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(71) Applicant and
(72) Inventor: SHANEFIELD, Daniel, J. [US/US]; 119 Jefferson Road, Princeton, NJ 08540 (US).

(74) Agents: WOODBRIDGE, Richard, C. et al.; Woodbridge & Associates, P.C., P.O. Box 592, Princeton, NJ 08542 (US).

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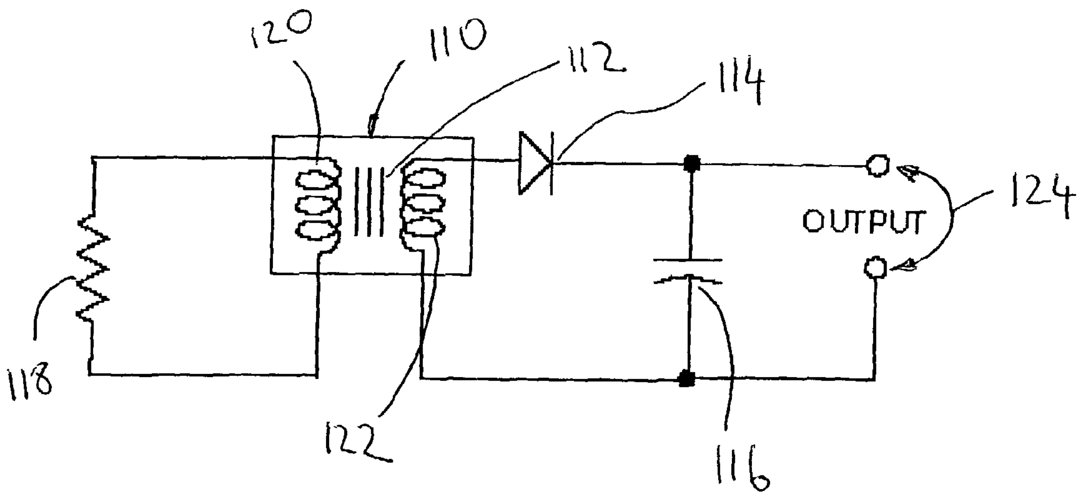
(54) **Title:** DEVICE FOR CONVERSION OF ENVIRONMENTAL THERMAL ENERGY INTO DIRECT CURRENT ELECTRICAL ENERGY



(57) **Abstract:** