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Australian Guided Weapons Analogue Computor

By the courtesy of Howard Beale, Minister for Supply.

The development of guided missiles involves the design of extremely complex electronic and electro-mechanical control equipment, and very great savings in time and expense can be effected if the functioning of this equipment can be investigated without actually firing a missile at a target.

Such investigation may be carried out with the help of an analogue type of Simulator, in which guidance and control data (such as radar ranges and bearings) are generated artificially by machine and circuits having characteristics analogous to those of real targets and real missiles. These artificially-produced data are then supplied to other equipment simulating the missile control system, the behaviour of which may thus be studied under laboratory conditions and at comparatively little expense.

Various analogue simulators for this type of work have been built in recent years, particularly in America and Great Britain, and they have rapidly become essential to any programme of practical missile development. Two years ago, therefore, the Australian Long Range Weapons Establishment, in conjunction with the British Ministry of Supply, began planning a machine for installation at the L.R.W.E. laboratories in Salisbury, South Australia.

AGWAC, the Australian Guided Weapons Analogue Computer, is a general purpose electronic simulator for investigating guidance and control problems. Its technical design is based on the very large three-dimensional simulator, TRIDAC, developed and recently built for the Royal Aircraft Establishment at Farnborough. Many of the components in AGWAC are, in fact, identical with those in TRIDAC.

Principles

AGWAC is designed to perform basically the same computation as TRIDAC, i.e., the study of the flight and control of aircraft and missiles against moving targets.

The basic unit around which the computer is designed is a D.C. amplifier. This is an electronic device which when connected in an appropriate manner with other units can be made to perform the standard mathematical operations of addition, multiplication and integration and differentiation with respect to time.

Other computing units are supplied which employ biased diode switches operated by the variable input voltage. These units have transfer functions that are made to approximate to particular types of non-linear characteristics such as square law, sine and cosine laws, etc.

Certain calculations are more easily carried out by electromechanical means rather than by purely electrical means, and for these electric servo-mechanisms are used. Examples are various types of trigonometric resolver, in which the servomotors drive accurate potentiometers giving output varying with the sine or cosine of rotation angle, and low-speed multipliers in which many quantities may be simultaneously multiplied by some slowly varying parameter (e.g., Mach number with height).

AGWAC is designed to work in "real time", that is the rates of change of all the voltages in the machine are the same as the rates of change of the real variables in the equipment simulated. This permits, if required, the inclusion of actual missile components such as fin actuators, stabilisers or dish rotation equipment.

It is also possible to work on a 10 : 1 slowed-down time scale, allowing more detailed analysis of, for example, the last critical moments during a missile's approach to a target, or the reaction of a control system to violent evasive action by a target.

Constructional Features

AGWAC makes use of standard plug-in units (called "bricks"). There are 280 of these, their individual dimensions being 12″ × 8″ × 3″ and they are inserted into standard trays in cabinets. To facilitate installation, the design is such that it can be dismantled quickly into a few easily-handled sections. These sections are described as rafts and contain four cabinets each and there are three rafts in the complete machine.

The whole equipment is controlled from a desk-type console containing meters, switches, fault-indication lamps and telephone-type connections for the interconnection of signals between the computing units in the various cabinets. This enables the simulator to be rapidly set up for any computation that may be required.

A special feature is the installation of a closed-circuit air cooling system employing a refrigerator, which enables the machine to work under extremes of temperature.

Ancillary Equipment

Besides the simulator itself, the AGWAC installation also includes a small differential analyser and a maintenance console.

The differential analyser is designed to solve two simultaneous second-order differential equations, but it is planned to add further equipment to extend its facilities. It will then be an invaluable aid in solving preliminary problems while constructing programmes for the main machine.

The differential analyser is built from the same "brick" units as the rest of AGWAC, though as it occupies only one cabinet no raft construction is involved. It is equipped with its own air circulation and cooling system.

A maintenance console has been provided in order to keep AGWAC in running order. It includes a comprehensive range of equipment specially made for tests peculiar to the machine, as well as a wide range of general-purpose instruments.

AGWAC has been designed jointly by the Ministry of Supply, the Department of Supply, Australia, and Elliott Brothers (London) Ltd., and it has been constructed by Elliott Brothers (London) Ltd. and installed at the Long Range Weapons Establishment, South Australia.

