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RADIOTRONICS

AMALGAMATED WIRELESS VALVE COMPANY LIMITED

Technical Bulletin No. 61

Issued 24th April, 1936

IN THIS ISSUE:
Dual-Wave Battery Receiver.

DUAL-WAVE BATTERY RECEIVERS

Using New Radiotron Battery Series

The design of a circuit and particularly one for use on short wave lengths begins with the valves. The new Radiotron Battery Valves 1C4, 1C6, 1B5, 1D4, together with types 30 and 19, provide a very flexible range from which to choose types for any requirement. However, it is essential to follow a definite sequence in order to produce a really satisfactory design, and it can be stated very emphatically that the first step is to choose the valves and their arrangement with a view to the A.V.C. action.

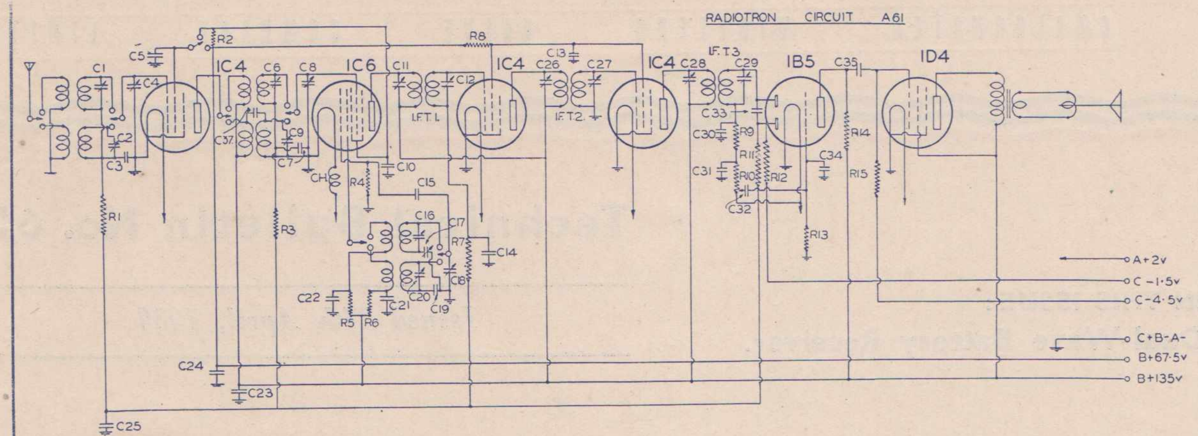
A. V. C. Characteristics

No receiver can be classed as satisfactory in its A.V.C. action unless it has two controlled stages with short grid base valves or three controlled stages with long grid base valves. The first valve, whether R.F. amplifier or converter, must have A.V.C., but a converter valve should preferably not have A.V.C. on short wavelengths. At least one I.F. valve should have A.V.C., but overloading may easily occur in this stage on strong signals, that is at some fairly high negative bias. It is not generally realised that with A.V.C. the bias is nearly equal to the peak voltage at the diode, while the peak signal voltage on the grid is equal to the peak voltage at the diode divided by the stage gain. This means that when the valve is biased back sufficiently to reduce the stage gain to unity, the peak grid swing will slightly exceed the bias. When the valve is biased back still further it will give attenuation of the signal and the peak signal voltage will exceed the bias, and in most cases grid current will result. This grid current will give audio distortion as well as adding to the bias voltage on all A.V.C. stages.

With short grid base valves the point where unity gain is given must be at a less bias than with a long grid base valve. In any case, the stage gain with the valve biased to a certain mutual conductance depends only on the coupling to the following valve. Therefore an improved coupling giving a higher stage gain will give a greater voltage at the diode and consequently an increased bias for any particular input signal.

There is another cause of distortion which occurs in any valve having a super-control characteristic. This is known as "modulation rise" and its effect is to increase the percentage of up-modulation of any signal impressed on the grid. The modulation rise permitted in good design is not more than 20%, since audio distortion becomes noticeable beyond this limit. In receiver design it is usually most convenient to test for audio distortion in place

