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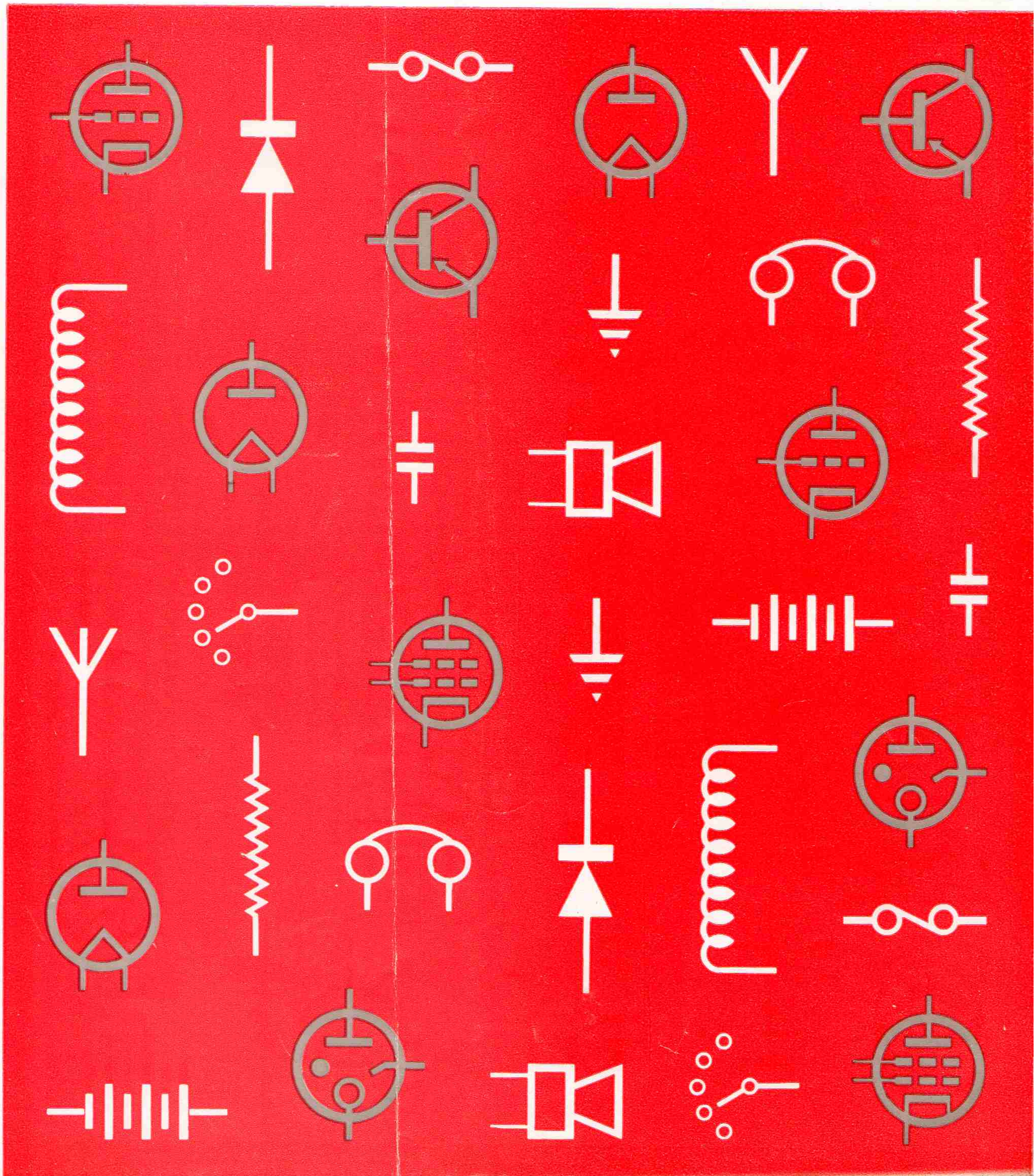

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IN THIS ISSUE

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FUEL CELLS

Devices that convert chemical energy directly into electricity, thus circumventing the inefficiency of the heat engines used to drive electric generators, are now under intensive development.

By Leonard G. Austin, University of Pennsylvania

Civilisation gets most of the energy it consumes from the energy of the chemical bonds in coal, petroleum and natural gas. But in the process of putting that chemical energy to work, it throws most of it away. The energy is first converted, by combustion of the fuel, into heat. The heat is then converted, by several kinds of heat engine, into mechanical energy, which may in turn be converted into electricity. These transformations yield less than half of the original energy as useful work. But the fault does not lie in the energy-converting machines. Though the most modern central power-stations manufacture electricity at an efficiency of only 35 to 40 per cent, the performance of boilers, turbines and generators has been improved over the years until it now approaches the maximum which can be expected from the heat-steam-electricity cycle. Internal-combustion engines have reached a corresponding peak of efficiency at 25 to 30 per cent, and high-temperature gas turbines are approaching their limit at 40 per cent. The ceiling on efficiency is partly imposed by the second law of thermo-dynamics, which dictates the downhill flow of energy throughout the cosmos. At the operating temperatures of heat engines — temperatures set by the strength of materials and the economics of heat transfer — this law decrees that more than half of the original chemical energy must be lost in irrevocably-wasted heat. Further energy is lost to the friction that is encountered in any machine.

With conventional energy-converting technology approaching a dead end, power engineers are seeking ways to bypass the heat cycle and to convert the chemical energy of fuels directly into electricity. The notion is not a new one. In 1839 the English investigator Sir William Grove constructed a chemical battery in which the familiar water-forming reaction of hydrogen and oxygen generated an electric current. Fifty years later, also in England, the chemists Ludwig Mond and Carl Langer developed another version of this device which they called a fuel cell. But the dynamo was then coming into its own, and although research continued spasmodically the difficulties encountered deterred any extensive effort to develop fuel cells. Since 1944, however, the fuel cell has come under active development again, and at least one is now in practical use.

The first voltaic pile and its modern descendant, the dry battery, are fuel cells in a sense; they convert chemical energy directly into electricity. But they use expensive "fuels" such as zinc, lead or mercury that are refined by the expenditure of considerable energy from fossil fuels or hydroelectric power. A true fuel cell uses the basic fuel directly, or almost directly. In theory the fuel cell may approach 100 per cent efficiency in converting the chemical energy of the fuel into electricity; actual efficiencies of 75 per cent — more than twice that of the average steam power-station — are quite feasible.

Fuel cells hold other attractions for contemporary engineering. An artificial satellite, for example, requires a small light battery that can deliver a high electrical output. The fuel cell can meet these specifications from energy compactly stored in a liquid or gaseous fuel and in oxygen, as opposed to the cumbersome plates of an ordinary battery.

In public transportation the electric motor possesses a number of advantages over the gasoline or Diesel engine, including higher speed, more rapid acceleration, quietness and absence of noxious exhaust gases. However, the high capital cost of the electrical distribution system has caused a decline in electric transport during the past two decades. A few battery-powered delivery trucks still operate in some cities, but they suffer competitively from the low power-to-weight ratio of their lead batteries and from the long periods required for recharging. A fuel cell that could operate efficiently on gasoline or oil and could be "recharged" by the filling of its tank might reverse the present trend toward gasoline and Diesel locomotives, trucks and buses. Ultimately fuel cells might make the quiet, non-air-polluting electric automobile a reality.

The realization of these attractive possibilities will require a great deal of development work. To understand some of the difficulties to be surmounted, let us consider the fuel cell in which hydrogen and oxygen combine to produce an electric current and water.

As everyone knows, hydrogen and oxygen burn to produce water. They do so because separately they possess more energy than water and therefore "prefer" to exist in combination. However, at ordinary temperatures and pressures, additional "activation" energy is needed to raise the molecules to the energy state at which the reaction will ignite; this energy barrier ordinarily prevents the reaction from proceeding at room temperature. Activation energy may be illustrated by the following analogy. In a large number of people there may be one man capable of clearing a seven-foot high-jump bar, several capable of clearing six feet, thousands who can jump five feet, and hundreds of thousands who can jump four feet, and so on. Molecules are like that with respect to their individual energy content; only a small fraction of them have high energies at room temperature. If the energy barrier for a reaction is comparable to an eight-foot hurdle, no reaction occurs. Raising the temperature has the effect of increasing the "jumping ability" of the molecules until some can clear the activation-energy barrier. At about 500 degrees centigrade a hydrogen-oxygen mixture will combine explosively, and the chemical energy is converted to heat.

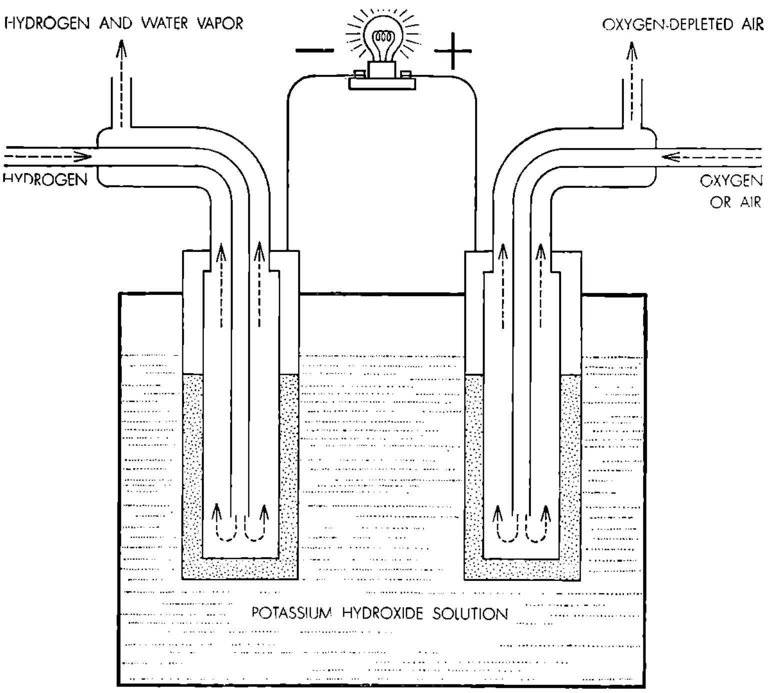
In a hydrogen-oxygen fuel cell essentially the same chemical reaction is made to take place, but the reaction is stepwise at a lower energy of activation for each step. This can be considered as analogous to requiring the molecule to jump several barriers only four feet high, instead of one barrier eight feet high. The reaction thus proceeds quite quickly at room temperature. The cell is also designed so that one of the essential steps in the reaction is the transfer of electrons, from the negative terminal of the cell to the positive terminal, by an electrical connection. The flow of electrons, which is, of course, an electric current, can be used to drive an electric motor, light a lamp or operate a radio. Instead of the chemical energy of the reaction being immediately converted to heat, a large part of it is carried by the electrons, which can give up the energy as useful electrical work.

The cell consists of two porous electrodes separated by an electrolyte, which in this case is a concentrated solution of sodium hydroxide or potassium hydroxide. On the negative side of the cell, hydrogen gas diffuses through the electrode; hydrogen molecules (H_2), assisted by a catalyst embedded in the electrode surface, are adsorbed on the surface in the form of hydrogen atoms (H). The atoms react with hydroxyl ions (OH^-) in the electrolyte to form water, in the process of giving up electrons to the electrode; the water goes into the electrolyte. This reaction is also aided by the catalyst.