New RCA Releases

RCA–6524 is a new, small, sturdy, twin beam power tube. It is intended primarily for use as a push-pull of power amplifier or as a frequency tripler in fixed and mobile equipment operating in the uhf range between 450 and 470 Mc. At lower frequencies in the uhf range, the 6524 can be operated with higher plate voltage and plate input to give increased power output. It is also useful as an af power amplifier and modulator.

This new type will have particular appeal to those radio amateurs operating in the 420-450 Mc. band, as well as those operating in the lower-frequency bands.

The 6524 has a maximum plate dissipation rating of 25 watts under ICAS conditions. Under these conditions in class C telegraphy and frequency-modulated service at 462 MC, the 6524 can deliver to load of output circuit a useful power of approximately 20 watts.

The excellent efficiency obtainable with the 6524 in push-pull service with circuits of the conventional line type is made possible by several design features. Included among these is the balanced compact structure of the beam power units which have low interlectrode capacitances, close electrode spacing, and a cathode common to the two units. RF losses are minimized by the use of short, heavy internal leads and high-conductivity seals. Use of a single cathode common to the two units reduces cathode inductance to a negligible value. Furthermore, input degeneration in push-pull service is prevented by the balanced arrangement of the units.

Some Notes on Sound Reinforcement Systems

By F. Langford Smith.

(1) The acceptability of speech and music with a single echo.

In any indoor sound-reinforcement system there is liable to be interference with speech or music from echoes, even though only a single loudspeaker is used. Also in any multiple-loudspeaker sound-reinforcement system, either indoors or outdoors, there is liable to be interference caused by two or more sound sources, for example by the original source and one or more loudspeakers within the hearing of a particular listener.

Findings from recent papers on this subject are given below:

(A) Haas.

The effect of a single echo on the acceptability of speech was first investigated by Haas (ref. 1). Some of the findings given in this article by Haas are summarized below:—

1. *Tests with echo delay differences between 1 and 30 millisecs* showed an increase in loudness in agreement with the law of the addition of energies and a pleasant modification of the sound impression in the sense of a broadening of the primary sound source, while the echo source is not perceived acoustically. The intensity of the echo must exceed that of the primary sound by 10db to make the echo separately perceptible in this range.

2. *Echo with greater delay differences* above a rather marked threshold value cause the sound impression of speech to be disturbed, even to complete unintelligibility.

The conception of a "critical delay difference" is introduced as a means of gauging the amount of the disturbance, and of comparing measurements made under different circumstances:

(a) *Its value* is approximately inversely proportional to the speed of speech in the range from 3.5 to 7.4 syllables per second, as tabulated below:

Critical delay difference in milliseconds.

Acceptability by 50% of listeners' echo level 0 db.

	Fast speech	Medium speech	Slow speech
Syllables/sec.	7.4	5.3	3.5
Echo delay time ...	50	68	92

It is evident from these results that hearers may well follow, without difficulty, slow speech in a room, whereas disturbances will arise with increasing speed of speaking.

(b) The intensity of an echo exerts an important influence on the critical delay difference. An attenuation of the echo intensity by only 5 db doubles the critical echo delay time.

Echo intensities more than 10 db below that of the direct sound do not disturb at all the reproduction of continuous speech. This finding has been challenged by Muncey, Nickson and Du Bout —see (B) below.

(c) The high frequencies of the echo determine the amount of the subjective disturbance. Their attenuation makes possible a considerable raising of the critical difference, with almost no noticeable reduction of the loudness of the echo.

(d) *The quantity of the echo disturbance* does not depend on the loudness in the range belonging to speech.

(e) *The direction of incidence of the echo* does not affect essentially the critical difference, provided that the direct sound is incident from the front.

(f) A longer reverberation time in a room produce a greater critical delay difference.

3. The short time-delay measurements were made outdoors, with a level of 50 phons at the observer. The longer time-delay measurements were made in an auditorium with a volume of 10,200 cubic feet and an average reverberation time for speech 0.8 second for the room full (the actual reverberation times were: 1 second at 200 c/s, 0.75 second at 1000 c/s, and 0.5 second at 8000 c/s).