RADIOTRON CIRCUIT A61



C1	5-20 µµf mica trimmer condenser
C2	5-20 µµf " " "
C3	.1 µf tubular paper "
C4	14-410 µµf variable "
C5	.1 µf tubular paper "
C6	5-20 µµf mica trimmer "
C7	.1 µf tubular paper "
C8	14-410 µµf variable "
C9	5-20 µµf mica trimmer "
C10	.1 µf tubular paper "
C11	10-90 µµf mica trimmer + 100 µµf mica condenser
C12	" " " " "
C13	.1 µf tubular paper condenser
C14	.05 µf " " "
C15	50 µµf mica condenser
C16	5-20 µµf mica trimmer condenser
C17	370 µµf mica + 10-50 mica trimmer condenser
C18	14-410 µµf variable "
C19	2300 µµf mica "
C20	5-20 µµf " trimmer "
C21	.05 µf tubular paper "
C22	.05 µf " " "
C23	.25 µf " " "
C24	.1 µf " " "
C25	.05 µf " " "
C26	10-90 µµf mica trimmer "
C27	10-90 µµf " " "
C28	10-90 µµf " " "
C29	10-90 µµf mica trimmer condenser
C30	200 µµf mica "
C31	250 µµf " "
C32	1000 µµf " "
C33	1000 µµf " "
C34	100 µµf " "
C35	.05 µf tubular paper "
C36	1 µf " " "
C37	10 µµf mica condenser
Ch	Fil. Choke 0.96 ohm 81 µH
T	Class B Audio Transformer Primary: ½ Sec = 2.2:1
R1	100,000 ohms 1/3 watt
R2	15,000 " 1 "
R3	100,000 " 1/3 "
R4	50,000 " 1/3 "
R5	50,000 " 1/3 "
R6	20,000 " 1/3 "
R7	100,000 " 1/3 "
R8	75,000 " 1/3 "
R9	100,000 " 1/3 "
R10	500,000 " potentiometer
R11	1 megohm 1/3 watt
R12	1 " 1/3 "
R13	1 " 1/3 "
R14	250,000 ohms 1 watt
R15	500,000 " 1/3 watt
R16	15,000 " 1 watt

INTERMEDIATE FREQUENCY
465 K.C.

2-VOLT DUAL WAVE BATTERY RECEIVER

AMALGAMATED WIRELESS VALVE Co. LTD., SYDNEY

of a direct test for modulation rise. This test may be made by ear, by oscillograph, or by measurement on a distortion meter. The audio volume control is turned down to a sufficiently low level to prevent any appreciable distortion in the audio stages even with the greatest input signal to be used. With a pentode output stage it is preferable to connect the screen to the plate so as to operate as a triode, and a larger audio output may be handled if desired by increasing the plate voltage and negative bias. The input from the signal generator is then gradually increased until distortion is noticed. Since the output of most signal generators is not sufficient for an input direct to the grid of an I.F. valve, it is necessary to use preliminary amplification. In order to avoid any further possible causes of distortion, the preliminary stage or stages should be operated on fixed bias and sufficiently negative to avoid grid current under the worst conditions. The audio distortion due to the converter valve may be minimised by using it as an amplifier at the intermediate frequency in a non-oscillating condition.

In order to secure a good A.V.C. characteristic up to high input signals, it is necessary that when only two stages out of three preliminary stages are controlled, the two controlled stages should be capable of giving attenuation. With all preliminary stages controlled it may not be necessary to reach attenuation, since the voltage at the diode may be greater than that at the grid of the first valve.

With short grid-base valves the modulation rise usually becomes serious before the valve runs into grid current, but on large signals and high negative bias both forms of distortion are present. The function of good design is to arrange a suitable compromise whereby the distortion is limited to a satisfactory level without impairing the level A.V.C. characteristic and without introducing undue complications.

Distortion, whether due to modulation rise or to grid current, may always be reduced by decreasing the signal applied to the grid while holding the bias constant. The first valve in a receiver would very rarely be called upon to handle a signal voltage of 1 volt, and allowing for the usual A.V.C. arrangement this valve would be biased well negative, so that under these circumstances distortion should be negligible. On the other hand, the last valve before the diode (that will be the I.F. or second I.F. valve) will have to handle a much larger signal voltage, which may be even as high as 16 volts. It will be seen therefore that the earlier stages may usually be neglected entirely as contributing to the total distortion, and attention should be paid to the final I.F. valve.

There are two simple methods for avoiding the distortion described. The first involves the use of two I.F. stages and is very strongly recommended for quality receivers and for all dual-wave receivers. The second method is a compromise made by the use of the 1C4 with medium grid-base and a negative minimum bias. The first method is described in detail in this bulletin, and the second will be described in Technical Bulletin No. 62.