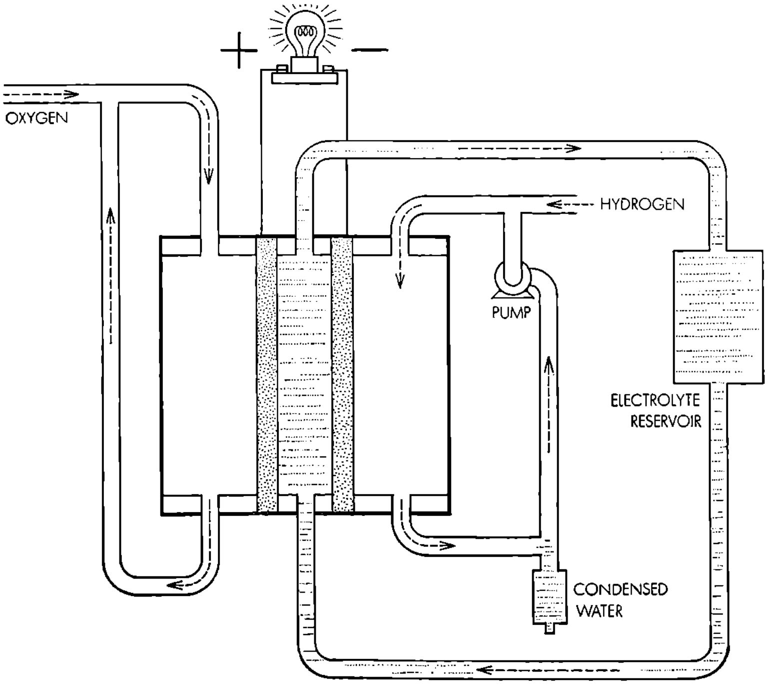
The flow of these electrons around the external circuit to the positive electrode constitutes the electric output of the cell and supports the oxygen half of the reaction. On the positive side of the cell oxygen (O_2), diffuses through the electrode and is adsorbed on the electrode surface. In a somewhat indirect reaction the adsorbed oxygen, plus the inflowing electrons, plus water in the electrolyte, form hydroxyl ions. Here again a catalyst helps the reaction to proceed. The hydroxyl ions complete the circle by migrating through the electrolyte to the hydrogen electrode.

If the external circuit is open, the hydrogen electrode accumulates a surface layer of negative charges that attracts a layer of positively charged sodium or potassium ions in the electrolyte; an equivalent process at the oxygen electrode similarly balances its accumulated positive charge. These electrical "double layers" prevent further reaction between the gases and the electrolyte. The presence of the electrical layers provides the potential that forces the electrons through the external circuit when connection is made.

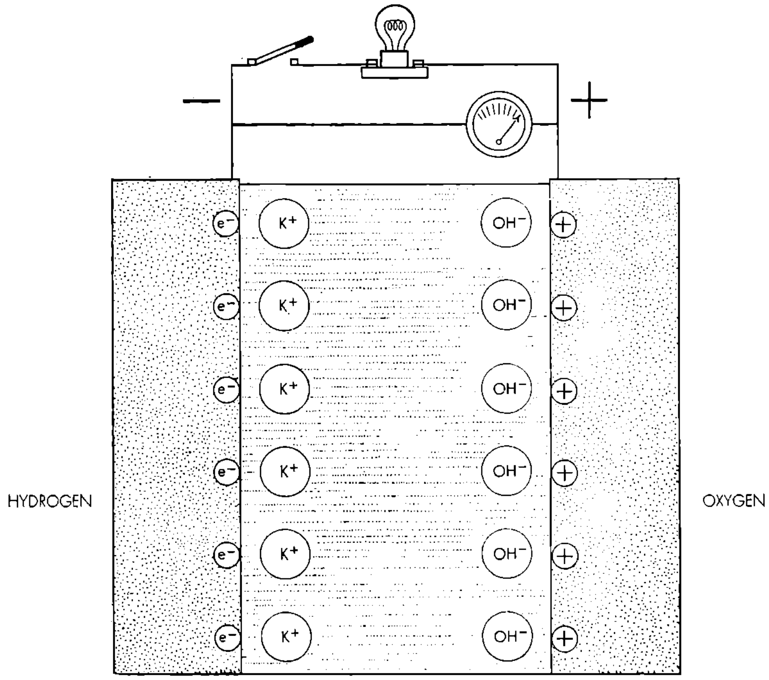
When the circuit is closed and the resistance across the external circuit between the electrodes is high, the reaction proceeds at a moderate rate, and a high percentage of the reaction energy is released as electricity, with only a little lost as



HYDROGEN-OXYGEN FUEL CELL, shown schematically, consists of two porous carbon electrodes (dotted areas) separated by an electrolyte such as potassium hydroxide. Hydrogen enters one side of the cell; oxygen, the other. Atoms of both gases diffuse into the electrodes, reacting to form water and to liberate electrons which flow through the circuit.



ANOTHER HYDROGEN - OXYGEN CELL was developed recently by Francis T. Bacon of the University of Cambridge. His cell consists basically of an electrolyte solution held between two thin electrodes of porous nickel. Gases under pressure diffuse through the electrodes and react with the electrolyte, which is held in tiny pores in the opposite surface.



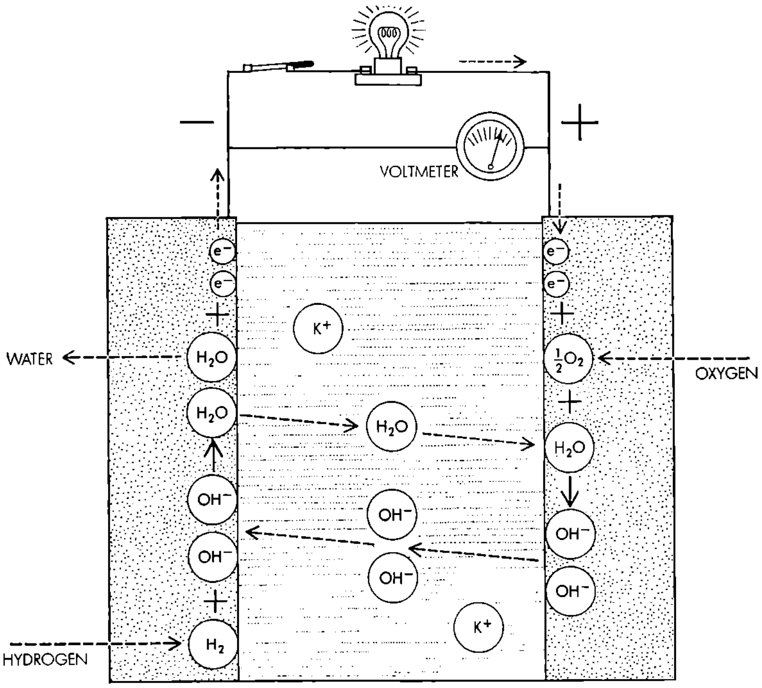
WHEN FUEL-CELL CIRCUIT IS OPEN, the hydrogen electrode accumulate a surface layer of negative charges that attracts positively charged potassium ions in the electrolyte solution. Similarly, the oxygen electrode attracts negative ions to balance its positive charge. These layers prevent further reactions between the gases and the electrolyte.

heat. Part of the energy is expended at all times, however, in driving the chemical reactions over the barrier of the activation energies of the reactions inside the cell, and this energy appears as heat within the cell. The function of the catalysts in the electrodes is to lower the energy barriers, thus decreasing the amount of useful energy that is converted to heat. As resistance in the external circuit goes down, the current flow increases and a rising proportion of the energy is consumed in overcoming the energy barriers within the cell. With the increase in the reaction rate, heat losses go up rapidly. At zero resistance (short circuit) the reaction proceeds so rapidly that it becomes equivalent to combustion, producing only heat. Thus the reaction energy of the fuel cell resembles the energy of water behind a dam. By allowing the water to escape slowly through the blades of a turbine, we compel it to do useful work. If we open the floodgates, the water gushes out without performing any work.

In addition to the expenditure of energy needed to drive the reaction over activation-energy barriers, the fuel cell must consume some energy to force gas molecules through the electrodes to the reaction area, to transport hydroxyl ions from one electrode to the other and to overcome the electrical resistance of the electrodes themselves. These losses reduce cell voltage below the theoretical ideal. A common working standard of voltage efficiency for fuel cells, however, is 75 per cent.

In practice, at the present stage of the art, other considerations loom larger than simple efficiency. For instance, a standard criterion is the power output per cubic foot of cell when the cell is converting 75 per cent of the thermodynamically available energy into electricity. Another important factor is the length of time a cell can operate before its performance falls off due to the deterioration of the electrode or the electrolyte.

In a typical hydrogen-oxygen cell the electrodes consist of porous carbon impregnated with catalysts: fine particles of platinum or palladium in the hydrogen electrode and cobalt oxide, platinum or silver in the oxygen electrode. To prevent flooding of the pores by the electrolyte, which would cut down the active surface, the electrodes are waterproofed with a layer of paraffin wax about one molecule thick. This thin film allows ions and individual water molecules to pass through to the internal surfaces of the electrode, but prevents the water from flooding the pores. To bring the electrodes closer together and thus speed ion transport, the electrodes are typically arranged as concentric tubes or adjacent plates. Cells of this type developed by Karl Kordesch of the National Carbon Company have won the distinction of being the first prac-



WHEN CIRCUIT IS CLOSED, the gases and electrolyte react to produce a flow of electrons. A catalyst embedded in the electrode dissociates hydrogen gas molecules into individual atoms, which combine with hydroxyl ions in the electrolyte to form water. The process yields electrons to the electrode. The electrons flow through the circuit to the positive electrode, where they combine with oxygen and water to form hydroxyl ions. The ions complete the circuit by migrating through the electrolyte to the negative electrode.

tical fuel cells; the U.S. Army uses them to power its "silent sentry" portable radar sets. Some have been in operation for more than a year with no appreciable decline in performance.

Low-temperature hydrogen-oxygen cells are limited in their applications, although they may find widespread special uses. Hydrogen is a costly fuel and the power-to-volume ratio of the cell (about one kilowatt-hour per cubic foot) makes it too bulky for use in vehicles.

An obvious way to improve the performance of hydrogen-oxygen cells is to operate them at higher pressures (which speed up gas transport through the electrodes) and higher temperatures (which speed up the electrochemical reactions). By appropriate design and insulation the waste heat liberated in the cell can be used to maintain the cell at the proper operating temperature.

The best-known cell of this type has been developed by Francis T. Bacon of the University of Cambridge. It operates at temperatures up to 250 degrees Centigrade with gas pressures up to 800 pounds per square inch. The electrodes are of porous nickel about 1/16-inch thick and are usually in the form of disks or plates. A thin surface layer on the electrode, penetrated by very fine pores, constitutes the reaction area. The electrolyte, a concentrated solution of potassium hydroxide, can enter these pores, but pressure differences within the electrode prevent it from flooding the larger pores in the body of the electrode, through which gas percolates to the reaction area. The Bacon cell produces six times as much power per cubic foot as the low-temperature cell. With this relatively high output, the cell should have bright prospects as a standby source of auxiliary power in airplanes. It can deliver as much as 150 watts per pound, as against 10 watts for the lead-acid storage batteries currently in use.

To produce economical power on a large scale, fuel cells must "burn" cheap fuels such as natural gas, vaporized gasoline or the mixture of gases obtained from the gasification of coal. The extraction of energy from such fuels calls for operating temperatures above 500 degrees Centigrade. Since aqueous electrolytes would boil away at these temperatures, the electrolyte consists of some molten salt, usually a carbonate of sodium or potassium mixed with lithium carbonate to lower the melting point. In the most efficient of these cells, the electrolyte is held in a matrix of porous refractory material. The electrodes, made of a variety of metals or metallic oxides, are tightly pressed against the "solid" electrolyte.

