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IN THIS ISSUE

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THE ECONOMY FIVE

A low-cost transistorized stereo amplifier for mains operation providing a music power output of 2.5 watts per channel

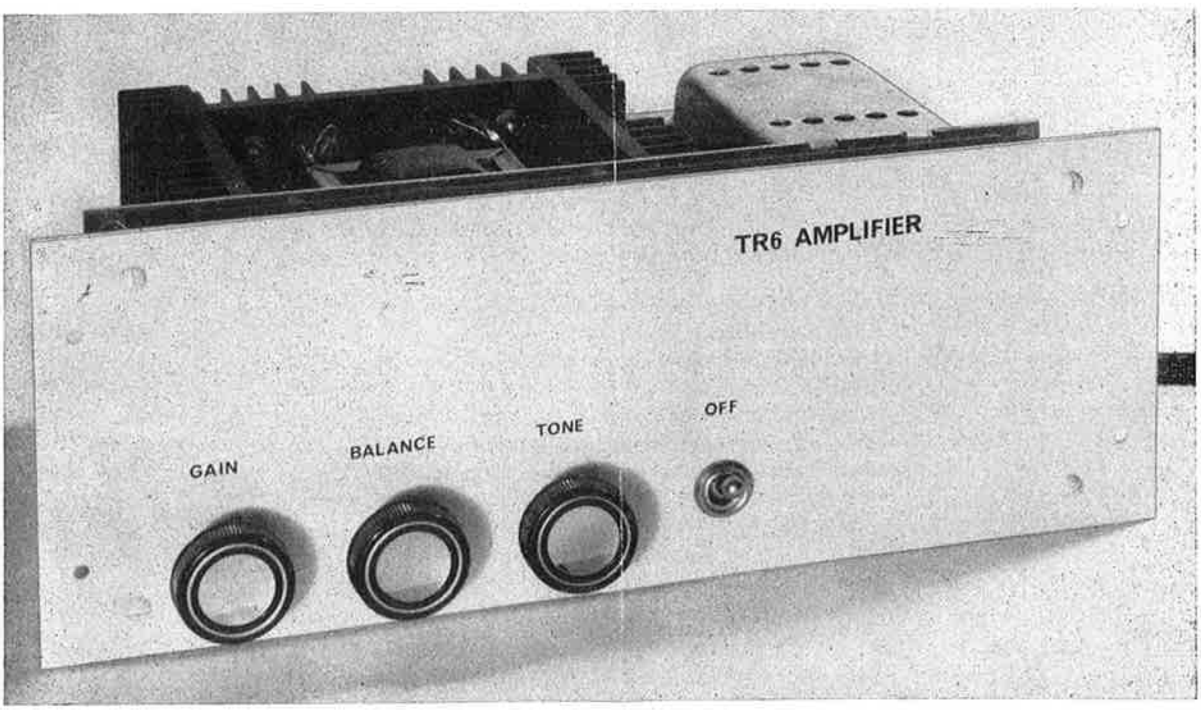
Introduction

Several requests have been received for a low-cost mains-driven transistorized stereo amplifier suitable for home use, where the economy angle precludes a unit of high fidelity standards. This is not the easiest problem to answer when using transistors, especially when the economy angle and low power required indicate Class A operation of one transistor for each channel's output stage.

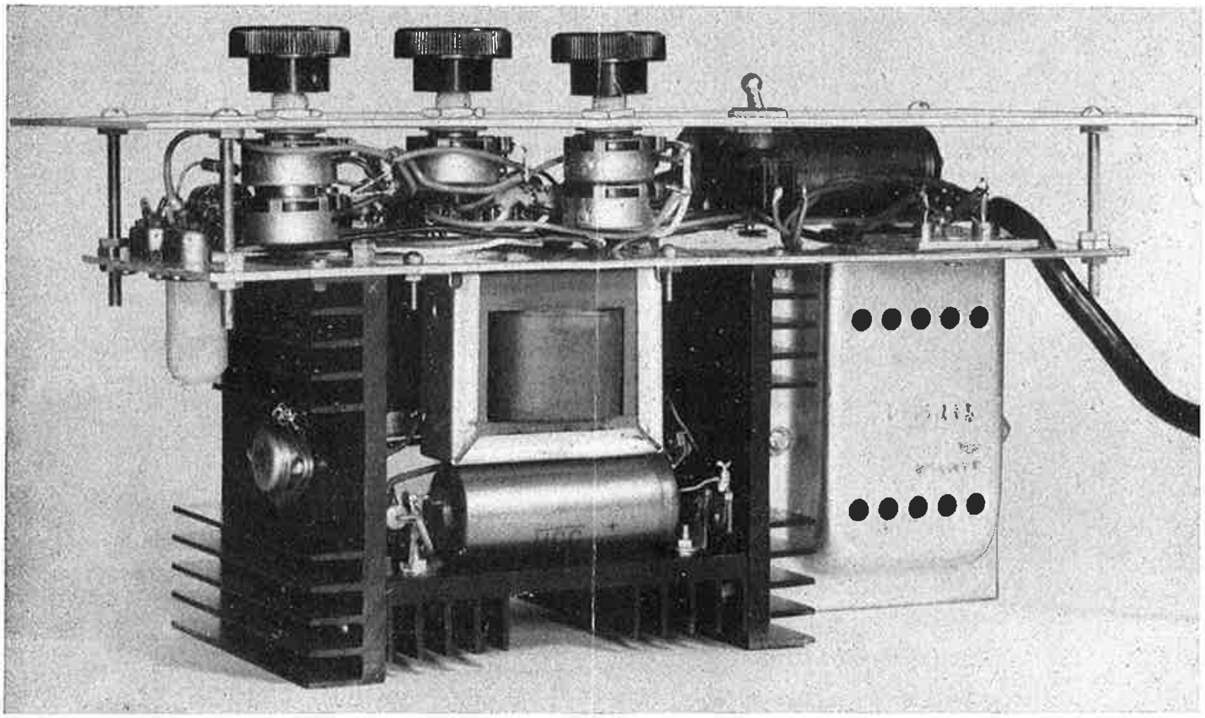
This, then, is one answer to this type of request. In line with the general economy angle, only a treble-cut type of tone control has been provided, and the amplifier has been designed to use a crystal or ceramic cartridge.

Circuit Description

The output stage in each channel of the TR6, as this unit is called in our records, consists of one 2N301 power transistor, which is coupled to the loudspeaker through a tapped output choke. The choke used in this design is suitable for loudspeaker loads of 16 ohms. The use of the simple output choke means that the speaker leads are live with respect to ground, as they carry the



View of the completed "Economy Five" Unit.



Rear view of the unit, showing the assembly of heat sinks and transformers on the rear mounting plate.

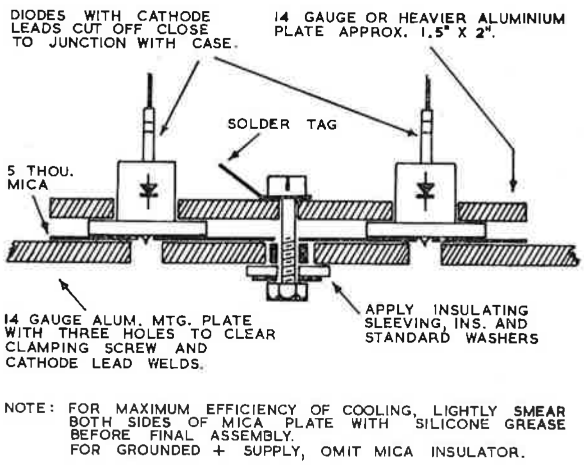
collector supply potential of approximately 15 volts negative.

The 2N301 power transistor is preceded by a 2N217S driver stage, the emitter of which is directly coupled to the base of the 2N301. The circuit arrangement is completed with two stages of amplification prior to the driver stage, one of which incorporates the simple feedback-type top-cut tone control. Both of these stages use type 2N408 transistors.

