to potting. Suflex Corp., 33-38 57th St., Woodside 77, N.Y.

Meters 162

An illustrated catalog features a full line of electrical indicating instruments. Covered are dc microammeters, dc milliammeters, dc ammeters, dc voltmeters, thermocouple rm ammeters, db, vu, and rectifier type ac instruments. Ruggedized types, commercial types, and types that conform to MIL-M-10304 are described. Sun Electric Corp., Harlem and Avondale, Chicago 31, Ill.

Precision Resistors and Networks 163

A fact-packed 8-page catalog covering a complete line of custom-made precision wire-wound, encapsulated resistors and rugged, hermetically sealed resistor networks is now available. In this comprehensive, compact catalog are several easy-to-read charts and graphs, and many illustrations, drawing, and specifications pertinent to the life-tested resistors and networks. General Resistance, Inc., 577 E. 156th St., New York 55, N.Y.

Epoxy Pumps 164

The operation of automatic epoxy pumps which mix, meter, and dispense two-part resins is explained in a recent brochure. Specifications and performance data are given for ten pump models. A technical advisory service which includes custom compounding is described in the same brochure. H. V. Hardman Co., 571 Cortlandt St., Belleville 9, N.J.

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Epoxy Thinner 167

Expanded data sheets on the properties and applications of epoxy resin flexibilizer NC 513 are available. The flexibilizer is used for epoxy coatings, encapsulation of electrical components and electrical potting compounds, tooling resins and plastic forming molds, epoxy resin adhesives, patching and splining compounds, and glass-reinforced epoxy resins. Minnesota Mining and Mfg. Co., 500 Doremus Ave., Newark 5, N.J.

High Temperature Wire 168

"Kulgrid 28, Nickel Clad Copper Wire" describes the chemical composition, mechanical properties, conductivity, and resistivity of a wire developed for high temperature use in electrical and electronic equipment. The technical bulletin also contains the results of comparative laboratory tests made on the resistivity of the wire at elevated temperatures. Sylvania Electric Products Inc., Warren, Pa.

Nonlinear Pots 169

With graphs, Technical Bulletin 10 shows the magnitude of resulting error due to external loads on several nonlinear potentiometer functions. The 4-page brochure also indicates a unique approach to nonlinear design and explains compensated winding procedure for any nonlinear functions. Technology Instrument Corporation of California, 7229 Atoll Ave., North Hollywood, Calif.

Miniature Pulse Transformer 170

Information about the ES-3, a subminiature pulse transformer for use in transistor circuits, is presented in a 1-page bulletin. The model is a spherical form encapsulated in epoxy resin to a maximum diameter of ⅜ in. for simplified mounting on printed circuit boards. The text covers the unit's features, construction, and ratings. A photograph shows its actual size. Pulse Engineering, Inc., 2657 Spring St., Redwood City, Calif.

Vacuum Systems

A 16-page product summary and price list shows a complete line of standard and custom high vacuum components, equipment, and systems. Mechanical and diffusion pumps, gauges, valves, analytical apparatus, furnaces, freeze drying equipment, and leak detectors are among the items listed. *For a copy of this catalog write on company letterhead directly to NRC Equipment Corp., 160 Charlemont St., Newton 61, Mass.*

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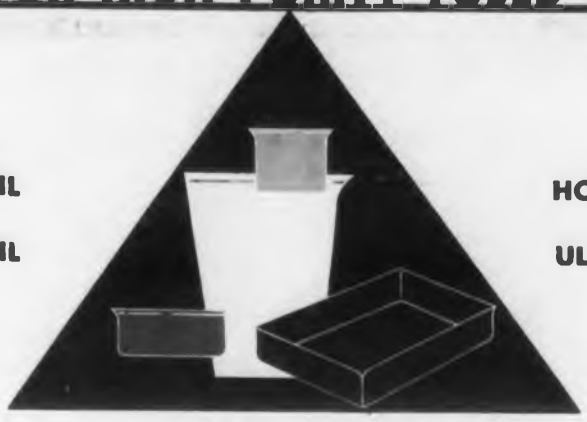