It should not be inferred from what has been said concerning distortion that short grid-base valves are unsuitable for use as I.F. amplifiers on A.V.C. On the contrary, they have been used and are being used very extensively in this application. The purpose of this discussion is to point out that such an arrangement, while entirely satisfactory for small aerial inputs, is definitely limited in its capability to handle larger aerial inputs. Under certain conditions and in certain localities such a receiver might well give excellent service. This is even more pronounced, since a receiver with only one I.F. stage would not be as sensitive as one with two I.F. stages, and as a consequence would handle satisfactorily a larger aerial signal. But if a receiver is to be extremely sensitive and also to be capable of handling large aerial signals, some further elaboration is essential.

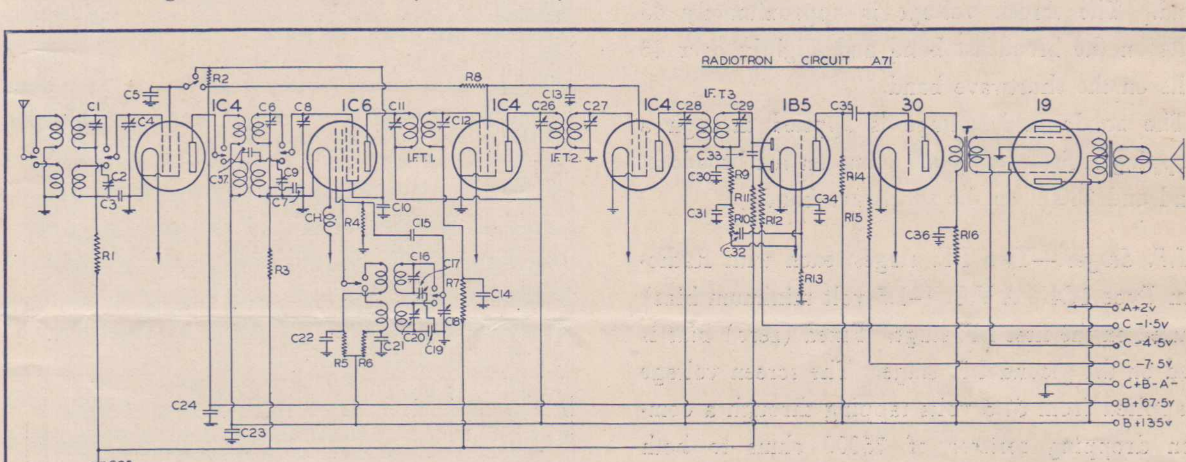
The A.V.C. system may now be considered as a whole with the various alternatives.

R.F. Stage.—A.V.C.

Converter.—May be A.V.C. on the broadcast band. Preferably fixed bias on the shortwave band. If no R.F. stage is used, A.V.C. should be employed on both wavebands.

First I.F. Stage.—A.V.C.

Second I.F. Stage.—Fixed bias preferred, but A.V.C. may be used on the shortwave band if desired. If only one I.F. stage is used, A.V.C. should be employed, but with certain modifications to reduce distortion.



C1	5-20 μμf mica trimmer condenser	C15	50 μμf mica condenser	C29	10-90 μμf mica trimmer condenser	R1	100,000 ohms 1/3 watt
C2	5-20 μμf " " "	C16	5-20 μμf mica trimmer condenser	C30	200 μμf mica "	R2	15,000 " 1 "
C3	.1 μf tubular paper "	C17	370 μμf mica + 10-50 mica trimmer condenser	C31	250 μμf " "	R3	100,000 " 1/3 "
C4	14-410 μμf variable "	C18	14-410 μμf variable "	C32	1000 μμf " "	R4	50,000 " 1/3 "
C5	.1 μf tubular paper "	C19	2300 μμf mica "	C33	1000 μμf " "	R5	50,000 " 1/3 "
C6	5-20 μμf mica trimmer "	C20	5-20 μμf " trimmer "	C34	100 μμf " "	R6	20,000 " 1/3 "
C7	.1 μf tubular paper "	C21	.05 μf tubular paper "	C35	.05 μf tubular paper "	R7	100,000 " 1/3 "
C8	14-410 μμf variable "	C22	.05 μf " " "	C36	1 μf " " "	R8	75,000 " 1/3 "
C9	5-20 μμf mica trimmer "	C23	.25 μf " " "	C37	10 μμf mica condenser	R9	100,000 " 1/3 "
C10	.1 μf tubular paper "	C24	.1 μf " " "	Ch	Fil. Choke 0.96 ohm 81 μH	R10	500,000 " potentiometer
C11	10-90 μμf mica trimmer + 100 μμf mica condenser	C25	.05 μf " " "	T	Class B Audio Transformer Primary: ½ Sec = 2.2:1	R11	1 megohm 1/3 watt
C12	" " " " "	C26	10-90 μμf mica trimmer "			R12	1 " 1/3 "
C13	.1 μf tubular paper condenser	C27	10-90 μμf " " "		INTERMEDIATE FREQUENCY 465 K.C.	R13	1 " 1/3 "
C14	.05 μf " " "	C28	10-90 μμf " " "			R14	250,000 ohms 1 watt
						R15	500,000 " 1/3 watt
						R16	15,000 " 1 watt