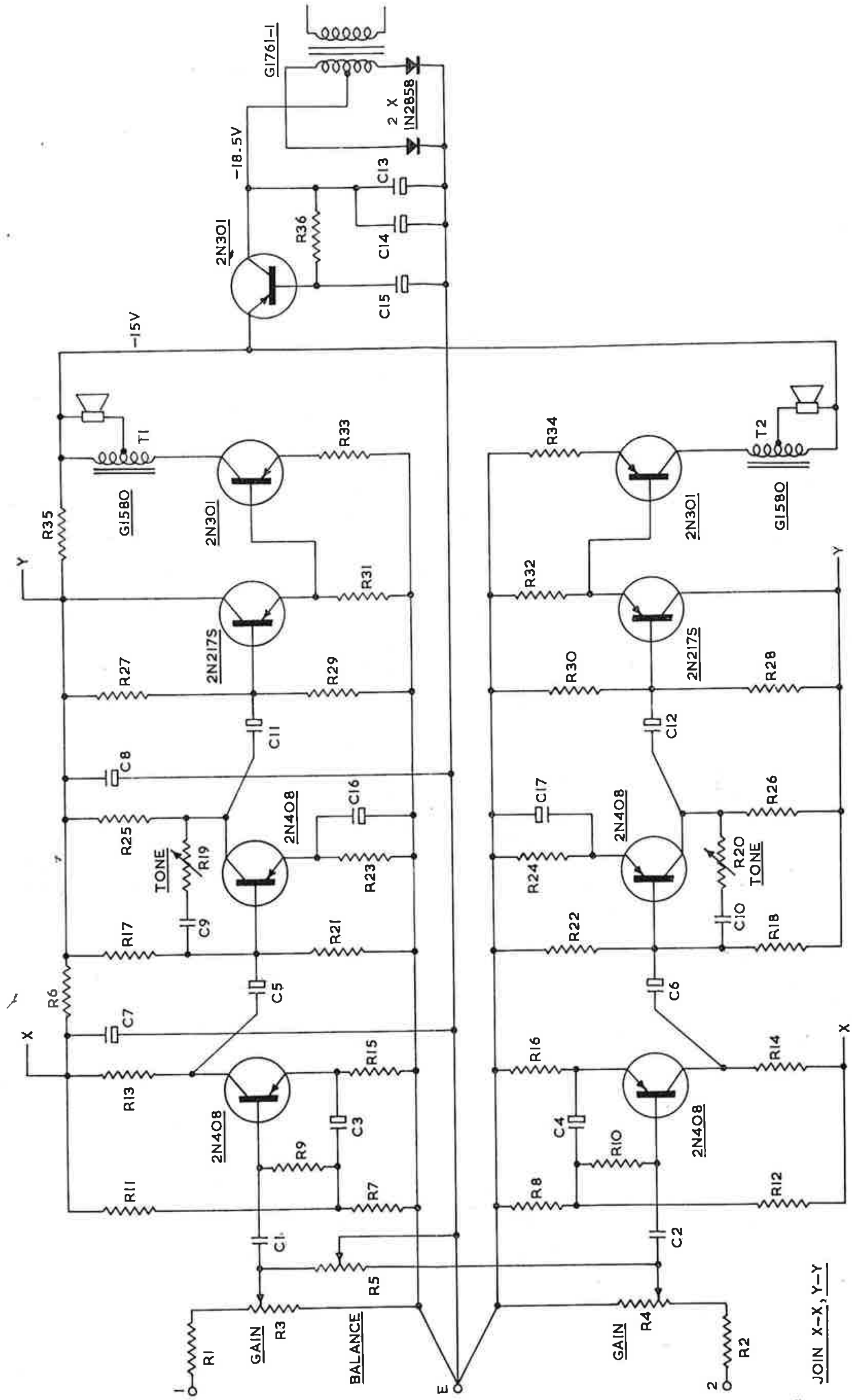
The power supply for this amplifier uses two 1N2858 silicon diodes in a full-wave rectifier arrangement with a capacitor input filter. A dynamic filter is used to ensure low noise and hum level, and uses a 2N301 power transistor in the familiar arrangement. Voltage at the input to the filter is of the order of 18.5 volts, whilst the collector supply voltage at the output of the filter is approximately 15 volts. Collector supply line decoupling is common to both channels in this amplifier. No instability arises from this arrangement, and it results in a small saving in components.

We have used the dynamic filter several times lately, and have received several questions about it. In some cases readers have attempted to use the device elsewhere and have not obtained the results they wanted. It may therefore be wise to mention one or two important points about this circuit. In the first place, the transistor must be so biased, by virtue of the collector-to-base resistor, that appreciable gain is obtained, as the effective output capacitance is the base-to-ground capacitor value multiplied by the gain of the transistor. This means that a loss of voltage slightly higher than this bias value will be involved, and must be allowed for in the design of the power supply and transformer.

A second point is that the value of bias used must at least equal the peak-to-peak value of the ripple present on the rectifier voltage applied at the input to the filter. This factor may mean



Method of providing a heat sink for the two 1N2858 silicon diodes. See text.



Circuit diagram of the "Economy Five" Unit, showing both channels and the power supply.

PARTS LIST

Semiconductors

3	AWV transistors, 2N301.
2	AWV transistors, 2N217S.
4	AWV transistors, 2N408.
2	AWV silicon diodes, type 1N2858.

Transformers

T1, T2	Output choke. M.S.P. sample type number G1580.
T3	Mains transformer. M.S.P. sample type number G1761-1.

Resistors

All resistors are ½ watt, 10% tolerance, except where otherwise stated.

R1, R2	270 K ohms.
R3, R4	Dual ganged potentiometer, 1 M ohm log.
R5	Potentiometer, 2 M ohm, linear.
R6	2.2 K ohms.
R7, R8	4.7 K ohms.
R9, R10	5.6 K ohms.
R11, R12	180 K ohms.
R13, R14	2.2 K ohms.
R15, R16	1.2 K ohms.
R17, R18	68 K ohms.
R19, R20	Potentiometer, dual ganged, 100 K ohms log.
R21, R22	10 K ohms.
R23, R24	390 ohms.
R25, R26	1.8 K ohms.
R27, R28	10 K ohms.
R29, R30	1.8 K ohms.
R31, R32	470 ohms.
R33, R34	1 ohm, 2 watt, wirewound.
R35	560 ohms, 1 watt.
R36	330 ohms, 1 watt.

Capacitors

C1, C2	0.1 μf, ceramic, 25 vw.
C3, C4	2 μf, 12 vw, electrolytic.
C5, C6	25 μf, 3 vw, electrolytic.
C7	75 μf, 12 vw, electrolytic.
C8	50 μf, 12 vw, electrolytic.
C9, C10	0.0047 μf, paper.
C11, C12	25 μf, 12 vw, electrolytic.
C13, C14, C15	1000 μf, 25 vw, electrolytic.

Miscellaneous

Three type 7001 heat sinks, 14-gauge aluminium panels, matrix board and pins, mains toggle switch, knobs, input and output connectors, miscellaneous hardware.

that the bias value may need to be increased still further (over the bias for reasonable gain) in order to set up this condition. This in turn would mean further loss in the output voltage of the filter.

When the bias voltage has thus been determined, the value of the collector-to-base resistor can be decided. In some cases the base is connected into a potentiometer consisting of two fixed resistors, connected across the unfiltered supply. The principle of operation is the same in each case. When the values required have finally been fixed, it is necessary to ensure that the permissible dissipation for the transistor used is not exceeded. The dissipation figure is simply arrived at by taking the product of the voltage drop across the transistor and the current flowing through it. Where small currents are concerned, as for example in supplying a preamplifier, a smaller transistor than the 2N301 could be used, within its dissipation ratings.

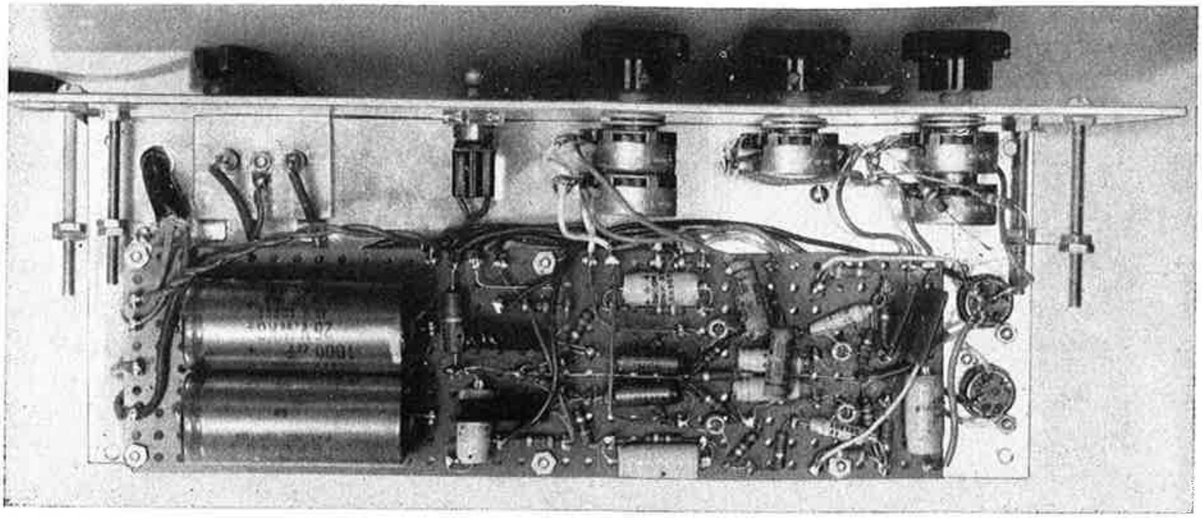
Construction

The construction of this amplifier is very simple. A large portion of the circuitry is made up on a section of matrix board, and can be completely assembled before incorporating it into the completed unit. The metal work involved is very small, consisting of two 14-gauge aluminium plates suitably drilled, and held together with spacers.

The first step in making up this unit is to assemble the matrix board section. The front and rear plates should be cut and drilled as necessary, with all holes completed, and the mating of the front and rear plates checked before proceeding further. The rear plate is then assembled completely, leaving only the front panel with controls to be added.

Because the three 2N301 transistors are operated in Class A, there is a continuous and fairly high dissipation in them, and it is necessary to use fairly substantial heat sinks to avoid thermal troubles, particularly when the ambient temperatures may be high. Three type 7001 4″ x 4″ heat sinks are used. Extra holes are drilled in the ribs of these heat sinks so that they can be bolted to the rear plate, with the third one bolted to the other two, as shown in the photographs. This makes a neat and space-saving arrangement, and also places the sinks with the fins disposed vertically, so that maximum efficiency is obtained. Care must be taken if this unit is enclosed in a cabinet that adequate air access is available to the surfaces of the three heat sinks.

Other units mounted on the rear panel are the mains transformer, the two output chokes, input



A further view of the unit, showing the front panel unscrewed and laid aside to expose the assembly. A close-up view of the component assembly on the matrix board.

and output connectors, the two 1N2858 silicon diodes in heat sink, and, of course, the matrix board preassembled. An accompanying diagram shows the method of heat-sinking the two 1N2858 diodes. In this case, the mica insert and insulation for the centre clamping screw should be used, although the supply is a grounded positive one. The mica can, however, be very thin, or even a thin sheet of paper.

The reason for this is to avoid earth current troubles which may otherwise arise from the fact that the chassis is carrying the supply current. The positive lead from the two rectifiers should collect the earthy sides of the filter and decoupling capacitors, and then be grounded at the earthy input terminal. Grounds for the two channels of the amplifier should be run separately and then grounded at the same point. This is shown in the circuit diagram, and should be followed.

When the assembly of the rear plate has been completed, the four controls may then be mounted on the front panel and the whole assembly then completed. It will be found that if the front and rear panels are brought together as shown in one of the photographs, the inter-connecting leads can be easily carried across. At the same time, the two panels can afterwards be opened up without disconnecting the leads, should access be required.

On such a simple unit as this there is little to be said further on the question of construction, except that silicone grease or equivalent should be applied to the mica washers under the 2N301 transistors to decrease the thermal resistance across the transistor to heat sink junction. It could also be applied in the heat sink for the rectifier diodes.

If a further simplification of the circuit is required, it would be possible to delete the balance control and so save one potentiometer, if the volume control were made a dual concentric control instead of a ganged control. This would permit separate adjustment of gain in each channel to achieve balance. Whilst a similar control could be used in the tone control position, there is little to be gained, and it could lead to some rather peculiar results, and is therefore not recommended.

Performance

The rated power output per channel of this amplifier is 2.5 watts music power, making a total of 5 watts for the two channels. The overload characteristic is gradual up to output powers of 5 watts, which means that even if the amplifier is overloaded, as can happen for short periods with low-power units, the objectionable effect of the overloading will be minimised. At the normal listening levels for small rooms in private houses, this amplifier will provide pleasant reproduction of recorded music.

The frequency response of this amplifier is surprisingly good for a simple unit, measuring ± 1.5 db into a resistive load over the frequency range of 50 cps to 15 Kc. The bass end response is down 6 db at 30 cps.

On older records, and with speakers capable of appreciable response over 10 Kc, the extended high-frequency range may be undesirable. The top-cut type tone control has a crossover point at about 1 Kc, and provides a maximum cut of 20 db at 10 Kc. This should cater adequately for older records and those with poorer recorded quality. The response figures were measured at the 1 watt level, as is customary.

The noise level also in this amplifier is good for a simple unit, mainly due to the use of the dynamic filter. The measured noise figure on the model was better than 60 db down on the rated power output of 2.5 watts. Crosstalk between channels is of the order of 40 db down when one channel is driven to the rated power output; this is more than adequate. Because the amplifier is intended for use with a crystal pick-up, no equalization has been provided; the recommendations of the pickup manufacturer should, however, be observed and followed. A high-level pickup of the "Ronette" or similar type should be used.

The sensitivity of this amplifier is 400 millivolts for the rated output of 2.5 watts, and 200 millivolts for an output of 1 watt. This is adequate for the types of pickup mentioned. In fact, with some types of pickup, the input may be sufficient to overload the amplifier at very low settings of the volume control. If this type of trouble is experienced, increase the value of the input series resistors R1 and R2 until the trouble is under control. These resistors may be increased to any reasonable value as required.

IRE GOLDEN ANNIVERSARY

The golden anniversary of the Institute of Radio Engineers (U.S.A.) was celebrated at a banquet in New York on 28th March last. On this occasion, Mr. David Sarnoff, Chairman of the Board of the Radio Corporation of America, addressed the gathering.

Mr. Sarnoff recalled the founding of the IRE, when "a venturesome trio of pioneers" met in 1912 in a restaurant in New York for that purpose. Continuing, the speaker recalled:

"Those of us who subscribed to the Institute's first declaration of purpose—'To advance the art and science of radio transmission'—were moved primarily by a vision of what this interplay of electrical and magnetic forces could mean to human progress. Even with the primitive instruments of that day, tapping out coded messages, we sensed a power to convey men's thoughts, voices and ultimately their images, across the barriers of space and time. We conceived the IRE not merely as a forum for the dissemination of new principles and concepts, but as a forge in which we could test, mould and temper the character of our infant technology in an atmosphere of free scientific enquiry."

"In a personal sense I can relate the growth of our technology to two events—one at each end of the 50-year span. In 1912, as the IRE was being formed, the S.S. 'Titanic' struck an iceberg and was sinking in the Atlantic some 1,500 miles from our shores. As the wireless operator at the Marconi Station on the roof of the Wanamaker Store in this city, it took me 72 hours, with the equipment then available, simply to receive the news of the disaster and the names of the survivors."

"Last month, using modern communications equipment, we were able to maintain almost continuous two-way contact with an astronaut who travelled 81,000 miles in space in less than five hours—about the same length of time it took me to travel between my home in New York and Washington, D.C."