(B) Muncey, Nickson and Du Bout.

Muncey, Nickson and Du Bout have carried out mechanical control equipment, and very great tests along similar lines, but including fast string music as well as fast speech (Ref. 2). These tests were in a highly damped room with a reverberation time of 0.15 second. The results obtained for acceptability by 50% of the listeners were:—

	Time delay in milliseconds	
Echo level	**Fast speech**	**Fast music**
0 db	30	50
—10	70	120
—20	120	250
—30	400	600

The value for fast speech with echo level 0 db is 30 milliseconds, compared with 50 milliseconds derived by Haas. One of the factors contributing to the discrepancy between the two figures is the reverberation time of the room. It is interesting to note that the time delay for fast music is very much greater than for fast speech. The authors point out that the statement by Haas that the echo has a negligible effect if it is 10 db lower than the original signal, is incorrect, at least under their conditions of test.

Comments.

Haas has shown that when a single echo is delayed behind the original sound up to 30 milliseconds, this echo has to be 10 db greater in intensity than the original sound to be heard as a separate source. Subtracting an arbitrary 3 db, we can assume that an echo may be up to 7 or 8 db greater in intensity and not be detectable as a separate source, while the apparent direction of the sound will be determined entirely by the original source.

Out of doors, there seems to be no reason to doubt the findings of Haas that an echo delay time of 50 milliseconds (equivalent to a path difference of 56 feet) is permissible with any form of speech when the echo is at the same level as the source. Indoors, the echo delay times found by Muncey, Nickson and Du Bout may be taken as the most extreme ever likely to occur in practice in a highly-damped room, namely 30 milliseconds (34 feet) for fast speech and 50 milliseconds (56 feet) for fast music, when the echo is at the same level as the source.

These findings have been applied in the design of auditoria, and public address systems. Some notes on these applications follow.

(2) The design of auditoria for music and speech reinforcement.

Much research is taking place to-day on this huge subject. Considerable progress has been made on the echo problem, and it is possible to design an auditorium for this purpose so as to eliminate completely all objectionable echoes and to put echoes to good effect by a sloping rear ceiling which directs them to the ears of the audience.

Under these conditions the level of the reflected sound may well approach 10 db greater than the direct sound, and it seems that the difference in acoustical path length between the direct sound and the reflected sound should not exceed 34 feet (delay time 30 milliseconds), adopting the values given by Muncey, Nickson and Du Bout.

In other cases where the reflected sound may not be so relatively strong, a somewhat longer delay time may be permissible.

(3) Sound reinforcing systems with multiple loudspeakers.

When two or more loudspeakers are used in any sound reinforcing system, it is desirable to avoid disturbing effects from neighbouring loudspeakers. The writer has made an approximate calculation, based on the results quoted above from Muncey, Nickson and Du Bout, for the case with two loudspeakers in the open air and no nearby large reflecting surfaces. Under these conditions the spacing between loudspeakers should not exceed 150 feet for each of the following two cases:—

1. Height of loudspeakers above listeners' heads equal to one-tenth of the spacing between loudspeakers.

2. Height of loudspeakers above listeners' heads equal to one-twentieth of the spacing between loudspeakers.

In this calculation it was assumed that the loudspeakers were non-directional, which seems to be the worst possible case.

From this result, it appears that the optimum spacing of loudspeakers should be based on the required uniformity of intensity level, and that any spacing found satisfactory on this basis would normally be substantially free from disturbing effects from neighbouring loudspeakers.

The most troublesome region appears to be nearly equidistant from each of two, or perhaps four, loudspeakers where the listener may have the impression of hearing from more than one direction. But this effect is unavoidable when multiple loudspeakers are used.

(4) Sound delay systems for auditoria.

