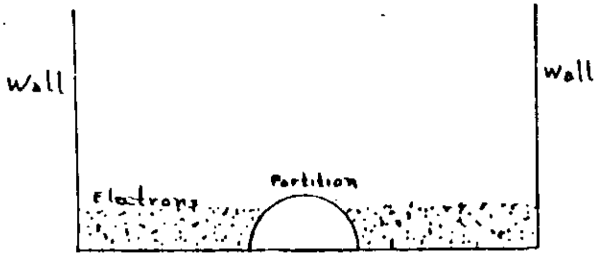
The physical basis for this invention is the surprising amount of power that is available if the fluctuation energy of heated electrons can be efficienctly converted to useful d.c. power. This fluctuation energy in its familiar form is considered a bad thing, as it is the source of the amplifier noise that limits the sensitivity of all electronic amplifiers including radio and TV receivers. To understand the nature of this fluctuation energy, the following drawing is useful.

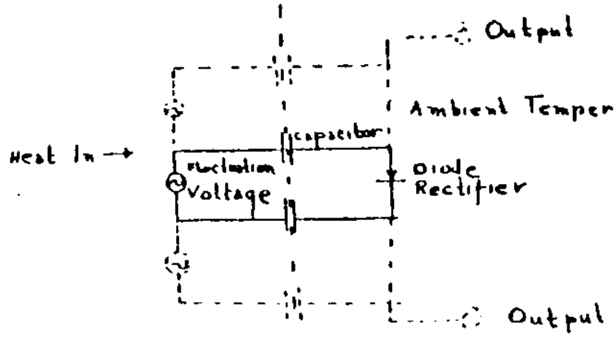


Consider the electrons on each side of the partition or potential barrier to be colliding with each other, the walls and the partition dividing the two groups. Also, consider that occasionally an electron will obtain enough velocity from these collisions to cross over the top of the partition. On the average, this will occur with equal frequency in both directions just as heads or tails will occur with equal frequency on the average in tossing a coin. But at any instant it can be expected that there will be an unequal number that have crossed in one direction as compared to the opposite direction. This change in the number of electrons on each side of the partition creates an instantaneous voltage difference across the partition. This, then, is an example of fluctuation energy that results from the thermal motion of electrons. Similar fluctuation energy occurs for resistors as well as the other electrical circuit components. The fluctuation energy that exists at the input of a radio receiver is called noise power or noise voltage. The only way to reduce this noise voltage is to lower the temperature of the component which also lowers the [illegible]lty of the electrons.

The purpose of this invention is to efficiently convert the fluctuation voltage resulting from the heated electron motion to a useful form of output power. The potential power output from this voltage source has apparently been overlooked as it is an impressive amount if it can be efficiently converted to d.c. power. This large potential power output exists because an important and fundamental aspect of the fluctuation energy output of a circuit component is that it is independent of the size and number of electrons in the component. This means that by making the component smaller, the power output per unit volume of the component is increased. The available fluctuation energy per component is small as it is only of the order of a microwatt. However, there is a large potential power output per unit volume for small components. As an example, if the circuit size is reduced to consist of 1 million free electrons, the total power output from the circuits that could be fabricated from 1 cubic centimeter of the metal would be 1000 billion watts. This example is given to show that material costs can be negligible as the circuit size is reduced. This potential power output requires, of course, a power input such as from solar energy of at least 1000 billion watts.

To realize this potential also requires the ability to fabricate circuits of these small dimensions. As Prof. Feynman, the Nobel Laureate in Physics, stated in an article aptly titled "There's Plenty of Room at the Bottom", there is no foreseeable limitation in this direction as he foresees the development of precise circuit size of a few atoms in width and with the tolerance on dimension size being that of a single atomic layer. Also, as we all know from the rapidly expanding field of micro electronics, the manufacturing costs are rapidly decreasing as is currently being demonstrated for the pocket calculators.

The purpose of the invention is to give the design of a circuit that will enable the efficient conversion of the available fluctuation energy to useful output power. This design is simple as can be seen from this drawing:



The input fluctuation voltage is rectified by a diode to produce a d.c. voltage input to the load. For this circuit the fluctuation voltage generator, which can be a resistor or another diode, is maintained at a higher temperature using input power from solar energy or other sources. The rectifying diode is maintained at the ambient temperature with a vacuum thermal barrier separating the input power from the rectifying diode. That is all there is to the circuit. Analysis of the circuit and extensive computations show that the maximum theoretical efficiency of the Carnot cycle for the operating temperatures can be achieved if significant thermal losses can be prevented from occurring across the thermal barrier. This result was shown in a paper published in the Physical Review in October 1974.

The vacuum thermal barrier can prevent these losses provided the spacing support for the vacuum can be at a small fraction of the total area. Analysis of the stresses and thermal environment indicate this can be done, however, the actual fabrication of this thermal barrier represents the big step that will demonstrate the feasibility of the concept.