"On that day I happened to be travelling by train to a White House meeting with President Kennedy, and through the media of home television, car radio, pocket radio and hotel television, I was kept fully informed on Colonel Glenn's epic journey. Listening to my pocket radio, I recall walking from my compartment to the dining car at the other end of the train. In the few minutes that this required, Colonel Glenn flew from the Hawaiian Islands to the Pacific Coast, a distance of some 2,500 miles."

"Such is the measure of progress in communications and flight made in the fifty years of IRE's life."

After some further recall of the early days of the IRE, Mr. Sarnoff went on to discuss the future, and proposed a Community of Science to guide and co-ordinate scientific endeavour for the benefit of all. The speaker showed the great avenues open for effort of this kind, and specified five broad categories of research ranging across the natural laws of life, matter and energy, and involving some of the most critically pressing human and physical problems of our time.

Genetics and Heredity

"We have begun the assault on the innermost mysteries of the life process—decoding the nucleic structure of the living cell, its activities, differentiations, and transmitted characteristics. Knowledge of these basic life functions might make it possible ultimately to alter or modify cellular structures. This could lead in time to the elimination of viral or bacterial diseases, and conceivably to more useful strains of animal and plant life."

Communications and Space

"In our own area of primary interest, communications, we are now in the planning and early development stage for a cosmic system of interconnected high-level synchronous satellites, low-level satellites, ground stations and networks. Such a system will enable us to furnish every type of communication to every place on earth, to space vehicles and to the planets beyond. Whenever man ventures from this planet, science is challenged with the supreme task of providing him with the means of seeing and talking with his fellow men wherever they may be."

"Another area of infinite promise for scientific collaboration in this general category is weather control. The success of the four 'Tiros' television weather satellites has already indicated the possibility that we can vastly strengthen the defence of person and property against the turbulance of the skies and the seas."

Conversion of Saline to Fresh Water

"Two-thirds of the peoples of the earth live in areas that are water-starved. For millions of them, the presence of a few feet of water spells the difference betwen life, bare existence or death. President Kennedy has said (that this problem) is as important as landing on the moon."

New Sources of Food

"Barely one-sixth of the world's people are well fed, and nearly half exist in a state of subnutrition or malnutrition. In the areas where food deficiencies are the greatest, the rate of agricultural production has been the slowest. In twenty years the population of the earth will increase by one billion, and forty years from now it will total six billion. For every plate of food on the table today, there must be two plates by the year 2000, and most of that second plate can come from the world's oceans."

"Acre per acre, the oceans can sustain at least as large a plant crop as the land; yet, the harvest of the sea today provides less than one per cent. of the human diet. The oceans offer an immediate challenge to improve food supplies by transforming fishing from a nomadic pursuit to an organized farming activity, including the scientific processing of highly nutrient algae and plankton for food purposes."

New Sources of Energy

"Research in atomics, electronics and other fields is now providing us with the means to convert solar energy, fossil fuel energy and atomic fission energy, directly into electric power. And through further research we shall ultimately learn how to make practical use of nuclear fusion energy. When that day comes, we shall be able to tap the limitless energy sources in the oceans. When we learn how to convert all forms of matter into energy for practical purposes, we will have at our disposal the maximum force in Nature."

In conclusion, Mr. Sarnoff reminded the gathering that four centuries ago, Francis Bacon said: "Knowledge is Power." At no time in history has this been more true.

NUVISTOR TWO-METRE TRANSMITTER

By R. M. Mendelson, W2OKO

(RCA Electron Tube Division)

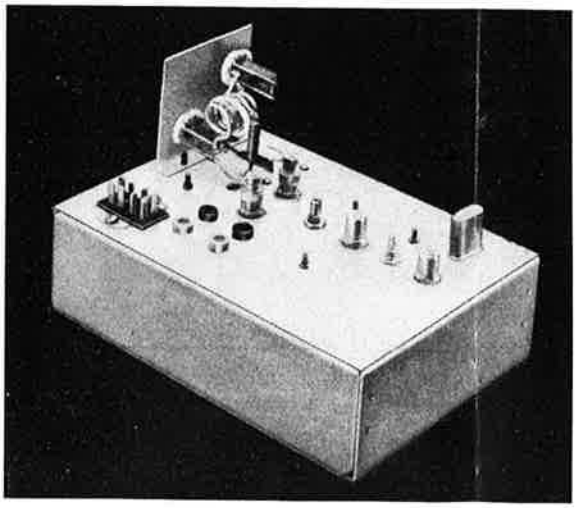
Announcement of a new valve type usually starts the construction-minded "ham" searching for ways to take full advantage of its improvements over older valve types. And when a whole series of new types, such as the RCA nuvistor line is introduced, the experimental possibilities become almost limitless.

To date, articles such as this one on nuvistor applications from RCA have been concerned solely with receiving circuits. (Consider the nuvistor two-metre converter, printed in "Radiotronics" for March 1962, and the nuvistor pre-amplifier, printed in "Radiotronics" for December 1961.) Can the amateur make good use of these same receiving valves in low-power transmitters? The answer is "yes." Nuvistors are ideal for miniaturized vhf mobile or fixed-station transmitting operation.

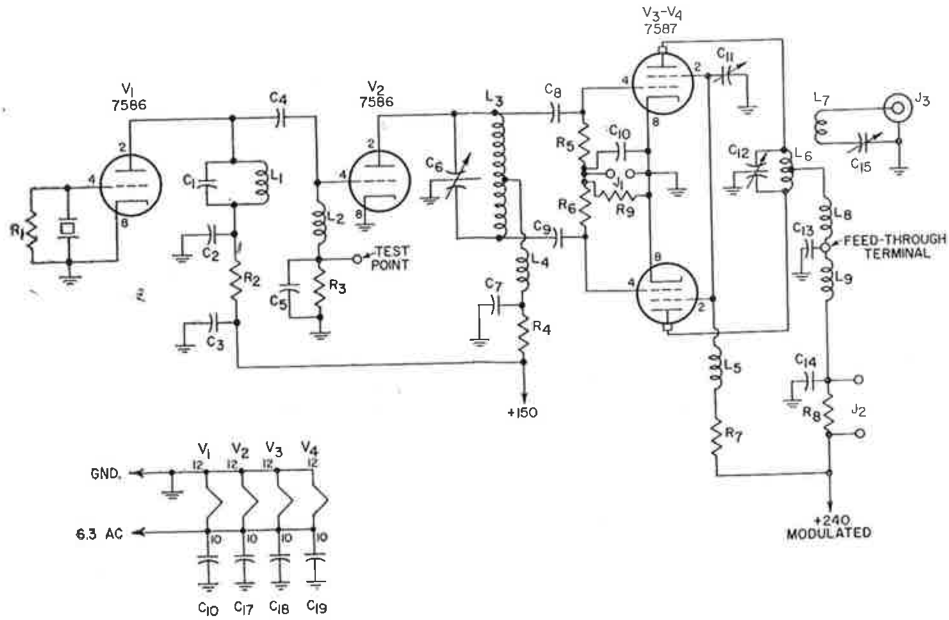
These valves have high plate dissipation ratings for their small size; they are easily usable up to 400 megacycles; and they have the rugged construction required for mobile operation.

The transmitter featured here points up the versatility of nuvistors, and how easily they may be put to work as transmitting valves. A 7586 nuvistor triode is used in a conventional overtone crystal oscillator at 48 Mc. Unnecessary loading of the oscillator is prevented by operating the valve with no frequency multiplication.

The second stage 7586 triples the frequency to 144 Mc, and provides the drive to the final stage. A pair of 7587 nuvistor tetrodes used in the final amplifier can be operated with a power input of up to 7.5 watts. The very low driving power for these valves is easily supplied by the tripler



Top view of W2OKO's two-metre transmitter, designed around two 7586 nuvistor triodes and two 7587 nuvistor tetrodes.



Schematic diagram of the two-metre transmitter.