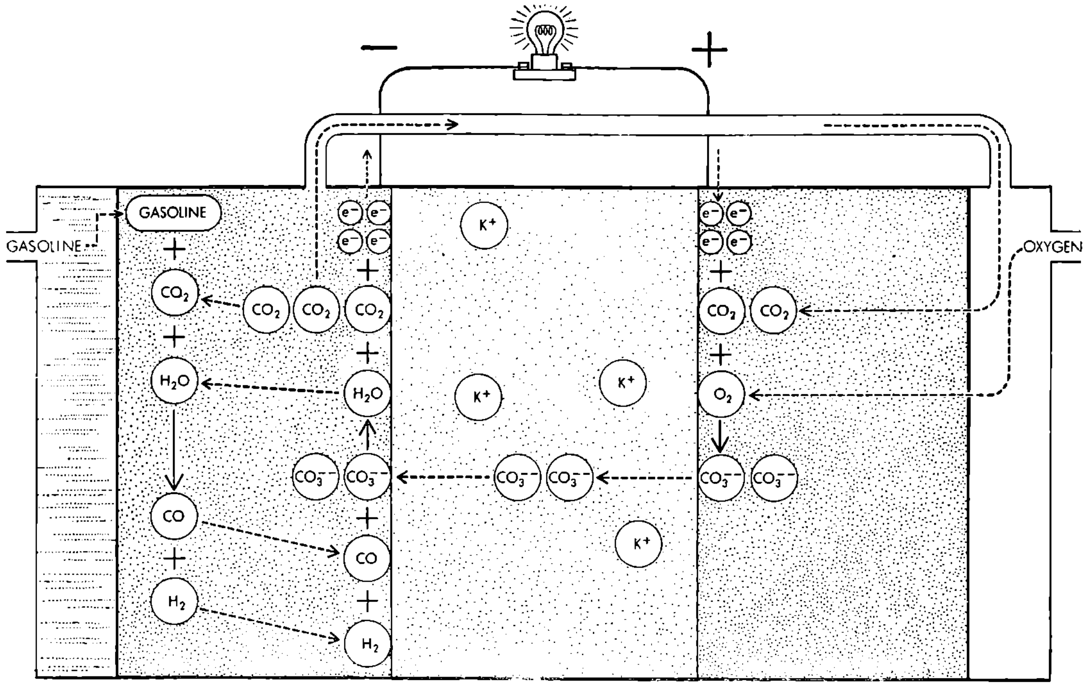
In these cells the fuel does not necessarily combine directly with oxygen as hydrogen does in the hydrogen-oxygen cell. Usually the fuel is "cracked" to hydrogen and carbon monoxide by reaction with steam and carbon dioxide, which the fuel cell produces as by-products. This cracking may be conducted outside the cell, or inside the cell on the electrode surface. In the current-generating reaction the hydrogen and carbon monoxide diffuse into the cell at the negative electrode, where they react with carbonate ions in the electrolyte, forming carbon dioxide and water and giving up electrons to the electrode. At the positive electrode, oxygen or air takes up the electrons flowing in from the external circuit and reacts with the carbon dioxide to produce the carbonate ions. The migration of carbonate ions through the electrolyte from the positive to the negative electrode completes the circuit.

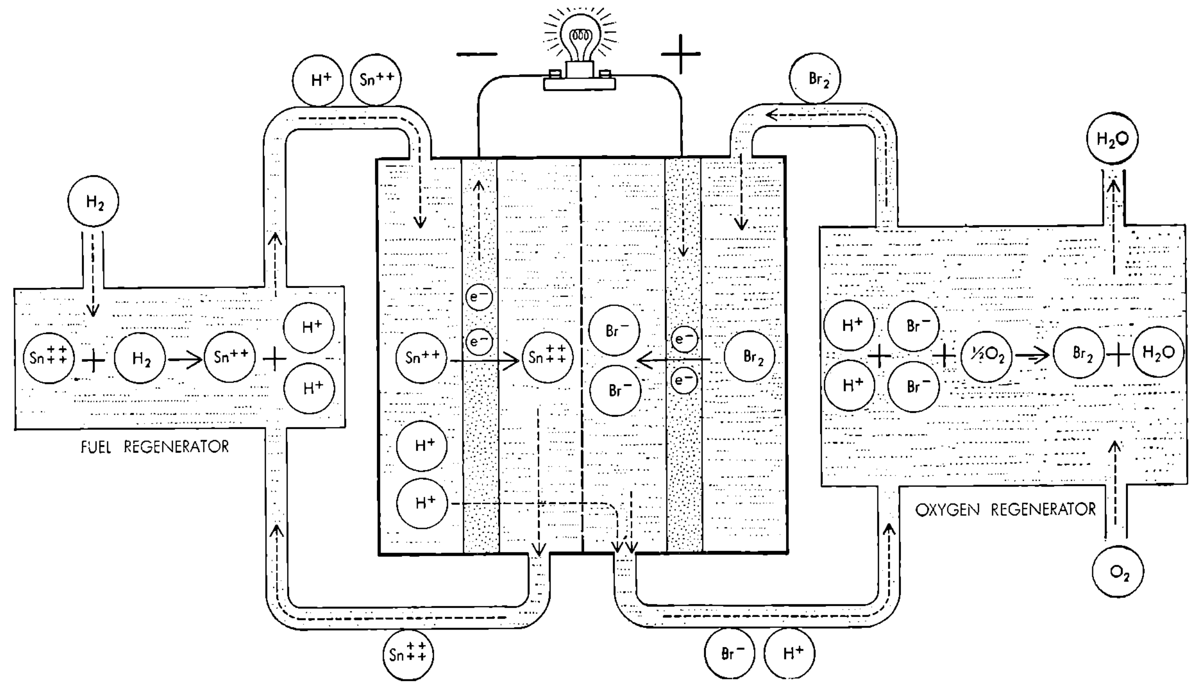
High-temperature fuel cells, intensively investigated only since World War II, still perform poorly. The best of them produce no more than half a kilowatt per cubic foot — half the yield of the low-temperature hydrogen-oxygen cell and a twelfth the yield of the Bacon cell. However, the progress already made in hydrogen-oxygen cells suggests further research can improve the performance of high-temperature cells by a factor of 10 or more.

In the "redox" cell — named for reduction and oxidation — the fuel and oxygen do not react directly with each other. Rather, the fuel and oxygen are made to react with other substances in "regenerators" outside the cell to produce chemical intermediates, which in turn generate current in the cell. The over-all reaction is the same as that of combustion, however, because the intermediates are regenerated. A typical cell of this type, developed in England under the leadership of Sir Eric Rideal, utilized tin salts and bromine as intermediates. The fuel reduces (i.e., adds electrons to) tin ions, which then give up the added electrons to the negative electrode and return to react with more fuel. The oxygen similarly oxidizes (i.e., takes electrons from) bromide ions, converting them to bromine, which then takes up electrons from the positive electrode and returns as bromide ions for regeneration. A similar cell, using titanium salts instead of tin, is under development by the General Electric Company.

In principle redox cells should be able to achieve high efficiencies. The intermediates can be chosen so that the electrode reactions are rapid and yield high currents with little energy loss.

HIGH-TEMPERATURE FUEL CELL operates above 500 degrees Centigrade and uses fuels such as gasoline or natural gas. The cell contains two electrodes tightly pressed against a "solid" electrolyte, which is usually a molten salt such as potassium carbonate. The fuel in the cell is usually broken down (by reaction with steam and carbon dioxide) to produce hydrogen and carbon monoxide. These gases then diffuse into the negative electrode, where they react with carbonate ions in the electrolyte, forming carbon dioxide and water and giving up electrons. The electrons flow through the circuit to the positive electrode, where they combine with oxygen and carbon dioxide to form carbonate ions. The carbonate ions complete the cell's electrical circuit by flowing back to the negative electrode.





REDOX CELL is so named because in it the fuel and oxygen react with oxidizing and reducing agents in two so-called regenerators. The hydrogen reduces (adds electrons to) tin ions, which then give up electrons to the electrode. The electrons flow to the positive electrode. On the positive side of the cell, oxygen oxidizes (takes electrons from) bromide ions, converting them to bromine. In turn, the electrons flowing into the positive electrode reduce the bromine to bromide ions, which are then returned for regeneration.

With suitable catalysts and operating conditions it may be possible to carry out the regeneration reactions at satisfactory efficiencies. However, the problems involved in the regenerators have not yet been solved. Moreover, the two electrolyte systems must be separated from each other by an impermeable membrane to keep the bromine from mixing and reacting with the tin or titanium ions. All known membranes of this sort have a rather high electrical resistance. It has not yet been demonstrated that the redox cell represents any improvement over simpler types.

Engineers are working on a number of other reaction cycles and combinations of cycles. Each of them presents knotty technical difficulties. But the fundamental processes of electrochemistry are fairly well understood, probably because electrochemical experiments require no expensive apparatus and thus fit well into university budgets. The future development of the fuel cell is thus a question of applied rather than basic research.

Low-temperature and moderate-temperature hydrogen-oxygen cells should come into use during the next few years as low-weight, easily "charged" batteries. The development of strong, light-weight containers, perhaps made of plastic-impregnated glass fibres, would reduce the poundage if not the cubic footage needed to store the reaction gases. Where cost is not too important, the hydrogen could be stored as solid lithium hydride and the oxygen as solid calcium superoxide. Moderate-temperature cells may well be used to power submarines. Such vessels, like nuclear submarines, could cruise for extended periods without surfacing and would be far quieter in operation than nuclear vessels.

Hydrogen - oxygen cells may also furnish a means of capturing the power of the sun. Investigators at the Stanford Research Institute have developed a catalytic process for decomposing water into hydrogen and oxygen by sunlight. Used in conjunction with fuel cells, which would recombine the hydrogen and oxygen into water, a solar photolysis plant covering two square kilometers of desert could provide as much energy as a 100,000-kilowatt power-station in continuous operation. The over-all efficiency of such a plant, estimated at 25 per cent, would be two and a half times that of present solar batteries or solar boilers.

In auxiliary installations at nuclear power-stations, hydrogen-oxygen cells may help to bring down the cost of nuclear power. The high capital cost of nuclear-power plants requires that they be operated at near-peak capacity if they are to yield cheap electricity. Power generated during daily or seasonal periods of low demand might be used to electrolyze water into hydrogen and oxygen, which would then be made to yield the stored energy via fuel cells during peak-demand periods. The large volume of gas generated might be stored in "sausage skins" of plastic film buried underground to eliminate wind damage.

If the performance of high-temperature fuel cells can be substantially improved, large-scale electric power might be generated near sources of cheap natural gas. The power produced would, of course, be in the form of direct rather than alternating current, and though high - voltage direct current is somewhat easier to transmit than alternating current, fuel cells apparently cannot produce high voltages. Large numbers of cells must be connected in series, and above 700 volts there is electrical leakage through the insulation separating the terminals. Large-scale power from fuel cells should therefore find its first application in electrochemical processes such as the production of aluminium, which utilize large quantities of direct current at low voltage. Electrochemical industries may then congregate near natural-gas sources as they now cluster around hydroelectric installations.