2-VOLT DUAL WAVE BATTERY RECEIVER

AMALGAMATED WIRELESS VALVE Co. LTD., SYDNEY

Description of DUAL-WAVE RECEIVER

This set has one R.F. stage (1C4), Converter (1C6), two I.F. stages (1C4, 1C4), second detector (1B5) and two alternative output systems, either a pentode (1D4) or a driver and Class B (30 and 19). The characteristics of the receiver are put in tabular form for ready reference, together with a brief description of each stage.

R.F. Stage.—Radiotron type 1C4 with A.V.C. Screen voltage 67.5 volts for shortwaves and 45 volts on the broadcast band, arranged through a common dropping resistor with the 1C6 screen. The grid bias is –1.5 volts minimum, in common with the other controlled stages, in order to give a higher delay voltage and so improve the A.V.C. characteristic. The effect on overall sensitivity is not very marked.

Converter Stage.—Radiotron Type 1C6. A.V.C. (–1.5 volt minimum bias) is used on the broadcast band only and fixed (zero) bias on the shortwave band. The screen voltage is approximately 45 volts on the broadcast band and slightly over 45 volts on the shortwave band.

The anode grid voltage is applied through a dropping resistor of 50000 ohms on the broadcast band and 20000 on the shortwave band.

I.F. Stages.—Two I.F. stages, each with Radiotron Type 1C4. A.V.C. (–1.5 volt minimum bias) is used on the first I.F. stage. Fixed (zero) bias is used on the second I.F. stage. The screen voltage is applied from 67.5 volts tapping through a common dropping resistor of 75000 ohms to both valves.

Second Detector.—Radiotron 1B5. One diode is used for detection and the other diode for delayed A.V.C. Additional delay voltage is obtained by returning the A.V.C. diode to –1.5 volt on the bias battery.

ALTERNATIVE OUTPUT SYSTEMS

(1) Pentode Output (Circuit A61)

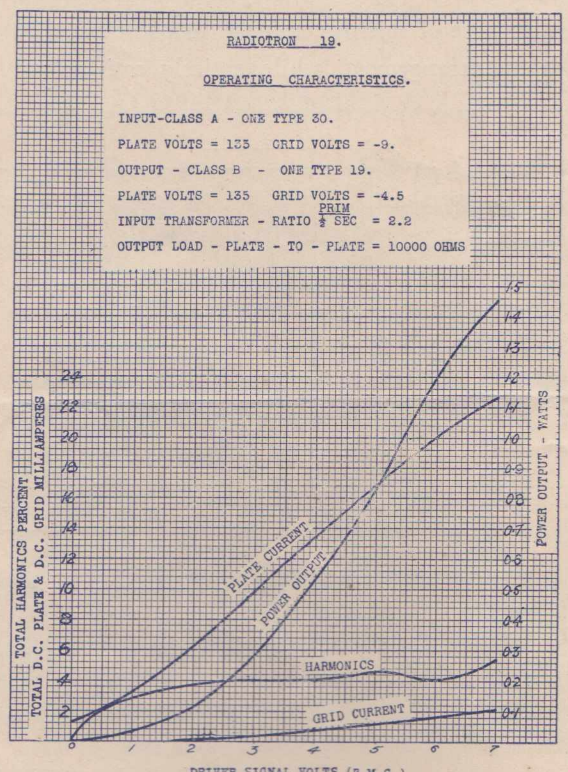
Radiotron 1D4 Pentode is used under standard operating conditions, drawing a total of 7.5 milliamps plate and screen currents to give a power output of about 300 milliwatts.