PARTS LIST

Valves

2	Nuvistors 7586, with sockets.
2	Nuvistors 7587, with sockets.

Capacitors

C1	30 pf, ceramic.
C2, C3	0.01 μf, ceramic.
C4	50 pf, ceramic.
C5	500 pf, ceramic.
C6	2.7 to 10.8 pf "butterfly" air capacitor, or equivalent.
C7	500 pf, ceramic.
C8, C9	20 pf, ceramic.
C10	500 pf, ceramic.
C11	7 to 45 pf, ceramic trimmer.
C12	As for C6.
C13, C14	500 pf, ceramic.
C15	3 to 32 pf, ceramic trimmer.
C16-C19	500 pf, ceramic.

(Exact replacements for the trimmer and tuning capacitors may not be available in Australia; in this case the nearest values should be used. No "ham" will find any trouble here.—Editor.)

Resistors

R1	100 K ohms.
R2	5.6 K ohms.
R3	15 K ohms.
R4	5.6 K ohms.
R5, R6	6.8 K ohms.
R7	27 K ohms.
R8	100 ohms.
R9	1 K ohm.

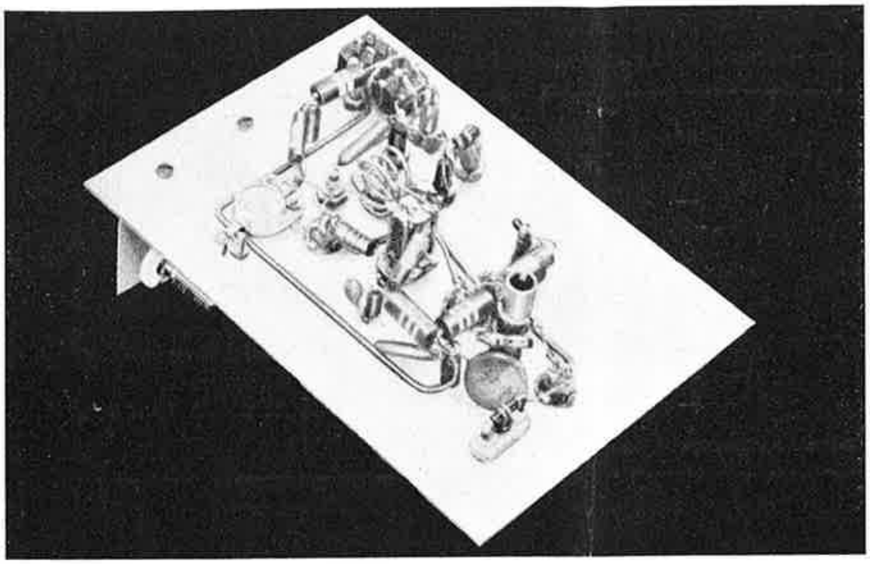
(All resistors are ½ watt rating, 10% tolerance.)

Inductors

L1	4¼ turns number 26 AWG enamelled wire, wound on a ⅜″ slug-tuned former, spaced to the wire diameter.
L2	RF choke, 7 microhenries.
L3	4 turns number 16 AWG tinned copper, air-spaced, wound to ½″ internal diameter, ⅝″ long, tapped at the centre.
L4, L5	RF choke, 1.7 microhenries.
L6	5 turns number 14 AWG tinned copper, air-spaced, wound to ½″ internal diameter, ⅝″ long, tapped at the centre.
L7	1 turn number 14 AWG tinned copper, insulated with sleeving.
L8, L9	RF choke, 1.7 microhenries.

Miscellaneous

Brass or copper plate, aluminium cover, power socket and aerial socket, crystal socket ,48.0 to 49.33 overtone crystal, miscellaneous hardware.



Bottom view of the author's two-metre transmitter, showing the component layout.

stage. Screen-grid neutralization is used, but adjustment of this feature is not critical.

An accompanying figure shows the circuit diagram of the complete transmitter. Table J shows typical operating voltages and currents.

Construction

The entire transmitter is built on a 5″ x 7″ piece of copper or brass, and an aluminium chassis is used as the base cover. The size of the plate is not critical, and the accompanying figures show that some reduction in size could be effected if necessary. The parts layout shows the arrangement that ensures short leads and correct parts orientation. A small bracket is used in mounting the final tank circuit, and a sketch of this is also shown.

Because of their small size, nuvistor sockets are clamped, not bolted, to the chassis by bending two lugs in the socket. After the chassis hole has been drilled, two notches for the lugs are hand-filed to ensure a tight fit of socket to chassis. For rf grounding, both socket lugs are then soldered to the chassis plate.

Adequate rf bypassing is applied to all critical parts of the circuit. Because the reliability of nuvistors makes it unnecessary to retune the transmitter every time it is put into service, a permanent meter is not required. Instead, two pairs of jacks are used to plug a temporary meter into the grid or plate circuits of the final stage. An eight-contact power socket used on the model unit allows for future development, but a smaller socket could be used if desired.

The plate cap connectors for the nuvistor tetrodes are made by bending a piece of piano wire into a tight-fitting one-turn coil. To keep lead inductance low, the leads to the plate tank capacitor are made from ¼″ wide copper strip. The one-turn output link is covered with a piece of plastic insulating sleeving and tightly coupled to the final tank coil.

Adjustment

This transmitter is very easy to tune. If all the coils have been wound to specification, there should be no trouble in finding the proper settings of the coil slug and of the tuning capacitors. Of course, a grid-dip meter makes tuning even easier.

To ensure that the oscillator will start every time voltage is applied, follow this procedure: Plug-in only the first 7586 and the crystal; apply heater voltage and the 150-volt plate voltage, and allow the valve to warm up. With a high-impedance voltmeter applied to the test terminal, adjust the slug in coil L1 until oscillation starts (shown by voltage at the test point). Adjust for maximum voltage, then back the slug out to give a slightly higher tuned frequency. A reading of about 10 volts should be obtained.

Next plug in the second 7586 and the two 7587's. Do not apply plate and screen-grid voltage to the final stage as yet. Plug a 5 ma meter into the grid circuit jack J1, and tune C6 for maximum grid current. A reading of between 2 and 3 milliamps should be obtained.

Then rotate the plate tuning capacitor C12 through its entire range; there should be very

TABLE I: TYPICAL OPERATING VOLTAGES AND CURRENTS

(All voltages are measured with respect to ground and may vary by 20%)

Voltage to ground	V_1	V_2	V_3, V_4
Plate	100	86	240 Volts
Screen Grid	—	—	75 Volts
Control Grid*	-9.5	-9.2	-15.1 Volts
Cathode	0	0	0 Volts
Currents			
Control Grid Final	—	—	2.3 Milliamperes
Screen Final	—	—	5.0 Milliamperes
Plate Final	—	—	32.0 Milliamperes

*Measured with vacuum-tube voltmeter. A low impedance meter will affect the circuit values.

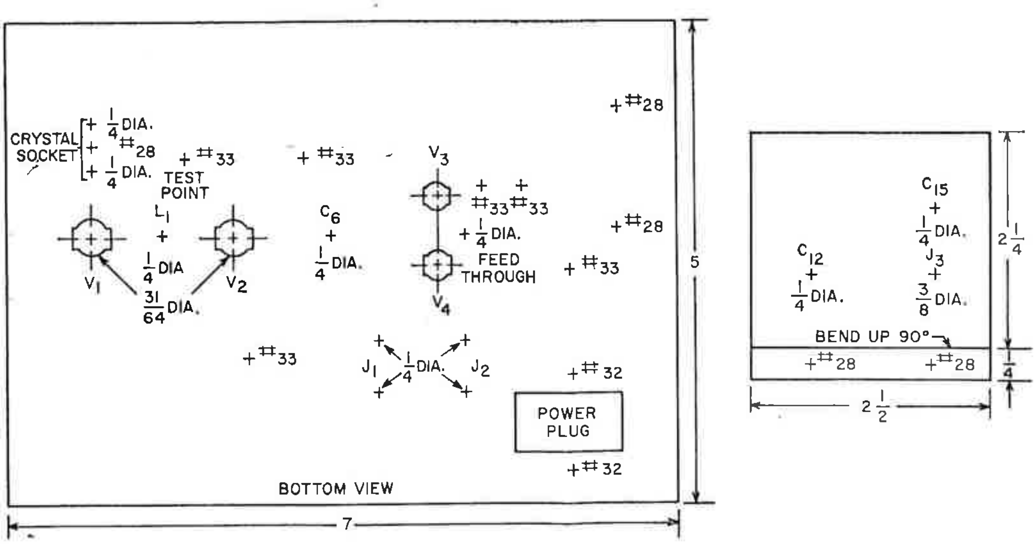
little effect on the grid current reading. In turn, slowly adjust the screen-grid bypass capacitor C11 while rotating the plate capacitor until a point is found at which the plate capacitor has no effect on the grid current. This adjustment is not critical.