The hydrogen-oxygen cell may make an unorthodox contribution of its own to the chemical industries. With slight modifications a low-temperature cell can employ instead of hydrogen a liquid fuel such as methyl (wood) alcohol, which it oxidizes to formic acid. The power output is very low, but the formic acid is almost free of impurities. Ethyl alcohol can similarly be oxidized to acetic acid, an important raw material in the manufacture of plastics and lacquers. Such processes, amounting to a sort of electrolysis in reverse, may prove useful in the manufacture of other industrial chemicals. Since the energy released would be extracted as electricity rather than heat, unwanted side reactions could be held to a minimum. It would be ironic if fuel cells should find their principal application in the production of chemicals rather than of power.

Attempts to construct cells that would operate directly on coke or coal, the cheapest of fuels, have been disappointing. Far more promising is the mixture of hydrogen, carbon monoxide and hydrocarbons that can be made from coal. With suitable equipment to remove tar and grit, it could be piped directly from the gasification plant and used hot. However, a really low-cost process for generating gas from coal has yet to be devised.

A high-output fuel cell operating on liquid fuel would find immediate application in trucks and locomotives. The technology of electric traction is well developed and is waiting for a compact power-unit utilizing a cheap fuel that can be easily stored and pumped. Designers will have to figure out a simple way to warm up the cell to operating temperature; the high-temperature cell is not a self-starter.

The possibilities of fuel cells are great, but not all these possibilities are going to be realized. Although much small-scale development work remains to be done, some cells have reached the stage where further progress will require large amounts of money and faith. No doubt some of this money will be wasted, and some of the faith will be misplaced. Fuel cell development is not a field for the faint-hearted.

(By courtesy of U.S. Industrial Digest)

Modulator and Converter Circuits Using the 7360 Beam Deflection Valve

Numerous uses exist for valves which provide output currents that are functions of the mathematical product of two input-signal voltages. This article deals with the design and application of such a valve, the 7360 beam-deflection valve. The 7360 incorporates novel design features which, with suitable circuits, permit improved performance in various equipments operating at frequencies as high as 100 megacycles.

This article also describes circuits in which the 7360 is used as a balanced modulator and a balanced mixer. Balanced-modulator circuits are shown for both the filter and phasing methods of single-sideband generation. A block diagram of a single-sideband transmitter employing these circuits is also shown to illustrate the advantages of the 7360.

Theory of Operation

In all multigrid valves, the cathode, control grid, and screen grid control the amount of space current passing through the screen grid. A second (outer) control means then determines the fraction of this space current drawn to each collector or plate. This process of current division is the basis of the product relationship.

In the case of suppressor-grid pentodes or pentagrid valves, the grid No. 3 allows some of the current to pass to the plate and returns the remainder to the screen grid. However, the returned current becomes a problem. Some of it passes back through the screen grid, alters the space charge in the grid-cathode region, and interacts with the grid-No. 3 voltage, and the product relationship is no longer valid. The returned current also causes electronic coupling between the inputs and alters the input impedance of the grid. Furthermore, it is seldom practical to utilize the current returned to the screen grid as a signal output because signal voltages are not desired on the screen grid.

The beam-deflection valve, however, does not return current to the screen grid, but divides the total space current between the two plates by electrostatic deflection. As a result, the signal inputs are well isolated, good linearity is achieved, and push-pull output is obtained.

Fig. 1 shows a cross-sectional view of the main elements of the 7360. The cathode, control grid, and screen grid form an electron gun which

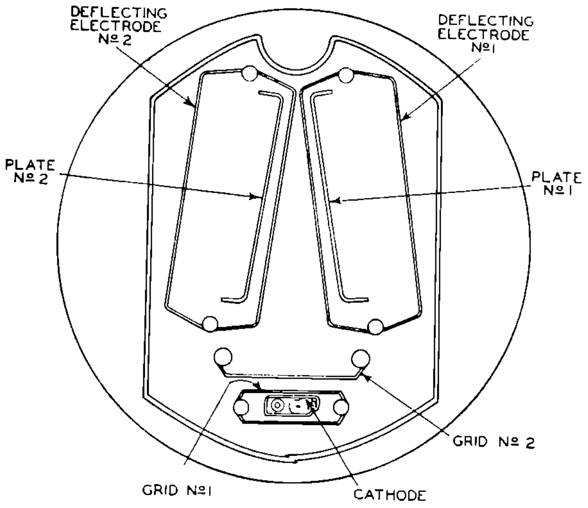


Fig. 1 — Cross-sectional View of the Main Elements of the 7360.

generates, controls, and accelerates a beam of electrons. The screen grid and the two deflecting electrodes act as a converging "electronic lens" to focus this beam.

As in a conventional multigrid valve, the total current to the two plates at a given plate voltage is determined by the voltages applied to the screen grid and the control grid. The division of the beam current between two plates is controlled by the potential difference between the two deflecting electrodes. In the balanced condition, the two plate currents are equal.

Deflecting-electrode design similar to that used in electrostatic-deflection cathode-ray tubes was discarded in favour of the arrangement shown in Fig. 1 which uses a new type of porous deflecting electrodes. This design not only improves sensitivity, but also avoids the problem of large deflecting-electrode currents when the beam is deflected because the grid wires intercept only a small fraction of the beam current.

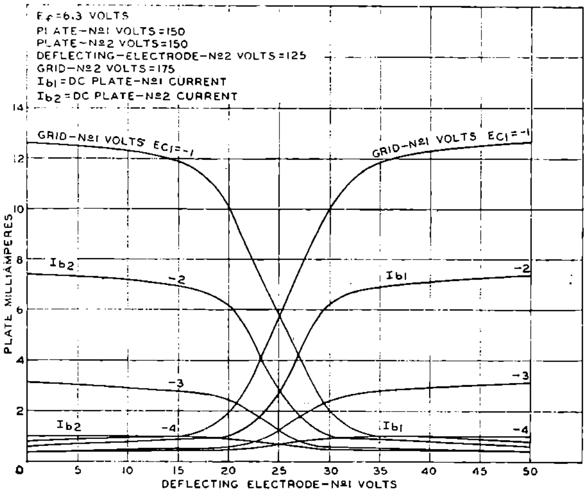


Fig. 2 — Deflection Transfer Characteristic for the 7360.

Operating Conditions

Operating conditions for the 7360 may be optimized for maximum deflection transconductance. One important parameter influencing deflection transconductance is mean deflecting-electrode voltage, which should be about 20 to 35 volts positive with respect to the cathode. Fig. 2 shows the deflection transfer characteristic (plate current as a function of differential deflecting-electrode voltage) for a mean deflecting-electrode voltage of +25 volts. Under these conditions, a deflecting-electrode signal of approximately 12 volts peak-to-peak is required to switch the beam completely from one plate to the other at a control-grid bias of -2 volts. When linearity is of prime importance, the deflecting-electrode drive should be reduced to about 8 volts peak-to-peak.

It is good practice to apply the input signal to deflecting-electrode No. 1 (pin 9). A bypass capacitor connected to deflecting-electrode No. 2 then provides some isolation between the input electrode and the two plates (pins 6 and 7) and minimizes the possibility of stray coupling.

Plate voltages between 100 and 150 volts produce the sharpest corners on the transfer curves of the 7360, although these voltages are not critical. The plate voltage must be sufficiently high to prevent the minimum instantaneous plate voltage from swinging in the vicinity of the "knee" region, which occurs approximately at a plate voltage of 50 volts. At this point, the resultant high screen-grid current creates excessive distortion.

For maximum deflection transconductance at a given beam current, there is an optimum value of screen-grid voltage. Although this value is not critical to within ±25 volts, best results are obtained with higher screen-grid voltages for higher beam currents. The effect of screen-grid voltage on deflection characteristics has an important implication for circuits using large control-grid signals.

Installation Considerations

An electron beam is affected by the presence of magnetic fields. Conventional valve structures can be subjected to the influence of small stray magnetic fields without adverse effect on performance. The beam-deflection valve, however, is extremely susceptible to the effect of stray magnetic fields.

In the beam-deflection valve, a potential on the deflecting electrodes is used to correct any plate-current imbalance caused by dc magnetic fields. AC magnetic fields also prevent full utilization of the valve's exceptionally good balance by producing an undesired output signal.

The 7360 is internally shielded to minimize stray magnetic effects. However, it is recommended that an external shield made of "magnetically soft" material be used to provide further protection from stray fields. For best operation, the 7360 should be located away from filter chokes, power transformers, motors, and other sources of strong magnetic fields.

Over-All Single-Sideband System

The unique features of the 7360 permit the simplification and consequent cost reduction of the conventional balanced-modulator and balanced-mixer circuits together with improved performance and simpler alignment procedures.

Fig. 3 shows a simplified block diagram of a single-sideband transmitter in which three 7360

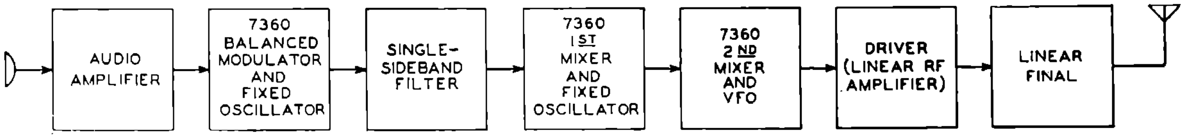


Fig. 3 — Simplified Block Diagram of a Single-sideband Transmitter.

beam-deflection valves are used. The high-level modulator produces a sideband ten times greater in amplitude than that obtained with conventional diode modulators. This increase allows full utilization of the sideband filter to obtain excellent noise rejection.

The use of the 7360 in such a system eliminates the need for separate oscillator valves. In addition, the over-all gain provides a signal at the output of the second mixer that is sufficient to drive the linear driver, and eliminates the need for the buffer amplifier stage usually found between the last mixer and the linear driver.

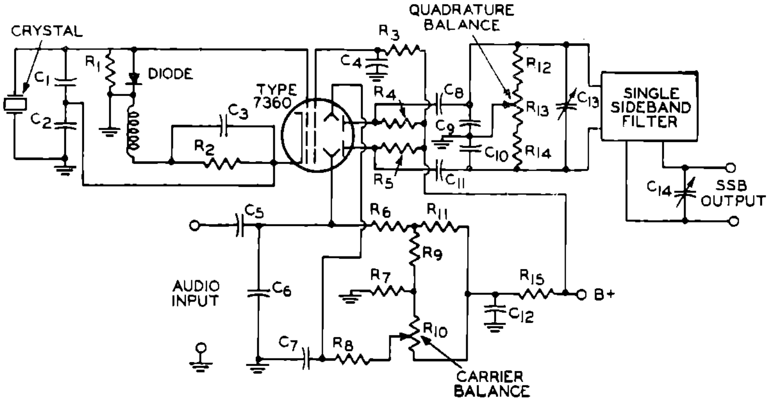
Balanced Modulator — Filter Method

The characteristics of the 7360 make it attractive for balanced-modulator applications. Fig. 4 shows a balanced modulator employing the filter method of sideband rejection. Use of the 7360 in this circuit allows both the audio and carrier inputs to be introduced single-ended, although a push-pull audio signal may be used if desired. The valve possesses a relatively high deflecting - electrode - to - plate transconductance (800 micromhos). The high input impedance to the deflecting electrode eliminates the need for the matching network usually found in diode modulators.

Oscillator Circuit

Either separate excitation or self-excitation can be used with the 7360. The preferred self-excited circuit uses feedback from the cathode. Hartley oscillators similar to those used with pentagrid converters operate satisfactorily. Feedback can be obtained either from the screen-grid or plate circuit.