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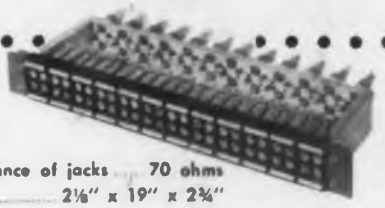
Jack panel components also available

TYPE 924

Nominal impedance of jacks	70 ohms
Size	2⅛" x 19" x 2¾"
Number of jacks	24
Mounting	Relay rack
Finish	Light Umber Gray



TYPE 948

Nominal impedance of jacks	70 ohms
Size	2⅛" x 19" x 2¾"
Number of jacks	48
Mounting	Relay rack
Finish	Light Umber Gray

LOOPING PLUG

PATCH CORDS 18" - 24" - 36"

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CIRCLE 172 ON READER-SERVICE CARD

NEW LITERATURE

Miniature Relays 174

Over 325 subminiature relays are described in a 12-page booklet. Designed for missile, airborne, and industrial equipment, the relays meet and surpass Mil-5757A, B, and C and Mil-R-25018 (USAF). Complete descriptions of the units include contact and vibration ratings. Photographs and diagrams illustrate the booklet. Radio Corporation of America, Commercial Electronic Products, Camden 2, N.J.

Batteries for Aircraft 175

A line of production batteries for unmanned aircraft and missiles, and 11 for manned aircraft, are described in this recently published bulletin. The bulletin covers nominal capacity, open circuit voltage, normal discharge voltage, maximum charging voltage, charging rate, maximum current conditions at 70 deg F, weight, battery dimensions, and case material. Yardney Electric Corp., 40-50 Leonard St., New York 13, N.Y.

Thyratron Grid Control 176

Bulletin 101-L features a packaged thyratron grid control for motor and generator controls, regulated power supplies, servo systems, and process control. The 4-page pamphlet presents circuit details, mechanical features, and typical applications. It is illustrated with graphs, schematics, and photographs. VecTrol Engineering, Inc., P.O. Box 1089, Stamford, Conn.

Electronic Parts Catalog 177

Listing over 27,000 items, this 404 page catalog describes a line of electronic parts and equipment. The catalog features 192 pages in rotogravure and 4-color covers.

The catalog emphasizes equipment for industrial maintenance, research, and production requirements. There are detailed listings of standard and special purpose electronic tubes, test instruments, voltage stabilizers, transformers, resistors, capacitors, printed circuit components, new transistors, rheostats, relays, switches, rectifiers, fuses, tools, wire, cable, photo-electric components, two-way radio telephones, sound powered telephones, counters, program clocks, timers, batteries, sockets, generators, power supplies, and a wide variety of other electronic components.

Also included in the bulletin are audio equipment and test equipment kits. Allied Radio Corp., 100 N. Western Ave., Chicago, 80, Ill.

ADVERTISERS' INDEX
April 30, 1958

CIRCLE 193 ON READER-SERVICE CARD

CIRCLE 194 ON READER-SERVICE CARD ➤

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A CASE HISTORY ...RCA-6AF4-A