Now that the final stage is neutralized, plug a 50 ma meter into the final plate circuit jack J2; attach the antenna or dummy load, and apply 240 volts to the plate and screen-grid circuit. Tune the plate tank for minimum plate current with capacitor C12. The tuning capacitor C15 in the output link is for balancing out feedline reactance to the antenna, and should be adjusted for best output. (Use a standing-wave-ratio bridge, a field-strength meter, or even signal reports from another station.) When fully loaded, a plate current of about 32 ma should be obtained.

Conclusion

Only after using this transmitter will the operator realize the merits of nuvistor ruggedness and reliability. Long periods of operation, or even long periods of idleness, have no effect on the nuvistor transmitter. It will stay tuned and ready to work well whenever needed.

(With acknowledgments to RCA)



Bottom view of the chassis plate, and diagram for the final stage mounting bracket. These sketches approximately half full-size.

Feature Book Review

"FORTY YEARS OF RADIO RESEARCH"

An autobiography by Dr. George C. Southworth, Bell Telephone Laboratories Inc., Ret. Published by Gordon and Breach, Science Publishers, Inc., New York, 1962

Dr. Southworth, like many scientists and engineers, toiled for many years to make a substantial contribution to the radio art and to mankind in general; yet, like them, he is known only to a few. It is fortunate that men of this calibre find their reward in accomplishing what they set out to do, rather than in the glare of more public recognition. And yet Dr. Southworth's major contribution is familiar to all of us, for he is "the father of the waveguide." It has been said with some justice that George Southworth did as much for shortwave and microwave radio as Marconi did for longwave radio.

Dr. Southworth won his Ph.D. from Yale in 1923, and at the time was one of a very small handful of formally educated physicists turning their attention towards electromagnetic phenomena. Radio at the time was in its infancy; in fact, the author tells us that in 1910, experts dogmatically stated that the frequency barrier for electromagnetic radiation was 1 Mc. Today the figure is around 100,000 Mc temporarily, and Dr. Southworth's work contributed in no small degree to push the frequency frontier back so far.

Individual Versus Team Research

In his highly individualistic way, Dr. Southworth describes and comments on the change over the years in the methods of conducting research. The change has been from the individual scientist working away on his project to the large teams of today, highly organized on to certain paths of enquiry. One suspects that he did not entirely approve of the replacement of the productive highly individualistic researcher by the proportionately less productive teams of today. To some extent, at least for many years, he ploughed a lonely furrow, beset by every kind of difficulty. It is therefore a tribute to his courage and determination that in spite of almost insurmountable natural and human obstacles, he achieved so much in his lifetime. The history of the radio art is like a long corridor full of doors: as soon as one door opens, another of a different pattern is revealed just behind it. Marconi and some of the early experimenters assumed that radio propagation was a simple matter; Dr. Southworth and other researchers found that this was far from the truth.

An Early "Ham"

Long before anyone realised that the word "Ham" was to find itself written into the language, the author of this fascinating tale relates how, as a young man in the 1920's, he purchased audio tubes from a company founded by their inventor, Dr. Lee DeForest (Dr. DeForest died only last year). These audio tubes were used by George Southworth, then a college student, to construct his own amateur radio station, one of the first, if not the first, ever licensed in the U.S.A.

Hard Work and Inspiration

This book reminds us once again that however glamorous a certain activity may seem, at least to the outside observer, the successful completion of any major undertaking is in fact a matter of hard work and application. Edison defined genius as a combination of 10% inspiration and 90% perspiration, and that's just about the way it is.

Dr. Southworth tells how at one period, convinced that he was right, but with no approval at that time to pursue the matter further, he carried work on clandesinely. This later proved embarrassing, because a time came when proof of his contentions was available, and the matter had once again to be brought out into the light of day. It is to the everlasting credit of those responsible that the author does not have to relate that they failed to rise to the occasion.

Two vignettes of that period serve to illustrate the matter more clearly. Speaking of the difficulties of getting approval to carry on "guided wave" experiments during the great depression, the author explains that at that time most engineers thought that the work had no future. At another time, when his work was being examined by management, an eminent mathematician who was called upon to comment on Dr. Southworth's theories stated: "I have arrived at a tentative conclusion that Southworth's proposed system of transmission is not practical." Shortly afterwards, the mathematician found a mistake in his own calculations.

Parallel Developments

The waveguide as we know it today could obviously not be useful without the parallel devices to go with it, particularly the necessary electron valve and allied devices. In many cases, development of the waveguide was delayed until valves capable of operating at higher and higher frequencies became available. Much of the early experimentation was carried out using Barkhausen oscillators. At the same time, to bring the waveguide into full use, a complete set of circuit elements had to be evolved, such as coupling devices, tuning devices, matching devices, and the like.

By the time the last war was coming closer, the techniques on which Dr. Southworth had been working for so long were becoming accepted, and of course the impetus of war finally overcame all obstacles. One of the interesting sidelights describes a visit by English scientists to gain more knowledge of guided waves and similar techniques. The author describes how, at the same time, they brought with them data on the cavity magnetron, an outstanding invention then being developed in England.

There is no doubt that the combination of these two elements played a key role in making allied radar devices such an outstanding success. It is a matter of history that the allies were very superior in this field, much of the development in Germany having followed the line of high-power klystrons.

Origin of the Guided Wave

Possibly one of the most striking facts to come out of this book is the story of how the author first met guided waves. Apparently he was at that time carrying out some work on the dielectric properties of water (this alone shows how early in time he was), and in connection with this work he set up troughs of water through which he was to propagate waves. It was found that the output of the detector used to receive the waves propagated through the water was not giving the anticipated results. Further investigation showed that this was due to waves reflected back and forth at various angles of incidence across the width of the tank or trough, in the manner now familiar to us all.

As this phenomenon was a nuisance to his experiments, the author modified his detector so as to eliminate the unwanted effect, and finished his work. Like all true researchers, however, the unexplained stayed in his mind until, several years later, the opportunity came to find out just what had been happening in his tanks of water. We all know the results. His theory held good and was vindicated, and a whole new technique came into being.

Out of these waveguide techniques came three well-defined and useful applications: (1) a new medium for propagating electromagnetic wave power from one point to another, (2) a new tuning technique that became effective at frequencies beyond the limit of conventional inductors and capacitors, and (3) a series of new antennas, some even more directional than searchlights.

Summary

It may be easy to think that this story is solely the story of the waveguide. This is not entirely true, for the author played an important part in many other fields of endeavour. But all famous men are remembered for one thing in particular, and that is the case here. It all makes a wonderful story, told in the most human way.

A REASSESSMENT OF STEREO

By B. J. Simpson

This article attempts to evaluate stereo reproduction in the light of some years of living with it, and free of all the initial claims that were made for it. An attempt is also made to explain some of the physical and psychological factors involved in listening to stereo reproduction.

Introduction

Stereo, like many other advances that are offered to the buying public, was introduced with a flurry of sales talk, some of which was based on fact and some of which was perhaps a little optimistic or even slightly misleading. Some of the more important factors were never mentioned, possibly because they were at that time understood only by a few, or because they needed a consideration and explanation that could not be condensed into a short sales cliche.

This situation was aggravated by the immediate introduction of "demonstration" records designed to show some of the more spectacular but possibly less important aspects of stereo reproduction. We even saw the introduction of records specially "doctored" for stereo. A long exposure to these records produced much the same results as an overdose of spectator tennis, a sense of repletion and a stiffening neck. Like all spectacular demonstrations, the impression created was superficial, and most listeners rapidly tired of listening to table tennis on record, or of having brass bands, railway locomotives and other paraphernalia rush through their lounge-room windows and out the kitchen door.