The crystal oscillator shown in Fig. 4 gives very good results. Although this arrangement uses a tapped-capacitance-tuned circuit, a tapped inductance such as that shown in Fig. 5 works equally well. The peak grid-cathode voltage must



92CM-10664

C_1, C_2: feedback capacitive voltage divider
C_3, C_7: 0.1 μf
C_4, C_5: 0.22 μf
C_6: 0.001 μf
C_8, C_{11}: 0.047 μf
C_9, C_{10}, C_{13}: sufficient to resonate input of single-sideband filter
C_{12}: 0.47 μf
C_{14}: sufficient to resonate output of single-sideband filter
R_1: 470,000 ohms
R_2: 300 ohms
R_3, R_{15}: 100,000 ohms
R_4, R_5: 68,000 ohms
R_6, R_8: 47,000 ohms
R_7: 12,000 ohms
R_9, R_{11}, R_{12}, R_{14}: 2700 ohms
R_{10}: carrier balance potentiometer, 5000 ohms
R_{13}: quadrature balance potentiometer, 2500 ohms

Fig. 4 — Tapped-capacitance Crystal-controlled Oscillator Circuit.

be prevented from approaching the zero-volt bias point too closely or excessive distortion will result; consequently, grid-leak bias is not recommended. The advantages of grid-leak bias can be obtained by the use of a diode clamp in the grid circuit, as shown. The cathode resistor is then used to supply a small minimum bias.

The grid signal should be approximately 10 volts peak-to-peak with respect to the cathode for either self-excitation or separate excitation. This value is not critical, however, and conversion gain can be optimized by adjustment of the grid-input-signal level.

Carrier Balance

Carrier suppression is not difficult with the 7360. A potentiometer in the deflecting-electrode circuit permits the positive bias to one deflecting electrode to be varied ±2 volts from a mean value of 25 volts.

A fixed positive bias of 25 volts is applied to the other deflecting electrode. This ±2-volt variation of deflecting-electrode bias is usually sufficient to balance the real component of current in the load circuit.

In a balanced modulator using two separate valves, the characteristics of one valve will differ somewhat from those of the other throughout the life of the valves. This difference necessitates the continual adjustment of the balance controls. Because the 7360 has a common cathode, control grid, and screen grid, the variations that occur during the life of the valve affect both plate currents equally. This compensating feature automatically maintains a stable balance and provides an inherent match of the two transfer characteristics.

The dc plate resistors also contribute to the inherent stability of the 7360. If, for any reason, the dc plate currents become unbalanced, a dc voltage difference appears between the plates. This voltage difference tends to correct the imbalance because of the relatively low differential plate resistance of the valve. This form of negative feedback is analogous to the stabilization of the plate current of a triode by use of a large series resistance.

Phase Balance

If phase imbalance exists, the single deflecting-electrode balance control may not be sufficient to obtain the desired carrier suppression. A 3.5-degree phase error between plates, for example, produces a carrier signal of only 35 db below the sideband output.

Phase imbalance can be caused by unequal capacitances between the control grid and the plates. Although the interelectrode capacitances from the grid to each plate are very small and nearly equal, precautions must be observed in lead dress so that the location of the grid leads does not permit introduction of a portion of the carrier signal into one of the plate leads. Similar care should be taken with regard to the deflecting electrodes so that the presence of carrier signal does not produce a phase imbalance. As an added precaution, the deflecting electrodes should be bypassed as effectively as possible at the carrier frequency.

If further carrier suppression is desired, a phase-balance control can be added to the circuit. Several methods are available and have been used with good results. One method is the addition of a quadrature component of carrier current to the load by coupling from grid-No. 1 to plate through a small capacitor. A differential capacitor to both plates permits a full range of adjustment. A resistive network such as that shown in Fig. 4 may also be used. This method is useful for tuned load circuits having a centre-tapped capacitor; if the C/L ratio is high and the resistance is large compared to the capacitive reactance, the quadrature adjustment is essentially independent of the in-phase balance adjustment.

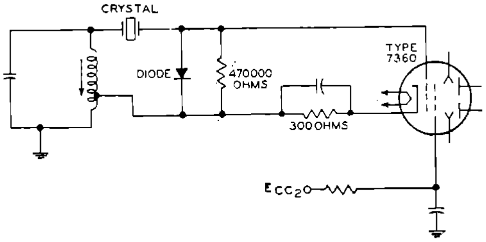


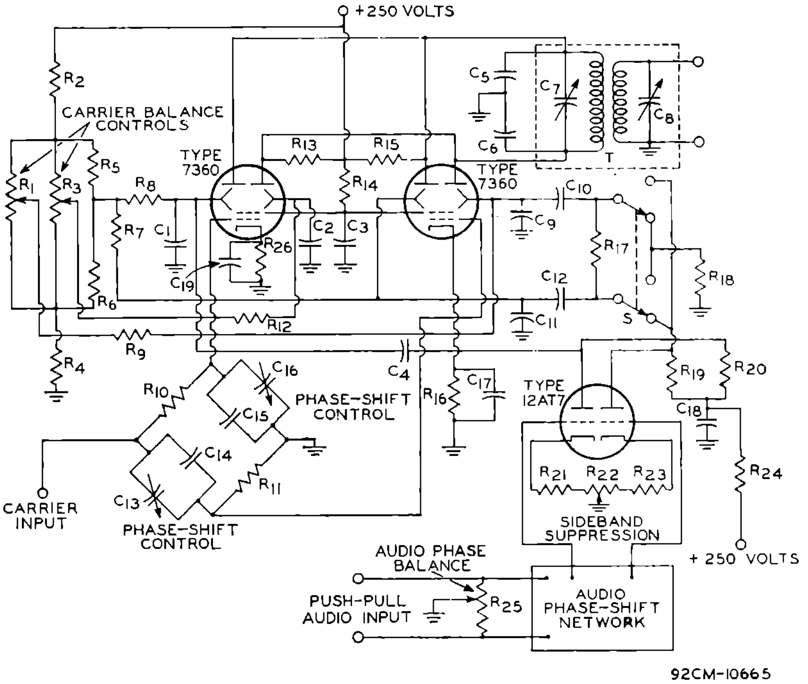
Fig. 5 — Tapped-inductance Crystal-controlled Oscillator Circuit.

Suppression.

When the circuit shown in Fig. 4 is operated under typical conditions, the carrier is suppressed 60 db below the single-sideband output. Suppression is accomplished by adjustment of the rf-balance and the quadrature-balance controls. The audio input is usually no more than one volt rms because of the limited peak input-signal capabilities of the filter. The carrier frequency is adjusted so that it falls within the passband of the filter. The value obtained for suppression, therefore, is a true indication of the capability of the valve. An additional 10 to 20 db of carrier suppression is obtained when the carrier frequency is centred on the slope of the frequency-response curve of the filter.

Distortion

All of the distortion measurements shown in this article are single-tone measurements. For



C_1, C_9, C_{11}: 0.0015 μf
C_2, C_{17}, C_{19}: 0.1 μf
C_3, C_4, C_{10}, C_{12}, C_{18}: 0.22 μf
C_5, C_6: 270 μμf
C_7, C_8: tuning capacitors
C_{13}, C_{16}: trimmer capacitors, 5 to 180 μμf
C_{14}, C_{15}: 680 μμf
R_1, R_3: potentiometer, 5000 ohms
R_2, R_{13}, R_{15}: 27,000 ohms
R_4: 3300 ohms
R_5, R_6: 2700 ohms
R_7, R_8, R_9, R_{12}: 47,000 ohms

R_{10}, R_{11}: 560 ohms
R_{14}: 1000 ohms
R_{16}, R_{26}: 1200 ohms
R_{17}: 1 megohm
R_{18}: 10,000 ohms
R_{19}, R_{20}: 22,000 ohms
R_{21}, R_{23}: 270 ohms
R_{22}, R_{25}: potentiometer, 500 ohms
R_{24}: 4700 ohms
T: 456-kilocycle if transformer modified for 395-kilocycle operation
S: double-pole, double-throw switch

Fig. 6 — Phase-shift Balanced Modulator.

simplicity, only the major in-band distortion products are given.

The third-order distortion product can be described as follows: If the two input frequencies are defined as f_1 and f_2, the desired output signal may be represented as either $(f_1 + f_2)$ or $(f_1 - f_2)$, the upper and lower sidebands, respectively. Third-order curvature of the conversion transconductance curve produces products at frequencies $(2f_2 \pm f_1)$, $(2f_1 \pm f_2)$, $3f_1$, and $3f_2$. The measured distortion product shown in the data is the amplitude of the frequency $(2f_1 + f_2)$, expressed in terms of decibels below the amplitude of the desired output frequency $(f_1 + f_2)$.

Similarly, fourth-order distortion products are generated at frequencies $(3f_1 \pm f_2)$, $(3f_2 \pm f_1)$, $(2f_1 \pm 2f_2)$, $4f_1$, and $4f_2$. The measured distortion product given in this article is the amplitude of the frequency $(3f_1 + f_2)$, expressed in terms of decibels below the amplitude of the desired ouput frequency $(f_1 + f_2)$.

The major third-order distortion product of the balanced modulator circuit is 47 db below the sideband output; the major fourth-order product is –55 db. These average values were obtained with a 10-volt peak-to-peak carrier signal and 1-volt rms audio signal.

Phase-Shift Balanced Modulator

For economic reasons it may be advantageous to generate a single-sideband signal by means of a phase-shift balanced modulator. This method, shown in Fig. 6, employs two 7360's, but eliminates the single-sideband filter.

The carrier passes through a 90-degree phase-shift network which consists of an RC bridge. Two output signals are produced, one +45 degrees from the original carrier and one –45 degrees from the original carrier. These signals are then applied to the control grids of the 7360's, as shown in Fig. 6.

The audio signal also passes through a phase-shift network which produces two audio signals phase-shifted by 90 degrees. Again, one signal is at a phase angle of +45 degrees and the other at –45 degrees. After passing through the 12AT7 voltage amplifier, these signals are coupled to the deflecting electrodes.

When there is no audio input, there is no output signal because the carrier is cancelled out across the output transformer. Carrier and phase adjustments enable the two 7360's to produce independent signals which are equal in phase and magnitude at the ends of the primary of the output transformer. Therefore, the advantage of inherent stability is maintained because the carrier balance is dependent on the individual valves and not on an interaction between valves.

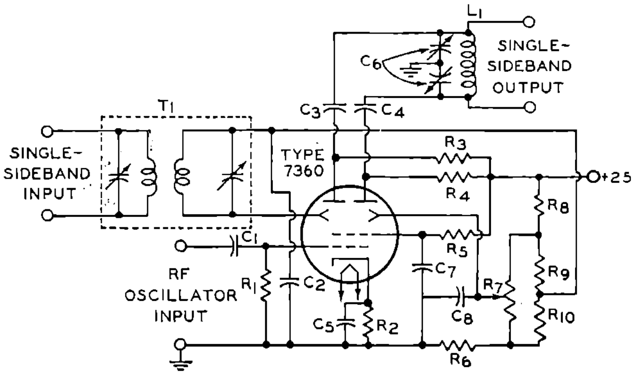
The rejection of the unwanted sideband depends upon balance between the two 7360's. Such precautions as separate cathode-bias resistors are recommended to maintain adequate sideband rejection with a minimum of adjustment. Further stability during life can be obtained through the use of separate screen-grid dropping resistors.

When the carrier is suppressed and an audio signal is applied, the resultant output signals in each of the four plate circuits are the sum and difference frequency components due to the product of the carrier and audio signals. Switching from the upper sideband to the lower sideband is accomplished by producing a 180-degree phase-shift in the audio input to one of the valves. This shift occurs when the audio input is switched from one deflecting electrode to the other by means of switch S shown in Fig. 6. It is important, however, to keep the deflecting-electrode-to-ground impedance approximately constant so that the rejection of the unwanted sideband will be maintained. Consequently, a double-pole double-throw switch is used to switch in a fixed resistance R_{18} between the unused deflecting electrode and ground. The value of this resistance is determined by the load resistance and plate resistance of the preceding audio stage. In the circuit shown, a value of 10,000 ohms was used; however, the value is not critical.

Each of the variety of phase-shift single- sideband exciter circuits described in available literature features some of the advantages listed below. The 7360, however, combines all of the following advantages and, at the same time, improves inherent circuit balance.

High input impedance. The rf-carrier phase-shift network can be a simple RC bridge. The audio phase-shift network can be used to connect the audio voltage amplifier directly to the deflecting electrodes without the use of a buffer stage. phase inverter, or push-pull stage. (Fig. 6 shows a conventional audio phase-shift network. Because the dc resistance of this network is too high for use directly in the deflecting-electrode circuit, a buffer stage is used).

Isolation between inputs. The screen grid provides effective isolation between the carrier and the audio input circuits and thus eliminates interaction between these circuits.



C_1, C_3, C_4: 0.001 μf
C_2, C_5, C_7, C_8: 0.04 μf
C_6: split-stator tuning capacitor to resonate with L_1
L_1: inductor
R_1: 0.47 megohm
R_2: 1200 ohms
R_3, R_4: 68,000 ohms

R_5, R_8: 0.1 megohm
R_6: 12,000 ohms
R_7: oscillator rejection potentiometer, 5000 ohms
R_9, R_{10}: 2700 ohms
T_1: tuned input transformer

Fig. 7 — Balanced-mixer Circuit having Separate Excitation.

Stable carrier suppression. The carrier is suppressed by a separate balance control in each of the two 7360's. Over-all carrier suppression of 60 db below the sideband output can be readily obtained, and will remain constant over the normal range of ambient temperatures without special components. The realizable over-all suppression (carrier plus unwanted sideband) is about 45 db. This limitation is almost entirely due to the audio phase-shift network.

Distortion. With a 2.5-volt rms audio signal to the deflecting electrodes, the plate-to-plate single-sideband output signal is 20 volts peak-to-peak across a plate-to-plate impedance of 40,000 ohms. The third-order distortion component is 42 db below this output, and the fourth-order distortion component is down more than 50 db.

Balanced Mixer

The choice of carrier frequency in the exciter section of a single-sideband transmitter is largely governed by the choice of exciter circuit. In phase-shift modulator circuits, variations in capacitance between the circuit components usually limit the upper usable frequency to about 10 megacycles. The operating frequency of filter-type balanced modulators is governed by the choice of the sideband filter and the frequency stability of the carrier oscillator.

Transmission at frequencies above the exciter carrier frequency requires some method of frequency conversion. Because the signal at this point already contains the modulation, the frequency conversion must be accomplished without destroying or distorting the original modulation. Obviously, it is impossible to use frequency multipliers; however, mixer or converter circuits may be used. In general, these circuits have had two limitations: (1) At the desired distortion levels, their signal-handling capacity is limited to 0.2 to 0.3 volt at the sideband input. (2) The local-oscillator injection frequency is always present at the output of the mixer or converter.

The 7360 is not subject to either of these limitations. The deflecting electrodes are capable of handling up to 8 volts peak-to-peak without serious distortion. Because the 7360 is operated as a balanced mixer, the oscillator signal is cancelled in the plate circuit independently of the deflecting-electrode signal.

Balanced-mixer operation is similar to that of the filter-type balanced modulator. As shown in Fig. 7, the sideband filter is replaced by a tuned transformer, and the quadrature balance control is eliminated. The other circuit elements remain basically the same. Although separate excitation is shown in this circuit, self-excitation may also be used, as shown in Figs. 4 and 5.

With no balance controls, at least 25 db of local-oscillator rejection can be expected. When further rejection is required, the addition of a deflecting-electrode bias adjustment improves the carrier rejection by an additional 15 db.

The deflecting electrodes should be effectively bypassed for the local-oscillator frequency. When bypassing is not possible, as is the case when the signal frequency is close to the local-oscillator frequency, the deflecting-electrode circuit impedances should be approximately equal.

With an oscillator injection of 10 volts peak-to-peak and a deflecting-electrode drive of 8 volts peak-to-peak, a single-sideband output signal of 25 volts peak-to-peak is realised across a 40,000-ohm output impedance. The major third-order distortion component is approximately 40 db below the sideband output, and the major fourth-order distortion component is down at least 35 db under the operating conditions given above. In low-level applications in which a mixer output as high as 25 volts may be undesirable, the mixer output level should be reduced by decreasing the drive voltage to the deflecting electrode, and the oscillator-injection voltage between the control grid and the cathode of the 7360 should be maintained at between 8 and 10 volts peak-to-peak.

Circuit Precautions

Balanced-modulator circuits require a mechanically and electrically stable circuit. Care should be taken to mount the circuit components rigidly and to avoid layouts in which heat or vibration affects only one deflecting electrode or plate circuit of the 7360.

(With acknowledgements to RCA)

SILICON DIODES FOR METER PROTECTION

There is an increasing use today of silicon diodes for meter protection, both in switchboard and similar installations, and in portable multirange meters for bench use. We all know how easily sensitive meters can be damaged by overloads. In the past, overload protection has been provided by the use of mechanical (inertia) trip devices or thermal trips or fuses. These devices have an appreciable operating time, and also require resetting. What is required is a device which affords instantaneous protection and does not require resetting.

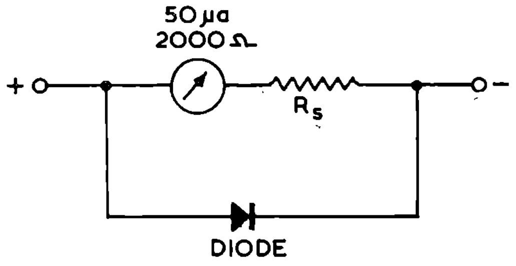


Fig. 1

Silicon diodes provide a very acceptable answer to this problem. They are passive devices, so that there is no operating lag. They do not require resetting. They are small and easily accommodated in instruments of existing as well as new designs. They are an economic answer to the problem.

Silicon diodes can be used for straight overload protection, using the non-linear forward characteristics of the diode. Silicon zener diodes can be used for range extension on meters; whilst this is not strictly meter protection in the true sense, it is a useful feature when considering the design of multirange or suppressed-zero meters. Silicon diodes and zener diodes were discussed in "Radiotronics" Vol. 24, No. 9, September, 1959 and Vol. 24, No. 10, October, 1959, respectively.

Overload Protection

Meters can be protected from overloads using the fact that conduction in a silicon diode commences at a low voltage, typically 0.25 volt, which is higher than the full scale deflection voltage drop across the meter movement. The diode is used as shown in Fig. 1.

Taking a typical case, we have a meter movement of 50μa full scale deflection, and an internal resistance Rm of 2000 ohms. This represents a voltage drop across the meter of 0.1 volts. Now we need a diode which commences to conduct at a voltage not too much in excess of this figure, say at 0.3 volt. The 1N1763 is being widely used for meter protection.

Because we want the diode to conduct as soon as possible after full scale deflection of the meter is reached, and so to carry the excess current, we ballast the meter with series resistance Rs so that Rm + Rs at full scale deflection produces a voltage drop of 0.3 volt. This condition is met by making Rs = 4,000 ohms. This is, of course, a severe case where protection of a delicate movement is required. Adaptation of the protected meter to a multirange voltmeter circuit is shown in Fig. 2.

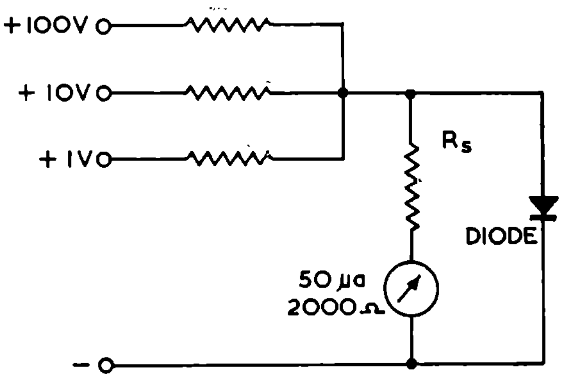


Fig. 2

Suppressed Zero

Suppressed-zero meters are used where it is necessary to have measurements of voltage over a limited range. For example, readings in the range of 80 to 1000 volts may be required. Special meters are made which, in this case, would commence to read at 80 volts, and would reach full scale deflection at 100 volts. The scale would, of course, be calibrated accordingly. In this way maximum utilization of the meter is achieved in the region of interest.

Normal meters can be converted into suppressed-zero types using zener diodes, as shown in Fig. 3. Here the zener voltage of the diode is the voltage at which the meter is required to start reading. Below this voltage the diode does not conduct a significant current, and above this voltage the diode resistance falls to a low value so that normal voltmeter action takes place. The scale will be non-linear and will require calibration against known voltages.

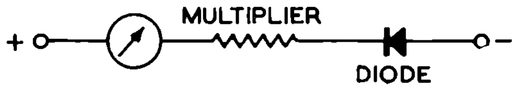


Fig. 3

USING A TEST PROBE

Are you familiar with the test probes that are designed to be used in conjunction with your test equipment? If you fail to employ test probes properly, you can be greatly misled by information registered on a vacuum tube voltmeter or oscilloscope.

Many modern vacuum tube voltmeters employ a single cable incorporating a dc/ac voltage test probe at the tip. The dc/ac voltage probe has a switch that provides for a built-in one-megohm resistor to be placed in series with the probe tip when used for dc measurement, and a direct connection when measuring ac voltages. The one-megohm resistor, inserted for dc measurements, acts to isolate the instrument from the circuit under test and becomes part of the overall input resistance of the voltmeter. The switch on a dc/ac test probe should always be set to the "DC" position for dc voltage measurements. When the switch on the probe is set to the "AC-OHMS" position, the isolating resistor is shorted out so that the probe tip may be connected directly to the input of the voltmeter. The switch should always be set to "AC-OHMS" position when resistance or ac voltage measurements are being made and whenever an associate crystal diode probe is used with the meter (a crystal diode probe extends the frequency range of the meter), see Fig. 1. When using a crystal diode probe, be certain to use the probe that is designed for use with the meter. Failure to observe this requirement will result in misleading voltage measurements.

The use of proper test probes is equally important in making waveform observations and peak-to-peak voltage measurements on an oscilloscope. Specially designed probes and cables are furnished with modern oscilloscopes that match the mechanical and electrical characteristics of the scope input circuitry. This provides for shielding, right out to the probe tips, minimizes hum and stray signal pick-up. Some oscilloscopes employ test probes that incorporate a switch that provides for both direct and low-capacitance probe application, see Fig. 2. When the probe is set for direct application the scope picks up voltage information with maximum sensitivity, but since the direct probe tends to load high frequency circuits it must be used with discretion. When set for low-capacitance operation, the probe shunts the circuit under test with very little capacitance and provides for peak-to-peak voltage measurements in high-frequency high-impedance circuits that could normally be completely upset by the shunt capacitance of a direct

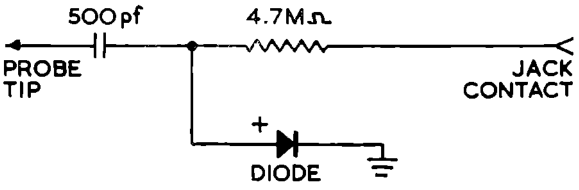


Fig. 1 — Crystal Diode Probe Used With a Vacuum Tube Voltmeter.