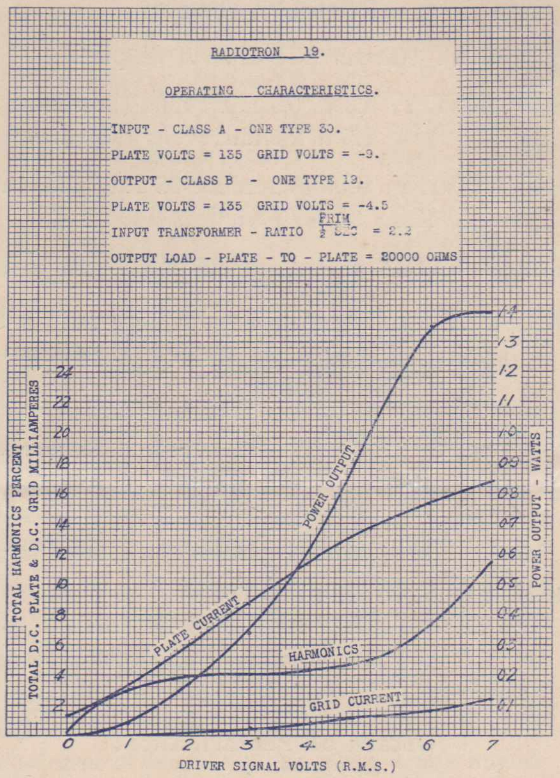
(2) Class B Output (Circuit A71)

The *Driver Valve* is Radiotron Type 30 operating on a bias of –7.5 volts and with a plate dropping resistor of 15000 ohms to reduce the plate current to the lowest practicable value.

The *Output Valve* is Radiotron Type 19 operating on a bias of –4.5 volts with a load resistance of 20000 ohms plate to plate. The power output is slightly over 1 watt, with a low degree of distortion.

Data on this application are given in Technical Bulletin No. 59.





The Class B (input) transformer has a ratio of 2.2:1 primary to half secondary. This transformer should have a high inductance, at least 40 Henries at the specified plate current. Its D.C. resistance should be as low as possible, preferably less than 3000 ohms on the primary and 1000 ohms on the whole secondary. The laminations should be chosen carefully for this application since low losses are essential to satisfactory performance. High incremental permeability silicon steel will give better results than the steel frequently used for power transformers. The watts loss per cubic inch is generally supplied by the manufacturer of the laminations and these losses should be used in a comparison of different steels.

Details of the transformer used in these tests are as follows:—

Core—

Material: Alleghany Grade Audio B.
Gauge No. 29.
Window: 1.125″ × 0.375″.
Tongue: 0.75″.
Stack: 0.75″.
Joint: Butt.
Nett section: 3.25 square cm.
Mean length of magnetic circuit: 13.3 sq. cm.
Weight: 0.60 lb.

Winding—

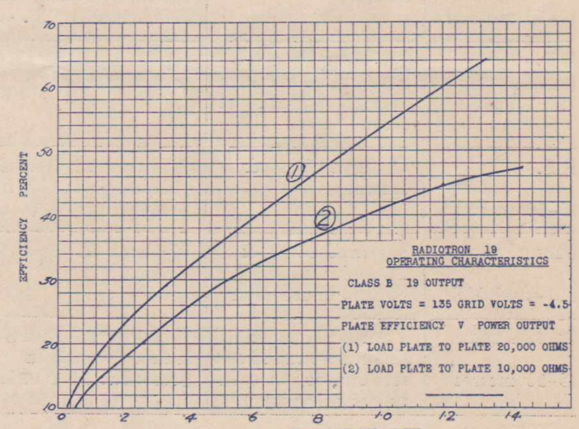
Traverse and margin 1/16″ + 15/16″ + 1/16″.
Form (inside dimensions): 25/32″ × 25/32″.
Length: 1-1/16″.

Primary—

Turns: 5000 No. 40 B. & S. Enamelled.
Location over insulated secondary.
Turns per layer: 240.
Layers: 21.
Insulation between layers: 1 mil. paper.
Insulation over winding: 12 mil. paper.
Mean length of turn: 5.3″.
Resistance at 25°C: 2500 ohms.