The ordinary type of speech reinforcement system suffers from the defect that the sound appears to come from the nearest loudspeaker which may be a long way from the source of the sound. This effect may be completely eliminated in single loudspeaker systems by placing the loudspeaker so that the sound from it arrives from 5 to 25 milliseconds later than the sound from the human speaker. The level of sound from the loudspeaker can be up to about 7 or 8 db higher than the original sound, measured anywhere in the audience, without being heard as a separate source. This effect can be obtained, for example, by placing the loudspeaker at least 6 feet behind, and about 20 or 30 feet above, the microphone. The loudspeaker should be highly directional, and have its axis of propagation pointed towards the back row of seats. This will normally ensure that acoustical feedback is not troublesome. A wider angle of coverage may be achieved by various methods, e.g., two loudspeakers side by side, or one bass loudspeaker and two more tweeters.

In larger auditoria, the same result may be achieved by using an electrical delay system. For example, in St. Paul's Cathedral, London, a pair of loudspeakers are placed near the pulpit, with no time delay, and the sound from this source reaches the listener first, while that from the first pair of loudspeakers in the nave arrives 5 milliseconds later and is 7 db greater in level. The second and third pairs of loudspeakers in the nave are still further delayed (10 to 15 milliseconds respectively). By this means all sound appears to be coming from the pulpit (Refs. 4 and 6).

Other installations in the new Free Trade Hall, Manchester, and Harringay arena have also been described (Refs. 4).

The delay systems in use include:—

1. A rotating disc, coated on the edge with magnetic material. The heads are spaced away, and there is no wear.

2. A rotating disc of plastic magnetic material extending beyond the periphery of the supporting turntable. The heads are in contact with the annulus, and when the disc becomes worn it can be replaced at very slight cost.

References to time delay systems and their applications: Refs. 4, 5, 6.

(5) Directional loudspeakers.

Directional loudspeakers are desirable on many counts—e.g., to minimize the variation in level from front to back of the hall, to reduce acoustical feedback, to control reflections from the back wall of the hall, and, in buildings with high ceilings, to reduce the total acoustical power required and the harmful effects of reverberation in the high ceiling.

The two principal directional types of loudspeakers at the present time are the horn and the line-source. The former is well known, but the latter is a comparative newcomer, although its basic acoustical features were fully understood a very long time ago. A line-source—commonly called a column loudspeaker—consists of a number of loudspeakers mounted close together in a straight line. A vertical line-source gives directionality in the vertical plane, but not in the horizontal plane. If a line source is "tapered" in strength so that the sound from each element varies linearly from a maximum at the centre to zero at either end, the directionality is improved. The column should be tilted slightly forwards so that the central loudspeaker points towards the back seats in the hall. The height of the column above floor level is adjusted to give the closest possible uniformity in acoustical level over the hall, consistent with other requirements.

Better results may be obtained by using two line source loudspeakers, a long column for the low frequencies, and a shorter column (one-quarter the length of the long one) for the high frequencies with a cross-over network for a cross-over frequency of, say, 1000 c/s. Small loudspeakers, with improved high frequency characteristics, are used in the shorter column.

The installation for speech reinforcement in St. Paul's Cathedral, London, uses low frequency loudspeaker columns about 10 feet high at the altar, pulpit and lectern, supplemented by shorter columns down the nave. Each of these includes a shorter high frequency column. (Refs. 4 and 6.)

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Components for Pi-Coupled Amplifiers

By Mack Seybold.

Most of the references on this subject present data for the determination of values of the components for pi-coupled amplifiers in terms of curves or formulas. To simplify the design procedure for the amateur, W2RY1 has compiled this data in easy-to-use tabular form.

The use of a pi network to couple the plate of an rf amplifier tube to the antenna provides several advantages over the use of a conventional parallel-tuned, inductively-coupled tank circuit. The ease with which a multiband transmitter employing a pi-network tank circuit with rotary or tapped coils can be operated on several bands, in addition to its harmonic-attenuation feature, has made this circuit appealing to designers of amateur transmitters. The circuit is also popular because front-panel controls can be used to compensate for reasonably large variations in transmission-line reactance.

The function of the pi network to match a transmission line having relatively low characteristic impedance to the plate of a tube which must "see" a relatively high resistive load to produce optimum power output. Table 1 lists the estimated plate loads for the various operating conditions of several popular tubes used in amateur transmitters. To determine the plate load for a given tube type, refer to Table 1 and select the operating condition that most closely fits the requirements; the estimated plate-load value for that operating condition is given in the last column of the table. The exact load for tubes not listed in Table 1 can be determined from a set of complicated calculations; however, a good approximation can be made with the formula:

$$\text{Estimated Plate Load (ohms)} = \frac{E_b}{2I_b}$$

where E_b is the plate supply voltage, and I_b is the dc plate current in ma.