The result of all this, as far as many people were concerned, was a complete negation of the entire concept, and we can hardly blame them. As far as they could understand, or as far as they were told, this was all there was to stereo. It was only natural that they were reluctant to progress to stereo, especially when one considers the large investment already existing in monophonic equipment. No one changes his investments without good reason, the good reason usually being the hope of gain.

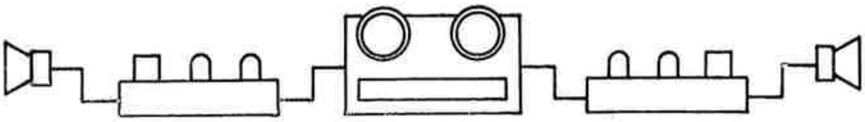
Better Sound?

One of the most frequently heard statements with respect to stereo is "My old mono system still sounds pretty good." One of the most frequently asked questions is "Does stereo produce better sound?" Let us dispose of the first statement first, because that is the simplest to answer. Of course a mono system can sound good; if this were not true it would mean that a large number of manufacturers, engineers and others have been wasting their time for years.

Before the development and know-how of recording techniques made the microgroove record available, the old 78 shellac discs were the last word, and no one could deny that the electrical recording and reproduction of these discs was a great advance on the acoustical gramophone. The vinyl microgroove record has demonstrated its superiority over the shellac disc, mainly in the matter of quality. The stereo disc now offers greater realism. The point is that each system in its time was the best available. So that many mono systems in use today, within the limits of single-channel reproduction, are as good as they reasonably could be. But now something better is available.

On the question of better sound, the answer must be "yes." Many of the advantages claimed for stereo are well known. It is claimed that stereo eliminates the keyhole effect present to some degree in mono systems. It is claimed that stereo provides greater realism by reproducing the spatial placement of a sound source. It is also claimed that stereo produces a "fuller" sound. All these claims are quite valid to a greater or a lesser degree.

But what has been widely publicised about stereo to date is far from being the complete story. So far is it away from the truth of the matter that it is now possible to make a rather provocative statement, to the effect that the elimination of the point source of sound and the illusion of directivity are two of the less important benefits of stereo. This argument will be developed further later in this article.



Before we leave this aspect of the subject, it may be interesting to remind ourselves of one or two anomalies, the explanation of which follows also from the argument to be developed. One fact that has been known for a long time, even pre-stereo, is that it is often possible to improve mono reproduction by using two or more speakers with some spatial separation, instead of one speaker only. The other fact is allied to this one, in that mono records frequently sound better when played on a stereo system. We must also remember that a stereo record played through a stereo system will usually produce better sound than a mono record of the same subject played through a mono system, even when the subject is in effect a point source, e.g., an unaccompanied solo vocalist. This fact alone shows that stereo can offer better sound and that the spatial location aspect is not the only benefit to accrue from stereo.

Chords and Discords

Sound is a subjective impression resulting from a stimulus of the ear mechanism by variations in air pressure. A special impression is gained when the variation of air pressure is sinusoidal; that is, when we are listening to a pure tone. A further special impression is gained when two or more sinusoidal tones are heard simultaneously. But whilst a pure tone always produces a favourable impression, the mixing of tones can produce either a pleasing or a displeasing impression.

In general, a pleasing impression is gained when the tones mixed have frequencies which are related to each other in ratios of small whole numbers, such as 1:2 and 3:4. Where the component tones have no such relationship, the resulting sound is displeasing. As the number of component tones without simple relationship is increased, the sound becomes just noise. It is possible to regard all sound, both pleasant and unpleasant, as a mixture of pure tones of differing frequencies and various amplitudes.

Simplifying the problem to just two tones, we know that when two tones of differing frequencies are brought together, the two tones modulate each other. The intermodulation produces a beat note, whose frequency is equal to the difference in the frequencies of the two original tones. Where the frequencies of the two original tones have a simple relationship, as mentioned above, they are harmonically related, and the beat note frequency may form simple relationships with the two original frequencies.

Where this happens, all three notes are harmonically related, and the resulting sound is pleasant. This is described as a chord, and chords can, of course, be formed of more than two original tones. It will be readily seen, however, that the more tones we mix together, the more difficult it will be to achieve harmonic relationships throughout both the original tones and the beat notes produced. Where three or more tones are used, the two or more beat notes produced will mix with each other to produce further beat notes, and so on.

When two or more tones which do not have a simple relationship are mixed, the original and beat notes do not have a harmonic relationship. The result is unpleasant, and is called a discord. Frequently such an arrangement produces very low frequency beat notes, resulting from mixing of higher harmonics of the two original tones. These low-frequency beats can be particularly unpleasant when not harmonically related to the original tones.

This mixing of frequencies can take place anywhere along the audio chain. As far as the ear is concerned, it can take place before the sound leaves the amplifier and speaker (intermodulation distortion) or it can take place in the air space between the speaker and the ear. It is this second aspect which is of particular interest in this context. It is important to note that mixing cannot take place once the sounds have been received by the ears. If we set up a system for binaural reproduction, using headphones, sounds heard by one ear cannot interfere or intermodulate with sounds heard by the other ear—there is no cross-modulation between the ears. This is one reason why some enthusiasts like to listen to stereo music on phones, even if the reason is not always understood.

Following this line of thought, the suggestion has been made by C. J. Hirsch (RCA) that it would be possible to write music especially for binaural reproduction (with earphones) which would be discordant, or less fully reproduced, when played through a monophonic system or, to a lesser extent, through a normal stereo system in which mixing can take place in the path between the speakers and the ear.

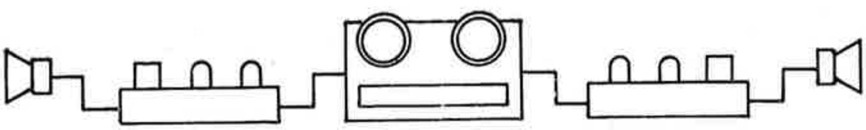
Phasing

In the foregoing section we discussed the mixing of tones and production of chords or discords. Here we are going to discuss a further effect when two or more tones are present at the same time. This effect however is not restricted to tones of different frequencies.

When two identical tones are transmitted through the same medium, whether it be an amplifier channel, the air space in which we are listening, or other medium, they will naturally be heard as a single tone because their frequencies are identical. The amplitude of the note heard however, will depend on their phase relationship. Dependent on the phase difference between them, they can add to or cancel each other. When they are perfectly in phase, the apparent amplitude will be the sum of the two, whereas when they are 180° out of phase, the apparent amplitude will be the difference of the two, and so on. If the two tones are of the same amplitude and 180° out of phase, complete cancellation will take place.

Because of distance differences between the listener and various instruments in an orchestra, it is possible for two instruments playing the same note, even two different instruments, to partially or completely cancel their common fundamental, leaving only the overtones or harmonics. This type of thing is comparatively common in orchestral works.

The problem here is increased because it is not of course possible to attain exact synchronism between different instruments in the instant of commencing a particular note. This means that the note from one instrument may have travelled some distance towards the listener before the same note from a second instrument has been uttered. The possibility of out-of-phase arrival at the listener is therefore very much increased. The problem can perhaps be more readily understood when we realise that one wavelength at the international standard frequency for middle C is a little over four feet. This means that a difference in distance of travel to the listener of about two feet could result in complete cancellation of the fundamental.

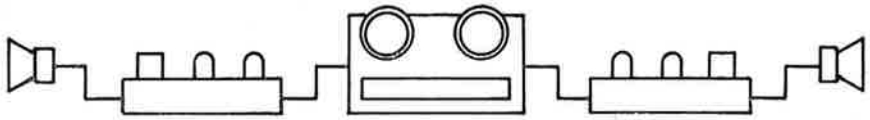


The remarks previously made regarding binaural reproduction with earphones applies here as well of course because this method of reproduction prevents interaction between the two channels. To a lesser extent this would also hold true for normal stereo reproduction. At the same time binaural reproduction cannot eliminate phase troubles in the recording studio any more than it can eliminate tone mixing in the studio. It must be understood that our argument here relates only to reproduction methods.