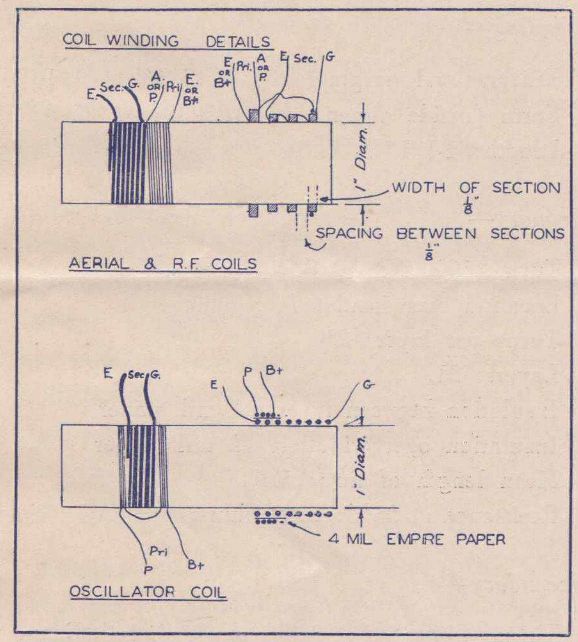
Secondary—

Turns: 4400, top at 2200 No. 38 B. & S. Enamelled.
Location next to core.
Turns per layer: 185.
Layers: 24.
Insulation between layers: 1 mil. paper.
Insulation under winding: 45 mil. paper.



Insulation over winding: 20 mil. paper.
Mean length of turn: 4.0".
Resistance at 25°C: 980 ohms total.

Efficiency approximately 70% at full load.
Inductance of primary at 4 volts 60 cycles and 3 mA. D.C. is 50 Henries.



Coil Details

Coil.	Primary.	Secondary.
Aerial 550–1500 KC	300 turns 40 SWG S.S.E. with one turn over hot end of secondary.	100 turns 5/40 Litz in 3 sections.
Aerial 19–50 metres.	35 turns 35 B & S Enam.	7½ turns 22 B & S Enamel wound in Screwcuts 24 T.P. 1.
R.F. 550–1500 KC	700 turns 40 SWG S.S.E. with one turn over hot end of secondary.	100 turns 5/40 Litz in 3 sections.
R.F. 19–50 metres	65 turns 35 B & S Enam.	7½ turns 22 B & S Enamel wound in Screwcut 24 T.P. 1.
Oscillator 550–1500 KC	30 turns 34 B & S Enamel wound over bottom of secondary	75 turns 31 B & S Enamel.
Oscillator 19–50 metres	8 turns 35 B & S Enamel wound in two sections, one at each end of secondary.	7⅛ turns 22 B & S Enamel wound in Screw cut 24 T.P. 1.

N.B.—Shield Can Internal Diameter 2⅛ inch.

Performance

SUMMARY (Circuit A71 Class B Output).

SENSITIVITY: 0.3 to 0.5 microvolts (broadcast).
1.5 to 2.6 microvolts (shortwave).

SELECTIVITY: 1000 to 1 ratio: 25 K.C. width at 600 K.C.; 35 K.C. width at 1400 K.C.

IMAGE RATIO: 20 metres (15 M.C.)—30 to 1.

NOISE LEVEL: Signal to noise voltage ratio at 5 microvolts input 22 to 28% (broadcast), 10 to 17% (shortwave).

B. BATTERY DRAIN:

	Broadcast.	Shortwaves.
No signal.	8.7 mA.	11.0 mA
at 300 mW output	15.0 mA.	17.3 mA
at 1000 mM output	22.5 mA.	24.8 mA

HARMONIC DISTORTION:

at 300 mW . . . . . 6.5% total.
at 1000 mW . . . . . 6.5% total.

Details of Performance:

Battery Drain

Battery Drain		Circuit A61		Circuit A71	
Stage	Valve	B.C.	S.W.	B.C.	S.W.
R.F. ..	1C4	0·9	2·2	0·9	2·2
Converter ..	1C6	3·3	4·3	3·3	4·3
I.F.1. ..	1C4	0·8	0·8	0·8	0·8
I.F.2. ..	1C4	0·8	0·8	0·8	0·8
2nd Det. ..	1B5	0·2	0·2	0·2	0·2
Driver ..	30	—	—	1·3	1·3
Output ..	1D4/19	7·5	7·5	1·4	1·4
Total drain		13·5	15·8	8·7	11·0

Sensitivity:

Circuit A71 (Class B)