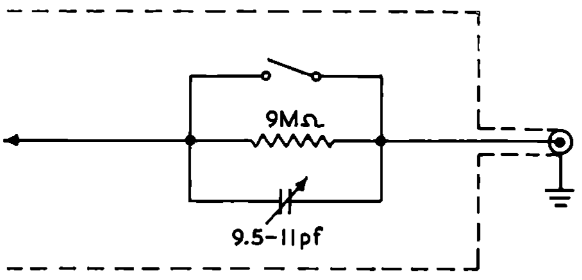


Fig. 2 — Direct Low-Capacity Probe.

probe and cable. Remember, however, that the application of the low-capacity probe attenuates the signal amplitude; don't forget to take this in consideration when making voltage measurements.

Signal tracing (demodulator) probes are available for use with most oscilloscopes; they are designed to be used as a signal indicating device rather than a voltage measuring instrument, see Fig. 3. This type of probe provides a means of observing response characteristics of individual high-frequency circuits. The low input capacitance of the demodulator probe permits its use in high-frequency circuits of television receivers without any serious detuning of the amplifiers. Avoid confusing crystal diode probes designed for use with a vacuum tube voltmeter with a demodulator probe intended for use with an oscilloscope. Each is designed for a specific purpose.

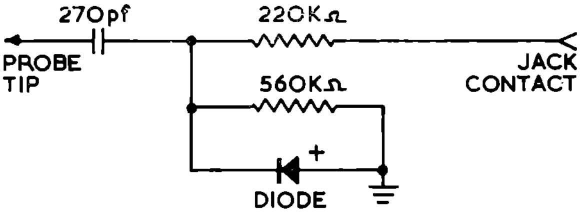


Fig. 3 — Demodulator Probe Used With an Oscilloscope.

Remember that the test probe is the all-important link between the vacuum tube voltmeter of oscilloscope and the circuit under test. Application of the right test probe at the right time is essential if dependable information is to be obtained from the use of your test equipment.

(With acknowledgements to RCA)

NEW RELEASES

JAN-1N538, JAN-1N540

JAN-1N538 and JAN-1N540 are military versions of the popular 1N538 and 1N540 silicon rectifiers of the diffused-junction type. These types are intended especially for use in power supplies of military equipment requiring rectifiers capable of operating at dc forward currents up to 750 milliamperes and temperatures ranging from 65° to +165°C. JAN-1N538 meets the requirements of military specification MIL-E-1/1084A dated January 28, 1958. JAN-1N540 meets the requirements of military specification MIL-E-1/1085A dated January 28, 1958.

2N1213 — 2N1216

These four thyristors form a new family of high-speed bistable switching-type transistors utilizing the JEDEC TO-5 package. They are designed for use in industrial and military data-processing systems, telephone switch boards, and automatic-control systems. These germanium p-n-p diffused-junction types combine the desirable features of Mesa transistors and thyratrons, are bistable, and perform like a switch with a memory. Like thyratrons, these unique semiconductor devices, once triggered, remain "on" even though the triggering (base) voltage is removed. Unlike thyratrons, they can be turned "off" by applying a voltage of reverse polarity to the control electrode (base).

2N1384

The 2N1384 is a germanium drift-field switching transistor combining exceptionally high-current and high-dissipation capabilities with high switching speed for use in industrial and military data-processing systems. This new transistor features:

collector current rating	500 max.	ma

transistor dissipation rating
  at 25°C .... 240 max. mw
minimum dc current transfer
ratio at $I_c = -200$ ma 20
maximum stored base charge
for $I_c = -10$ ma and
  $I_b = -1$ ma .... 800 coulombs

These features, in particular the high-collector-current and high transistor-dissipation rating, make the 2N1384 especially useful in saturated memory-core-driver, pulse-amplifier, inverter, flip-flop, and logic-gate circuits where the use of such saturated circuits were previously limited by the low-current and low-dissipation capabilities of conventional drift-field transistors.

2N1491, 2N1492, 2N1493

These are double-diffused n-p-n silicon mesa transistors for high frequency applications in industrial and military equipment. They have alpha cutoff frequencies of 250, 275 and 300 Mc respectively, with a high temperature rating of 175°C and a free-air dissipation of 0.5 watt at 25°C. These units are particularly useful in large-signal power-amplifier, video amplifier and oscillator circuits operating in the hf and vhf regions.

2N1511, 2N1512, 2N1513, 2N1514.

These are four new high-power diffused-junction silicon transistors and are the industry's first silicon power units in the JEDEC TO-36 stud-type cold-seal package. These units are electrically indentical with the popular silicon types 2N1487, 2N1488, 2N1489, and 2N1490 respectively, but utilize the single-ended stud package.

2N1524, 2N1525, 2N1526, 2N1527.

Four new germanium p-n-p drift-field transistors for if amplifier and converter service, the 2N1524, 2N1525 are identical except for case size; the same applies to the 2N1526, 2N1527. The 2N1524 and 2N1525 are capable of a maximum power gain of 54.4 db, with a gain of 33 db in a neutralized 455-Kc single-stage amplifier circuit. The 2N1526 and 2N1527 have a maximum power gain of 48.9 db, with a useful conversion power gain of 35.8 db in an AM broadcast receiver.

2N1631, 2N1632, 2N1633, 2N1634, 2N1635, 2N1636.

These are six new germanium p-n-p drift field transistors for use primarily in AM broadcast band receivers. The 2N1631, 2N1632 are for rf amplifier service, the 2N1633, 2N1634 for if amplifier service, and the 2N1635, 2N1636 for converter service. Each paired type is identical with the other except for case size.

The 2N1631, 2N1632 have a maximum power gain of 47.7 db at 1.5 Mc and an unneutralized useful power gain of 25.6 db. The 2N1633, 2N1634 have a maximum power gain of 55.7 db, and a gain of 36.7 db in a single-stage neutralized 455-Kc amplifier circuit. The 2N1635, 2N1636 have a maximum power gain of 55.7 db, and a conversion power gain of 36 db in a self-excited converter circuit.

2N1637, 2N1638, 2N1639

These are three new germanium p-n-p drift field transistors for use primarily in AM broadcast band automobile radios. The 2N1637 is intended for rf amplifier service; it features a maximum power gain of 47.7 db and a useful unneutralized power gain of 25.6 db. The 2N1638, for if amplifier application, has a maximum power gain of 61.5 db and a useful unneutralized power gain of 36.6 db. The 2N1639 has a useful conversion power gain of 37 db at 1.5 Mc.

6BN6

The 6BN6 is a beam valve intended especially for use as combined limiter, discriminator, and audio-voltage-amplifier in TV and FM receivers. This 7-pin miniature type is also useful in limiter, sync-separator, and sync-clipper circuits of TV receivers. The 6BN6 is provided with separate base pins for the cathode and for grid No. 3 (quadrature grid). This basing arrangement makes this valve especially useful in quadrature-grid FM discriminator circuits.

4015

The 4015 is a new travelling-wave tube incorporating periodic-permanent-magnet focusing. The 4015 is an intermediate-power amplifier tube intended for use in X-band microwave systems. It

THERE ARE MORE NEW RELEASES ON PAGE 228

AWV 2N217S TRANSISTOR

Tentative Data

The AWV 2N217S is an hermetically-sealed p-n-p germanium alloyed junction transistor intended primarily for use in audio frequency medium-power output stages. The AWV 2N217S is available in matched pairs if required, giving 1 watt output in a Class B push-pull stage when used with a heat sink, at ambient temperatures up to 55°C (131°F). The 2N217S uses a TO-1 case and outline, as used for 2N217. Separate clip-on sleeve or flag-type cooling fins are available.

Maximum Ratings (Absolute)

Collector-base voltage	–27 volts
Collector-emitter voltage (emitter cutoff)	–27 volts
Collector-emitter voltage (resistance between emitter and base <500 ohms)	–27 volts
Emitter-base voltage	–12 volts
Storage Temperature	–55°C to +85°C
Junction Temperature	85°C

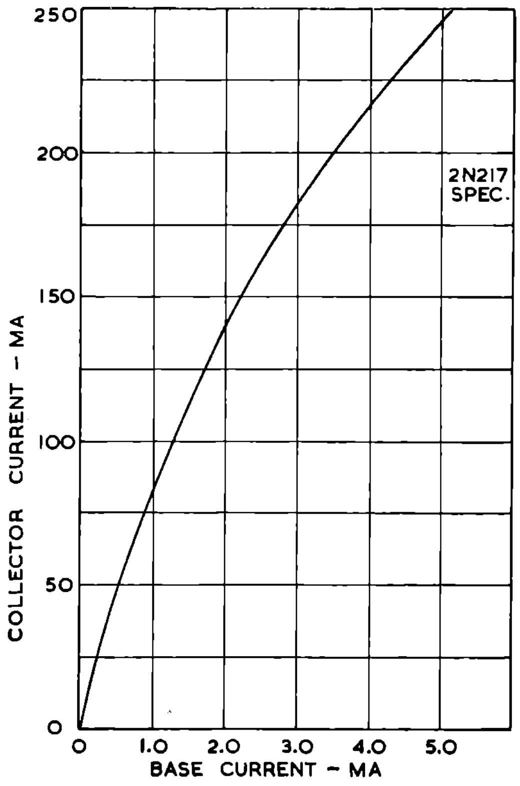


Fig. 1 — Current Transfer Characteristic of AWV 2N217S.

Characteristics (At 25°C unless stated)

Thermal resistance between transistor element and can surface (max)	115°C/w
Thermal resistance between transistor element and free air using a flag-type fin attached to a 4-square-inch horizontally-mounted heat sink (max each transistor)*	160°C/w
Thermal resistance between transistor element and free air using a sleeve-type heat fin (max)	225°C/w
Collector reverse current at $V_{CB} = -12$ volts and I_E = zero:	
Typical at 25° C	—5 μa
Maximum at 25°C	—12 μa
Maximum at 70°C	—200 μa
Collector reverse current at $V_{CB} = -30$ volts and $V_{EB} = -3$ volts, (max)	—20 μa
Emitter reverse current at $V_{EB} = -12$ volts and I_C = zero, (max)	—16 μa
DC current transfer ratio h_{FE} at $I_C =$ 150 ma and $V_{CE} = -1$ volt, (typical)	70
Alpha cutoff frequency f_{ab} at $V_{CB} = -6$ volts and $I_C = -1$ ma, (typical)	1.5 Mc
Extrinsic base resistance r_{bb}', (typical)	70 ohms
Saturation voltage, collector-emitter V_{CESAT}, at $I_C = -300$ ma and $I_B = -30$ ma, (max)	0.3 volt
Ratio of h_{FE} at $I_C = -300$ ma to h_{FE} at 100 ma (min)	0.6
Matching of pairs, h_{FE} at 75 ma, within	1 db

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* Thermal resistance between can surface and free air using flag-type fin and a heat sink will vary with the design mounting of the heat sink. For a 4 square inch plate mounted horizontally and holding two transistors this thermal resistance has a typical value of 45°C/w per transistor. This must be added to the thermal resistance (115°C/w) between the transistor element and the can for each transistor to determine the overall temperature drop.