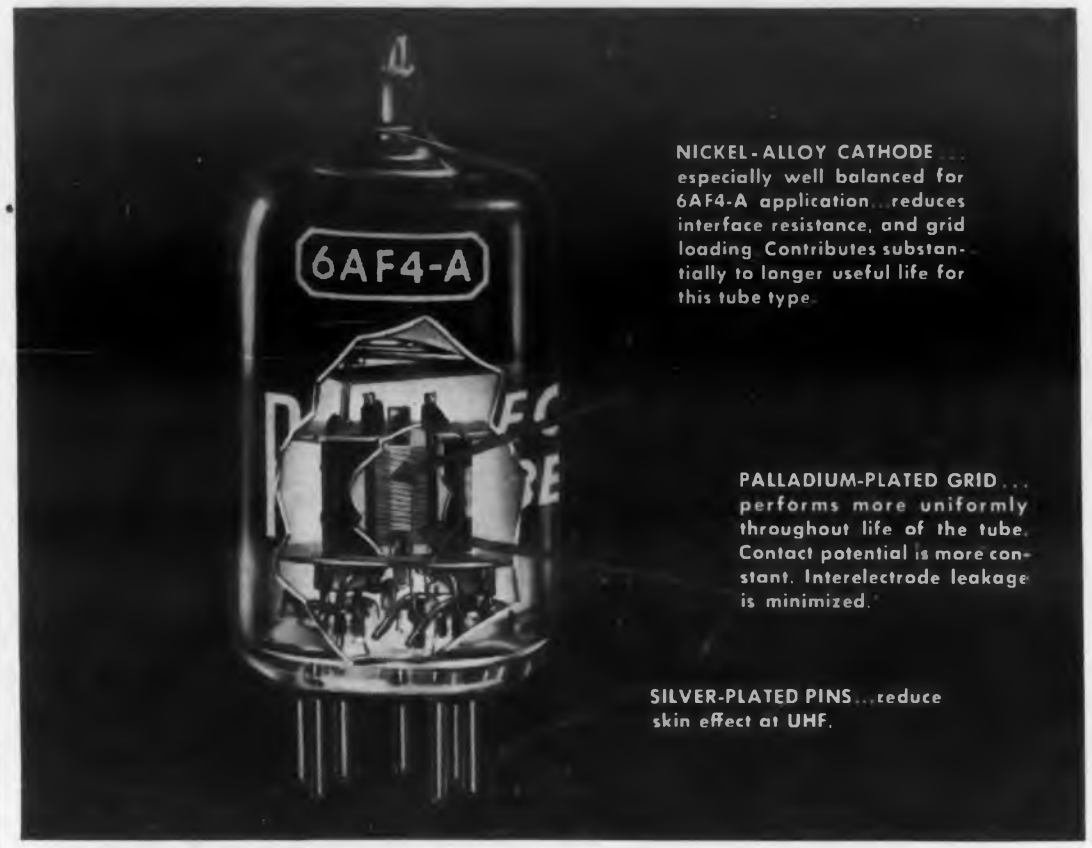
Demonstrates How RCA's Preferred Tube Types Program Improves Tube Quality

The development of the RCA-6AF4-A...outstanding for superior quality...is just one example of the effectiveness of RCA's continuing program to provide manufacturers with tubes of uniformly high quality at moderate cost.

Troublesome days—The "cage" structure originally used in the 6AF4 was the only one readily available that would satisfy the oscillator-service requirements of UHF television receivers. In spite of certain shortcomings of the 6AF4 structure, the tube has been popular with manufacturers needing a UHF-oscillator triode. To eliminate the shortcomings of the 6AF4, RCA undertook an extensive redesign of its structure.

Now, an outstanding tube—Today, the RCA-6AF4-A is considered by manufacturers to be outstanding in all respects. Critical evaluations show clearly that the improved RCA-6AF4-A offers such distinct advantages as minimized slump, product uniformity, and long life.

Dynamic life-tests prove RCA's quality—Projected average life for this tube type is 4,000 hours or more, based on life tests under dynamic conditions at 1,000 Mc. The new RCA-6AF4-A, a Preferred Tube Type, is certainly the right choice for manufacturers designing new UHF-TV tuners and receivers.



RCA's Preferred Tube Types Program currently offers a list of 62 tube types for TV and radio receiver applications. Tube types on this "list" have qualified as Preferred Tube Types by meeting these 4 important requirements: *Quality*...it performs adequately in each function for which it is chosen; *Versatility*...the tube's characteristics are suitable for a wide variety of applications; *Popularity*... it is among the popular currently used types; *Economy*...the tube is adaptable to low-cost manufacturing techniques.

You, too, can gain for your own designs and products, the benefits offered by RCA's Preferred Tube Types Program. Contact your RCA Field Representative for the up-to-date list of RCA Preferred Tube Types. Or, write RCA Commercial Engineering, Section D-18-Q-3. Harrison, N. J.

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