Position	Frequency	Sensitivity	5μV Noise Level*	Stage Gain
2nd I.F. grid	465 kc	24,000 mV		
1st I.F. grid	465 kc	380		63·
Converter Grid	465 kc	12·9 BC 4·5 SW		
	600 kc	13·5		28·
	1000 kc	13·5		28·
	1400 kc	15·0		25·
	6 Mc	9·0		42·
	10 Mc	10·8		35·
	15 Mc	14·6		26

R.F. Grid ..	600 kc	0·9		15·0
	1000 kc	2·2		6·1
	1400 kc	1·3		11·5
	6 Mc	3·0		3·0
	10 Mc	3·2		3·4
	15 Mc	3·0		4·9
Aerial Terminal	600 kc	0·3	22%	3·0
	1000 kc	0·5	22%	4·4
	1400 kc	0·4	28%	3·25
	6 Mc	2·0	17%	1·5
	10 Mc	2·6	10%	1·3
	15 Mc	1·5	14%	2·0

* Voltage. ratio.

A. V. C. Characteristic

On the broadcast band a good A.V.C. characteristic prevents overloading and distortion due to strong signals, and for this reason it should be made as level as possible up to the maximum aerial input signal. Radiotron circuit A71, having three short grid base controlled stages, together with what is essentially amplified A.V.C. (through the second I.F. stage) and a fairly high delay voltage, gives an almost ideal A.V.C. characteristic on this band on aerial inputs up to 1 volt. The high degree of sensitivity also plays a very important part in the good A.V.C. characteristic, it being obvious that the greater the "controlled" amplification, the greater is the range of control. The "controlled" amplification in Radiotron Circuit A71 is 24,000 times on the broadcast band. On the shortwave band the position is somewhat different since very large input signals do not normally have to be considered. On the other hand, extremely bad fading conditions will frequently be encountered and a receiver to give good results under listening conditions should have a perfectly level A.V.C. characteristic up to at least 50,000 microvolts. Radiotron Circuit A71 has only two controlled stages on the shortwave band and for this reason its performance on very large input signals is not so good as on the broadcast band with three controlled stages. It is, however, entirely satisfactory under all conditions obtaining on the shortwave band and the addition of a third controlled stage makes no appreciable improvement. The essential feature of good A.V.C. characteristics on the shortwave band is that the output should continue at the same level down to very low signal inputs. It is sometimes stated that a very high degree of sensitivity on the shortwave band is unnecessary, and this may be true under certain conditions where no fading occurs. But it is certainly true that, in order to secure the full benefits of A.V.C. on badly fading signals, a very high degree of sensitivity is essential. With a shortwave sensitivity of about 2 microvolts Radiotron Circuit A71 performs remarkably well under all listening conditions.

It should be pointed out in order to avoid confusion that the distortion which frequently occurs during fading is a distortion of the incoming signal and cannot be avoided by the design of the receiver.

Noise Level

The noise level with any particular aerial input signal is taken as the ratio of output *voltages* with modulation 30% and zero, the carrier being maintained constant. It may be measured at any signal input desired, but there can be no fair comparison between different receivers unless the tests are conducted at the same aerial input signal. All tests made by Amalgamated Wireless Valve Co. Ltd. are at an input signal of 5 microvolts with modulation 30% and zero. This level has been found most satisfactory under most conditions and is taken as a standard test. Under these conditions the noise level of Radiotron Circuit A 71 is from 22% to 28% on the broadcast band and from 10% to 17% on the shortwave band. Most listeners will tolerate considerably more than 28% noise level, especially if it only occurs during fading, but owing to the difficulty of setting a standard of noise the method outlined is considered preferable.

Distortion

The distortion given in the summary (6.5% total at 300 and 1000 mW output) is the overall distortion of the whole receiver on 30% modulation with aerial input signals below 50,000 microvolts. On larger input signals the distortion in the R.F., Converter and I.F. stages will add to this amount. Although most battery receivers will not normally be subjected to very large input signals, there will necessarily be a proportion which are situated in close proximity to a broadcast station. Those receivers which are of low sensitivity are less likely to give trouble than those of fractional microvolt sensitivity for obvious reasons.

The circuit described in this bulletin has been designed with a view to its use on occasional very powerful signals, and in spite of its extreme sensitivity the performance under such conditions is excellent. The distortion rises steadily to 10% at 500,000 microvolts and 12% at 1,000,000 microvolts. This means that a signal strength well over 1,000,000 to 1 is possible without noticeable distortion.