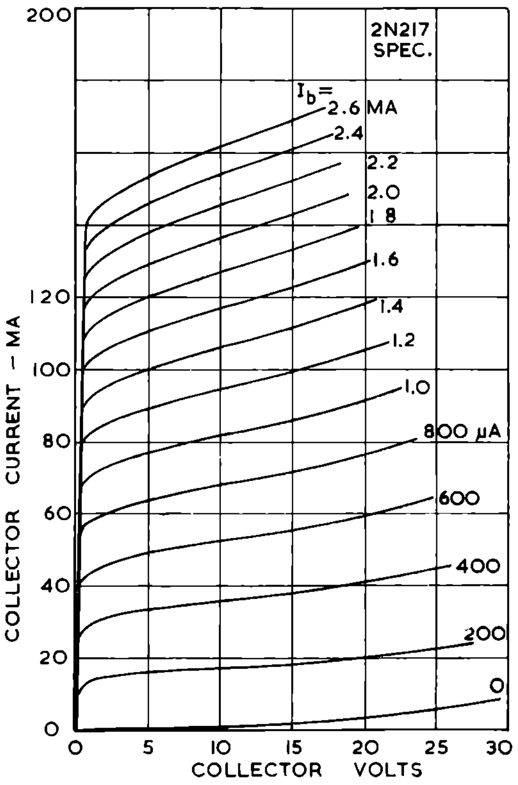

Fig. 2 — Collector Characteristics of AWV 2N217S.

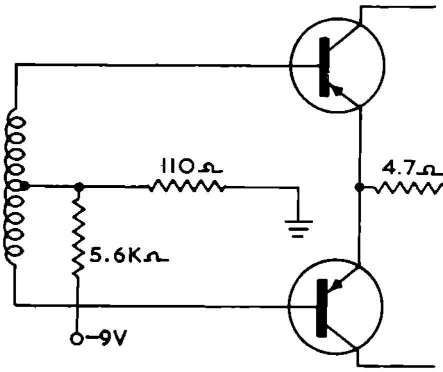

Fig. 3 — Typical Class B Audio Amplifier Circuit using AWV 2N217S Transistors.

Typical Operation in Push-Pull Class B Audio Amplifier using Sleeve-type Heat Radiating Fin.

$T_a = 20°C$, $f_o = 400$ cps

Unless otherwise specified, values are for two transistors operating with the bias supply circuit shown in Fig. 3.

DC Supply Voltage	9 volts
Zero-Signal dc collector current	3.0 ma
Zero-Signal dc base-emitter voltage	150 mv
Peak Collector Current per Transistor	150 ma
Signal Source Impedance, per transistor	800 ohms
Load Impedance, per collector	50 ohms
Power Gain, measured at primary of output transformer	24db
Maximum Signal Power Output (measured at primary of output transformer)	800 mw
Maximum Operating Ambient Temperature:	
Steady tone amplification	40°C
Broadcast programme amplification	55°C
Total Harmonic Distortion:	
At Power Output = 800 mw	10%
At Power Output = 50 mw	1.5%

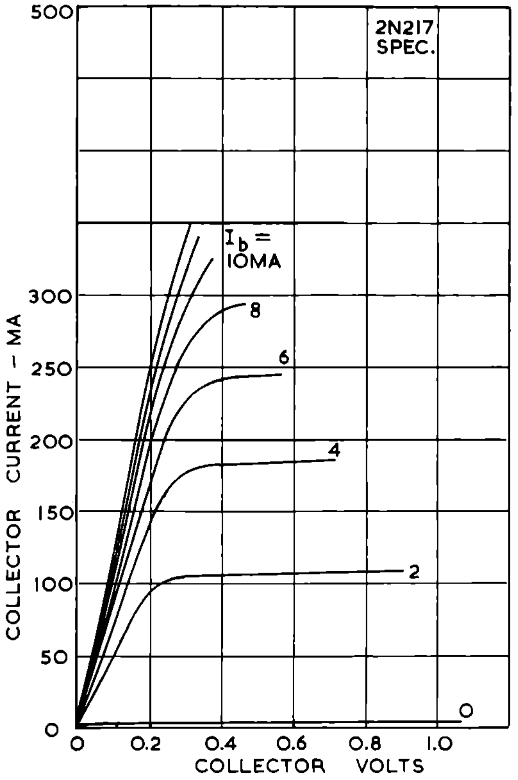

Fig. 4 — Collector Characteristics of AWV 2N217S.

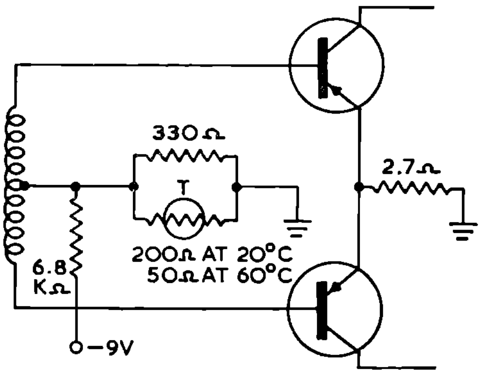

Fig. 5 — Typical Class B Audio Amplifier Circuit using AWV 2N217S Transistors.

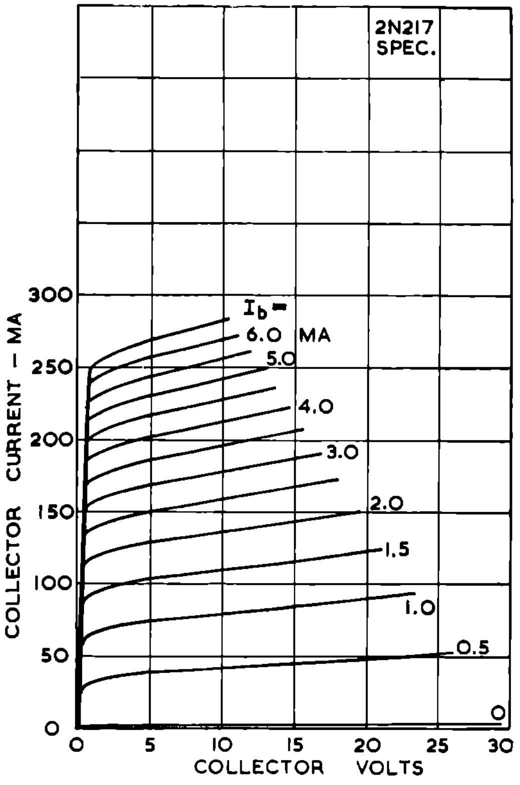

Fig. 6 — Collector Characteristics of AWV 2N217S.

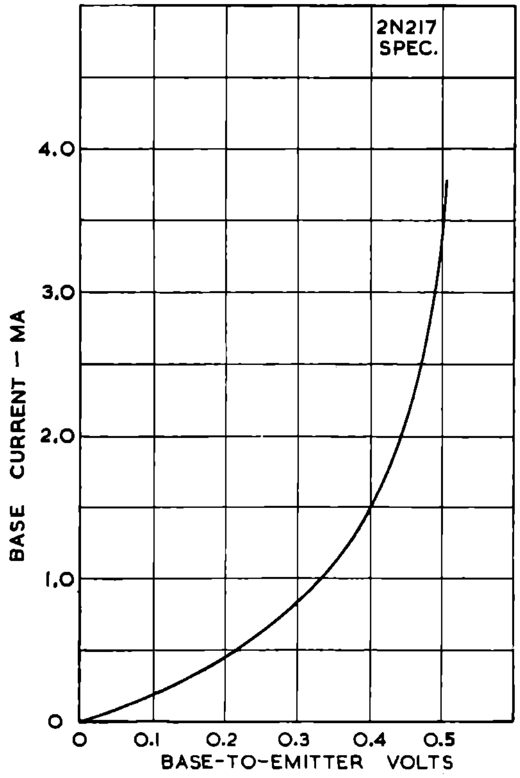

Fig. 7 — Base Characteristics of AWV 2N217S.

Typical Operation in Push-Pull Class B Audio Amplifier using Flag-type Heat Fin Mounted on a 4 square inch Heat Sink.

$T_a = 20°C$, $f_o = 400$ cps

Unless otherwise specified, values are for two transistors operating with the bias supply circuit shown in Fig. 5.

DC Supply Voltage	9 volts
Zero Signal dc collector current	3.5 ma
Zero Signal dc base-emitter voltage	160 mv
Peak Collector Current, per transistor	210 ma
Signal Source Impedance, per transistor	800 ohms
Load Impedance, per collector	31 ohms
Power Gain, measured at primary of output transformer	27 db
Maximum Signal Power Output, (measured at primary of output transformer)	1.1 w
Maximum Operating Ambient Temperature:	
Steady tone amplification	40°C
Broadcast programme amplification	55°C
Total Harmonic Distortion:	
At Power Output = 1.1 watt	8.7%
At Power Output = 50 mw	1.7%

NEW RELEASES

(Continued from page 224)

can deliver 1-watt of cw power throughout the frequency range of 8000 to 12,000 Mc. The typical small-signal gain is 37 db in this range.

Although the 4015 is a specific commercial type, variants of this prototype can be provided to satisfy particular equipment requirements. These variants may take the form of minor mechanical modifications and/or different ratings to cover requirements of a specific system. For example, variants are possible which would yield a higher gain over a narrower frequency range; a tighter fine-gain structure, and so on.

7649

The 7649 is a new Cermolox valve — with its ceramic-metal construction and perfectly-aligned grids — designed specifically for pulse applications where dependable performance under severe shock and vibration is essential. This very small, forced-air-cooled, uhf beam power valve is intended for use in grid-pulsed and plate-and-screen-pulsed rf oscillator and amplifier service at frequencies up through 2000 Mc in compact airborne, mobile and fixed equipment. When used under CCS conditions as a plate-and-screen-pulsed rf amplifier in a cathode-drive circuit at 1215 Mc with a 10-microsecond pulse duration and 0.01 duty factor, the 7649 can deliver about 4500 watts at peak of pulse with a driver power output of about 450 watts at peak of pulse.

7650, 7651

The 7650 and 7651 are ceramic coaxial-electrode forced-air-cooled, uhf beam power valves designed for use in missiles and in compact aircraft and mobile equipment. Both types are rugged and reliable — able to take vibrational accelerations of 20g and to withstand shock impacts as great as 500g. Both valves have maximum plate dissipation of 600 watts, and can be operated with full ratings at frequencies up through the Aeronautical Radio-Navigation Band of 960 to 1215 Mc, and are useful at higher frequencies. The 7651 is designed for pulse operation and can deliver a peak power output of nearly 40 kilowatts at 1215 Mc. The 7650 when used under CCS conditions as an rf power amplifier and oscillator in class C telegraphy service, has a maximum plate-voltage rating of 2500 volts and a maximum plate-input of 1250 watts.

7746

The 7746 is a new head-on multiplier phototube intended for use in scintillation counters for the detection and measurement of nuclear radiation and in other applications involving low-level light sources. Guaranteed for every 7746 is a pulse-height resolution capability of under 9 per cent by actual measurement in factory test equipment using Cesium 137 and Thallium-activated Sodium-Iodide crystal. In addition, the 7746 has extremely small spread in electron-transit time, high-current amplification, and a newly developed enclosed, in-line dynode structure. The spectral response of the 7746 covers the range from about 3000 to 6500 angstroms. Maximum response occurs in the blue region at approximately 4400 angstroms. When operated at a supply voltage of 2000 volts, the 7746 has a median luminous sensitivity of 1200 amperes per lumen and a current amplification of 16,000,000.


AWV