Reverberation

Reverberation or echo is present to some extent in all auditoria, and forms part of the performance that we hear there. Some halls are notoriously bad in this regard in that the reverberation time is too long, the hall is too "lively," and the echoes seriously interfere with the performance. On the other hand, a hall so damped as to have a very short reverberation time will sound "dead," and the performance will be unpleasing from this factor. There obviously remains a happy medium, which only a few auditoria constructed in recent years with a full understanding of the problems involved are lucky enough to possess.

When we consider some of the factors involved in reverberation alone, the magnitude of the problem of sound reproduction can be seen more easily. Reverberation as experienced at any one point in the hall, and it will vary as the listener moves about the hall, is dependent on the many different paths by which sounds can reach the listener apart from the direct line of travel. Different sounds will arrive in various phase relationships, giving rise to cancellation and augmentation, their frequencies will give rise to beats with notes displaced in time by long echo distances, and so on. Reverberation will vary with the temperature and humidity, because changes in sound velocity will vary the time of arrival and phase of tones arriving at the listening position. The reverberation time will vary according to the number of people in the audience, whether the windows are opened or closed, and similar factors.



But out of all this there remains the fact that when we listen to music, we expect to hear some reverberation. It gives atmosphere, body, realism, colouration, or call it what you will, to the performance, and it is preserved more fully in stereo recording and reproduction than in mono systems. To this extent, realism is added to the performance. Experienced concertgoers will hear in many modern recordings of high quality that familiar "audible hush" of the concert hall which creates the feeling of expectancy, and the familiar sidelights of the performance, horns echoing from the rear of the hall, the dying away of the sound at the end of a statement or movement. In fact, this is one of the things that lifts recorded music out of the can and gives it life.

High Fidelity

It is important not to confuse the two terms "stereo" and "high fidelity." They do not mean the same thing. High fidelity means that the sounds fed into the system are reproduced with a minimum of all types of distortion. Stereo, on the other hand, means the employment of two or more channels in the attempt to reproduce the sound in such a way that the environment in which the recording was made is also reproduced. One term is related to measured quality, whilst the other is related to a subjective effect. Either can exist without the other. It is a fact that many listeners prefer a stereo system of moderate quality to a mono system of the highest quality. The ideal is to have both qualities together.

It is also important to realise that we are now at the stage where technical limitations have just about ceased to exist as far as the reproduction of recorded music is concerned. Fine equipment is now available which can handle the whole gamut of musical frequencies and a dynamic larger than the ear can detect. Stereo was therefore a major step forward in bringing us more sound, better sound and more realism, depending on the point of view. How it does this will now be seen.

Stereo in Action

We have already seen some of the ways, though by inference only, in which stereo has something to contribute. There is no doubt among those who have listened carefully that stereo produces a better or more realistic sound. This applies not only to such works as grand opera, where the spatial concept helps us to follow and identify the performers, but in works where space and direction have no meaning. From this it follows that whilst the spatial illusion is helpful, there is a lot more to stereo than that.

These tests can be repeated very simply by playing a stereo system whilst operating the mono-stereo switch back and forth, covering one ear or moving the two speakers to the same position. On any type of material, once the stereo concept is destroyed in one of these three ways, the general quality, besides the loss of the spatial sense, is degraded. This is largely a psychological property or illusion, as far as the spatial sense is concerned, but there is a deep underlying physiological effect which is just as, if not more, important.

Stereo, by providing reproduction less hampered by phase and mixing problems, brings us a standard of reproduction more complete in both original tones and harmonics, and less prone to the production of discords. In other words, the sound is better because it is "cleaner." It is important to remember that these facts, and not the issue of directivity, decide the better quality of stereo sound. To this extent the directional effect is only incidental, and in fact is significant only on certain types of material.

Stereo, however, has a direct contribution to make to high fidelity. As mentioned already, stereo is not necessarily high fidelity. The lower production of beats with a stereo system does allow us to move further into the highest range of tones with less distortion and fewer discords. In this way, stereo opens the way to better quality reproduction than may be attainable with a mono system. This is another factor which has nothing directly to do with directivity.

It must be recognised that the theoretical ultimate in reproduction is probably binaural listening using earphones. Many enthusiasts are already using this method, but it also has disadvantages. The most obvious one is that the whole concert hall swings as the head is turned. In this case, whilst good quality is obtained, the directional aspect is sometimes a nuisance. For group listening, this method is generally unacceptable for a number of reasons. In this case, stereo offers a good approximation.

Summary

Stereo reproduction has a great deal to offer in the faithful reproduction of recorded music. The largest dividend available is that it opens the way to better overall quality by reducing cancellations and discords throughout the musical range. Because stereo reduces discords, it also allows us to use an extended high register in reproduction with less risk. The directional effects possible are useful only on certain types of material, and are of secondary importance in relation to the general overall improvement in quality.

NEW RELEASES

NEW SILICON RECTIFIERS

A new range of silicon rectifiers in tubular cases with axial leads is announced by RCA. In some cases, insulated-case versions of these rectifiers are also released. The 1N3193 to 1N3196 inclusive are uninsulated types, with PIV ratings of 200, 400, 600 and 800 volts respectively. The first three types have forward current ratings of 750 ma and the 1N3196 500 ma, all at 75°C. The 1N3253 to 1N3256 inclusive are insulated versions respectively of the previously mentioned types. The forward current ratings quoted are for resistive or inductive load; for capacitive load, the forward current ratings are 500 ma and 400 ma.

1N3563

The 1N3563 is a new 1,000-volt silicon rectifier in a miniature insulated tubular case with axial leads. The maximum dc forward current rating at temperatures up to 75°C is 300 ma. This rectifier is designed to meet stringent temperature-cycling and humidity requirements in critical industrial and consumer-product applications.

1N3754, 1N3755, 1N3756

These three diffused-junction silicon rectifiers utilize the JEDEC TO-1 case, and are intended for industrial and consumer-product applications. They have PIV ratings of 100, 200 and 400 volts with dc forward current ratings of 125 ma at up to 65°C. These units offer up to 90% space-saving and improved stability over conventional selenium units.

2N398B

The 2N398B is a new improved version of the 2N398 family of germanium alloy-junction transistors. Among the improved ratings available in this type are a 40% decrease in thermal resistance and a $66\frac{2}{3}\%$ increase in the power dissipation capability.

2N834

The 2N834 is a silicon planar epitaxial transistor primarily intended for computer applications, in very high-speed saturated switching modes. This unit, in the JEDEC TO-18 package, has a typical collector saturation voltage of 0.25 volt at 10 ma collector current, and a storage time of 25 nanoseconds maximum. This transistor meets the mechanical and environmental requirements of MIL-S-19500B.

2N914

The 2N914 is a silicon planar epitaxial unit for use in high-speed saturated logic switching and vhf amplifier applications. This unit uses the JEDEC TO-18 package, and has a maximum collector saturation voltage of 0.7 volt at a collector current of 200 ma.

2N1711

The 2N1711 is a silicon triple-diffused planar transistor for industrial and military applications. The 2N1711 is intended for a wide variety of small-signal and medium-power applications, and utilizes the JEDEC TO-5 package. This transistor has a high minimum gain-bandwidth product of 70 Mc, and is suitable for operation at case temperatures up to 200°C. The planar construction insures exceptionally low noise and low leakage characteristics. Typical saturation voltage at 150 ma collector current is 0.5 volt. Collector to base breakdown voltage with emitter open is 75 volts at 100 ma collector current.

NEW SILICON N-P-N POWER TRANSISTORS

The 2N1700 to 2N1703 inclusive 2N2338 and 2N2339 are six units intended for a wide variety of applications in industrial equipment, such as converters, inverters, choppers and regulator service. These units may be operated at case or mounting flange temperatures up to 200°C. They have collector current ratings ranging from 1 ampere up to 7.5 amperes, and dissipation ratings ranging from 5 to 150 watts. Various case configurations are used according to type.

Editor .... Bernard J. Simpson

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