The estimated plate load is then used as the key to Table II. This table lists the actual values of the pi-network components for the estimated plate load; Fig. 1 shows the location of these components in the circuit.

Example.

An RCA 6146 is to be used in a 7 Mc/s CW transmitter with 750 volts on the plate, and the signal is to be fed to a 50-ohm, coaxial line. Table 1 shows the estimated plate load to be 3,100 ohms. As shown in the 3,000-ohm column of Table II, 7 Mc/s operation requires 90 $\mu\mu$F for C_1, 6.2 μh for L, and 700 $\mu\mu$F for C_2.

Table I

Estimated Plate Loads for Typical Operating Conditions

Tube Type	Service	Emission	E_b volts	E_{c_2} volts	I_b ma	P_o watts	Plate Load ohms
813	ICAS	CW	2,250	400	220	375	5,100
	CCS	CW	2,000	400	180	275	5,500
	CCS	CW	1,500	300	180	210	4,200
	ICAS	Phone	2,000	350	200	300	5,000
	CCS	Phone	1,600	300	150	180	5,300
813's (Parallel)	ICAS	CW	2,250	400	440	750	2,600
	ICAS	Phone	2,000	350	400	600	2,500
807	ICAS	CW	750	250	100	54	3,700
	CCS	CW	600	250	100	40	3,000
	CCS	CW	500	250	100	32	2,500
	ICAS	Phone	600	300	100	44	3,000
	CCS	Phone	475	250	83	28	2,900
807's (Parallel)	ICAS	CW	750	250	200	108	1,900
	ICAS	Phone	600	300	200	88	1,500
6146	ICAS	CW	750	160	120	70	3,100
	ICAS	CW	600	180	150	66	2,000
	CCS	CW	600	150	112	52	2,600
	ICAS	Phone	600	150	112	52	2,600
	CCS	Phone	475	135	94	34	2,600
812-A*	ICAS	CW	1,500	—	173	190	4,300
	CCS	CW	1,250	—	140	130	4,500
	ICAS	Phone	1,250	—	140	130	4,500
	CCS	Phone	1,000	—	115	85	4,300
4-65A**	CCS	CW	1,500	250	150	170	5,000
	CCS	CW	600	250	140	54	2,100
	CCS	Phone	1,500	250	120	145	6,200
	CCS	Phone	600	250	117	50	2,500
4-125A/4D21	CCS	CW	2,500	350	200	375	6,200
	CCS	CW	2,000	350	200	275	5,000
	CCS	Phone	2,000	350	150	225	8;200
	CCS	Phone	2,500	350	152	300	6,700
4-250/5D22	CCS	CW	3,000	500	345	800	4,300
	CCS	CW	2,500	500	300	575	4,100
	CCS	Phone	3,000	400	225	510	6,700
	CCS	Phone	2,500	400	200	375	6,200
2E26	ICAS	CW	600	185	66	27	4,500
	CCS	CW	500	185	60	20	4,200
	ICAS	Phone	500	180	54	18	4,600
	CCS	Phone	400	160	50	13.5	4,600

*Grid Neutralization

**Typical operating conditions at higher plate voltages are published, but plate impedances are too high for convenient pi-network operation.

When a 50-ohm, non-reactive load is applied to the coax output connector, optimum loading at 7 Mc/s will occur with components approximating the above values. In a practical transmitter, a capacitor of 1,000 $\mu\mu$F should be used for C_2, so that the loading can be reduced when desirable, and so that compensation can be made for variations in antenna reactance. Capacitor C_1 should be capable of tuning through resonance at 7 Mc/s; all variations in reactance considered, a capacitance of 150 $\mu\mu$F would be considered to be a safe design value for C_1.

Recommendations.

Design and constructional details for pi-coupled finals are amply covered in the articles listed in the accompanying bibliography. These articles should be examined thoroughly for ideas and suggestions before construction is begun.