One method of fabrication that has been designed consists of thin films of dielectric substrate material such as quartz maintained in tension on one or both sides of the thermal barrier. This design of the film support struct ollows the analysis shown in the Applied Optics paper in Feb. 1975 (pp. 526-536) in which the tension exerted at the perimeter of the film maintains an optically flat surface for the film. The distortions under environmental forces can easily be computed for the film support structure and several alternate designs for the film have been analyzed. The results of the analysis show that thermal conduction losses can be maintained within the limit required for the thermal barrier. Also, the computations show the design can withstand the thermal bending stress, radiation pressure, and the gravitational forces. The design can accommodate several modifications and one of these is to include an additional spaced film on the outside surface of each film support structure. These additional films could shield the inside films and circuits from the outside environment and atmosphere while maintaining the required thermal steady state values.

The design alternatives that were analyzed do show that whereas the solution to problems posed by thermal conduction losses require careful attention, there are apparently no inherent physical limitations to the concept that will prevent the design of a satisfactory thermal barrier. The power output potential per unit area of the film or rigid supporting substrate is dependent on how many circuits are placed per unit area. For circuits spaced 10^{-3} cm apart and with an adequate energy input, the power output potential is 10 kilowatts per sq. meter of film area. For spacings between 10^{-5} cm and 10^{-6} cm apart and with an adequate energy input, the power output potential is 1 billion watts per sq. meter of film or rigid substrate area.

In the development of this invention, the first step will be to fabricate and test a model containing the thermal barrier. This will be the decisive and important step required to open the way for parallel development of the device for many applications. If this first step verifies the theory, then rapid and predictable progress can be expected. These parallel developments include applications for outputs ranging from outputs below the microwatt level of heat pump capacity for lowering the temperature of the input circuit of a low noise receiver to outputs above the hundred megawatt level for space solar power stations. These applications include the following:

1. Earth Solar Power. By concentrating the solar radiation a high input temperature for the device can be achieved so as to enable efficiencies of 80% to 90% to be achieved for the power conversion of solar energy. The present maximum achievable efficiency of silicon solar cells is 15%. A design has been made for a thin solar concentrator layer that can effectively increase the temperature of the first layer so as to obtain these efficiencies. Other types of concentrators of the solar energy can be also used including either the MIT mirror concentrator announced last week or the MIT Lincoln Lab grid concentrator announced this spring.

2. Steam Power Plants. Steam power plants are limited to 40% efficiency for electric power generation using fossil fuels. Using fossil fuels, furnace temperatures of 1700° can be achieved and this would enable power conversion efficiencies of 80% to be achieved using this device.

3. Topping and Tailing. The wider temperature operating range of the device for efficient power conversion can enable the device to work off the unusable temperature of the waste heat of many other types of power plants. The range of efficient operation for this device can be from 350°K to the highest furnace temperature so that either by tailing or topping the efficiency of the other types of power plants can be increased. This increase, for example, has the potential of doubling the power output of existing steam power plants.

4. Space Solar Power Stations. The high output power per unit weight of the micro modules of this invention can enable a weight reduction of an order of magnitude or more to be achieved over the weight of a silicon cell solar power station if similar efficiencies were achieved. In addition, if the potential

conversion efficiency of the device of 90% for the space environment is achieved, then the weight reduction and/or power output advantage over a space solar power station using silicon cells is further increased by several fold.

5. <u>Heat Pump or Refrigerator.</u> The reversible cycle resulting from the minimization of losses enables the same thermal cycle to be used in a heat pump mode and a refrigeration mode in addition to the power conversion mode. This mode is the most difficult mode to explain but it can be utilized by simply increasing the voltage at the output terminal so as to reverse the current through the circuit. There is, then, an input of power to the circuit at the former output terminal. This, in effect, takes heat away from the cold side and delivers it to the hot side. An important aspect of this mode that is often overlooked is that for most operating temperature ranges, much more heat can be delivered to the hot side than can be achieved from the same input power delivered directly to the hot side. This enables the efficiency of the input power for heating purposes to be increased several fold.

For home use this reversible operation can result in large energy savings. The same device can be used to generate power for the home, air conditioning for the home, and heating for the home. To give an example of this saving, the power in 1 square meter of sunlight can be converted into 1 KW of power output by the device operating in a power conversion mode for the home. This output power can be stored and later used to operate the device in a heat pump mode for the home. Then if, for example, this heat pump mode is operated with the low temperature reservoir at 32°F and the high temperature reservoir at 90°F, the heat equivalent of 10 KW hours of power can be delivered to the high temperature for each 1 KW hour of output power stored from the solar power conversion.