In addition to the many valuable suggestions in the literature on the design of multiband rigs using pi-coupled finals, there are two precautions to be observed: (1) The driver should be a straight-through amplifier employing a conventional tuned tank circuit. (2) The final amplifier should not be operated as a doubler. These recommendations are important because the pi-coupled amplifier, in addition to attenuating harmonics effectively, will pass signals at frequencies below the fundamental more readily than an amplifier employing a parallel-resonant plate circuit. If the low frequency signals from preceding multiplier stages are not permitted to reach the control grid of a pi-coupled final amplifier, successful operation will be assured.

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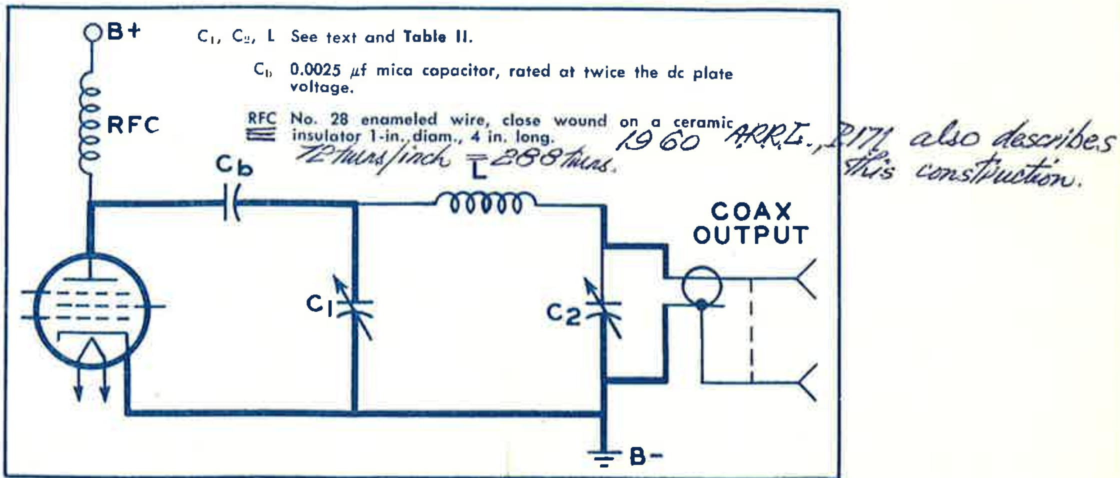

Fig. 1. Plate circuit for the pi-coupled final. Mount the components so that the connections and "chassis" paths, shown as heavy lines, will be as short as possible.

Table II Components for Pi-Coupled Final Amplifiers*

Estimated Plate Load (ohms)		1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	6,000*	NOTES
C_1 in μμf,	3.5 Mc	520	360	280	210	180	155	135	120	110	90	The actual capacitance setting for C_1 equals the value in this table minus the published tube output capacitance. Air gap approx. 10 mils/100 v E_b.
	7	260	180	140	105	90	76	68	60	56	45	
	14	130	90	70	52	45	38	34	30	28	23	
	21	85	60	47	35	31	25	23	20	19	15	
	28	65	45	35	26	23	19	17	15	14	11	
L in μh,	3.5 Mc	4.5	6.5	8.5	10.5	12.5	14	15.5	18	20	25	Inductance values are for a 50-ohm load. For a 70-ohm load, values are approx. 3% higher.
	7	2.2	3.2	4.2	5.2	6.2	7	7.8	9	10	12.5	
	14	1.1	1.6	2.1	2.6	3.1	3.5	3.9	4.5	5	6.2	
	21	0.73	1.08	1.38	1.7	2.05	2.3	2.6	3	3.3	4.1	
	28	0.55	0.8	1.05	1.28	1.55	1.7	1.95	2.25	2.5	3.1	
C_2 in μμf,	3.5 Mc	2,400	2,100	1,800	1,550	1,400	1,250	1,100	1,000	900	700	For 50-ohm transmission line. Air gap for C_2 is approx. 1 mil/100 v E_b.
	7	1,200	1,060	900	760	700	630	560	500	460	350	
	14	600	530	450	380	350	320	280	250	230	175	
	21	400	350	300	250	230	210	185	165	155	120	
	28	300	265	225	190	175	160	140	125	115	90	
C_2 in μμf,	3.5 Mc	1,800	1,500	1,300	1,100	1,000	900	800	720	640	500	For 70-ohm transmission line.
	7	900	750	650	560	500	450	400	360	320	250	
	14	450	370	320	280	250	220	200	180	160	125	
	21	300	250	215	190	170	145	130	120	110	85	
	28	225	185	160	140	125	110	100	90	80	65	

* Values given are approximations. All components shown in Table II are for a Q of 12. For other values of Q, use $\frac{Q_a}{Q_b} = \frac{C_a}{C_b}$ and $\frac{Q_a}{Q_b} = \frac{L_b}{L_a}$. When the estimated plate load is higher than 5,000 ohms, it is recommended that the components be selected for a circuit Q between 20 and 30.

New RCA Releases

R.C.A.-5728/FG-67 is a three electrode, mercury-vapor thyratron of the heater-cathode type intended for use in inverter service where a short-deionization time is required. It has a control characteristic whose range extends into both the negative region and the positive region.

Two 5728's in a typical parallel inverter circuit are capable of supplying a maximum ac power output of 1.4 kilowatts assuming sine-wave output, zero voltage drop in the tubes, and no circuit losses.

The 5728 may be used as a replacement for the discontinued type 1904, which has a positive-control characteristic, provided the equipment is modified to supply the required negative-grid bias which may be needed in some applications.

R.C.A.-1X2-B is a half-wave vacuum rectifier of the 9-pin miniature type designed particularly for rectifying the high-voltage pulses produced in the scanning systems of television receivers.

Rated to withstand a maximum peak inverse plate voltage of 22,000 volts (absolute), the 1X2-8 can supply a maximum peak plate current of 45 milliamperes and a maximum average plate current of 0.5 milliampere.

"RADIO LABORATORY HANDBOOK", by M. G. Scroggie, B.Sc., M.I.E.E., sixth edition. Published by Iliffe & Sons Ltd.

This standard reference book on laboratory electronic techniques, written by a well-known consulting engineer, is intended for both professional engineers and amateurs. It first describes the layout and furnishing of an up-to-date laboratory, and then the various types of apparatus available. Both commercial instruments and improvised equipment are covered. Later chapters deal in detail with methods of making measurements and tests of every kind. Finally, a large section is devoted to general principles and reference material of everyday use to the radio engineer.

The book is particularly suitable for workers in sciences other than radio, such as physiology, in which electronic techniques are being increasingly used. Because comparatively little radio experience is assumed adequate explanations and references are given, while particular attention is given to the general principles of experimentation and interpreting results.

The large amount of information contained in the volume has been presented as concisely as possible and made easily accessible by the very comprehensive system of cross-references, table of contents and index. A special feature is the many carefully-selected references to further information.

"Radio Laboratory Handbook" was originally published in 1938, and quickly gained recognition as a lucid and not-too-solemn practical manual filling the gap between "popular" home experimenters' literature and the advanced professional textbooks. In the intervening period, there have been extensive developments in techniques and equipment, with which subsequent editions have kept pace. This sixth edition has been almost entirely rewritten and greatly enlarged, and is now presented in a new format. The usefulness of the text is enhanced by diagrams.

Some 300 photographs, drawings and circuit.

"RADIO VALVE DATA: Characteristics of 2,000 Valves and C.R. Tubes", compiled by the Staff of "Wireless World". Fourth Edition. Published by Iliffe & Sons Ltd.

The latest edition of this widely-used reference book contains full operating data on over 2,000 types of British and American radio valves and some 200 cathode-ray tubes. Seventeen British valve manufacturers are presented, all of whom have co-operated with "Wireless World" in ensuring that the information given is accurate, comprehensive and up-to-date.

The main tables give the electrical characteristics of each valve, and separate tables show their base connections. The main tables further classify the valves into current replacement or obsolete types as recommended by the makers. An index enables any valve to be found in the tables immediately, while a valuable new feature is the full list of equivalents.

"Radio Valve Data" is an essential tool for every radio designer, service engineer, dealer and experimenter.

Copies of both of the above books have been received with the compliments of the publishers.

Editor . . . . Ian C. Hansen

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