Finally, it may be appropriate to mention an application to an area that brings the utilization of fluctuation energy full cycle and for this application the circuit is used in a refrigeration mode to reduce the input noise voltage and increase the sensitivity of radio receivers and amplifiers. For this application a multi-stage circuit of micromodules is sufficient to produce the microwatt heat pump capacity required to lower the temperature of the input stage of the receiver to very low value so as to effect a large decrease in the bad fluctuation energy or noise power existing at the input of the receiver.

For the above applications and others, there can be a parallel development as all applications depend on the same basic circuit.

In considering this invention, it is perhaps useful to attempt to estimate and predict some of the long range applications that will occur if the initial step in the development is successful. In approximately 5 to 10 years it could be expected that the mass production could be fully automated using a microfabrication technique such as X-ray lithography to reproduce the circuits. Even at that stage, it can be expected that manufacturing costs will be the dominant cost as the material cost can be made truly negligible. This can easily be seen from the example given in the Physical Review article of October 1974, which shows that a cubic meter of these circuits had the capability of delivering 100 KW to each person in a world population of 10 billion. Regardless of the material cost per unit volume of the material in the circuits, this result indicates how truly negligible the material cost per kilowatt output of power capability would be. This is even more evident when it is realized that if tunnel diodes are used, all the circuit components can be made of relatively inexpensive metals and, if supporting films are used, the support structure can also be made of an inexpensive material such as glass.

On the basis of this assessment, it appears that, provided the first step in the development verifies the theory of the device, that it is reasonable to expect that the cost per kilowatt will be far below the $200 level that has been stated to be the level at which solar energy becomes more attractive for most applications than the alternative methods of power generation. The size of this device required to generate 1 kilowatt of solar power is only 1 sq meter in area with the thickness given by the thickness of the film or rigid substrate support structure. The material costs will be negligible and it appears reasonable to expect that the cost of manufacturing will continually decrease with time and with the quantity being manufactured.

As an example of an application for which large quantities are required, consider the application of solar power for the home. A MIT study has shown that if 125 watts of electric power plus approximately 700 watts of thermal heat power into water was made available to a home from solar power, a roof top solar energy unit costing $5000 would pay for itself in 5 to 7 years. It would seem reasonable to expect this performance to be feasible early in the development of this technique as less than 2 sq meters of effective circuit area exposed to the direct sun can achieve this performance even if we assume only a 50% efficiency is achieved for the solar power conversion. If this effective circuit area was increased to 20 sq meters or approximately 10% of a typical roof area, power output of 10 kilowatts output power could be obtained for a 50% circuit efficiency. This output power, if stored, is approximately 40 times the present electric power needs of a typical home or about 13 times the heating energy needs of a home. The heat energy requirement for a home can be reduced 10 fold if the device is also used in the heat pump mode for the operating conditions given in the previous example. For this example, the 10 kilowatts output power represents 130 times the heating energy needs of a typical home. For this almost universal application, it seems reasonable to expect, if the first step in the development verifies the theory, that since the material costs are negligible for the 10 kilowatt device and since the manufacturing cost would continue to decrease with time for the high volume production, that by perhaps 1990 the cost of each unit will be much less than $200.

Trying to ask even further down the road, it becomes necessary to speculate and perhaps dream a little, but it does seem worthwhile to hope that the day will sometimes come when a lightweight portable inexpensive solar power unit can be available to everyone as this may be the only way the people of the undeveloped regions of the world can lift themselves by their bootstraps. Then, these people can more efficiently move about to develop their land without awaiting the development of large power stations and expensive distribution systems. The most hopeful aspect of this dream is that this source of power is effectively limitless and will not create any thermal or atmospheric pollution of our planet.

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For own company and as consultant investigated new concepts for signal relays and for power conversion. This involved studies in the fields of space physics, optical and microwave reflectors and grating arrays, and energy fluctuation theory. Some of the work led to a program at Stanford Research Institute for a space launch of original concept of communication satellite and other work led to papers on novel concepts in the above fields. Currently working on a National Science Foundation Grant on a study of power conversion.

Earlier experience at Mitre, Cornell Aeronautical Laboratories, University of Michigan and University of California as a research physicist and project engineer in fields of space physics, sensor and data collection systems, thermal design of power systems and statistical mechanics.

PUBLICATIONS: "Power Conversion of Energy Fluctuations" Physical Review A, October 1974.

"Space Reflectors for Radar and Astronomy" Applied Optics, February 1975.

"Signal Relay System Using Large Space Arrays" IEEE Trans. on Communications, December 1972.

Earlier papers in fields of space physics, high energy radiation fields, stability regions of charged particle motion and thermodynamics in Technical Reports on work at Mitre, Cornell Aero. Labs., University of Michigan and University of California Radiation, Lab.

PATENTS: Communication Satellite, U.S. Patent No. 3,427,623, issued February 11, 1969.

Power Conversion of Energy Fluctuation, U.S. Patent Application filed September 15, 1975.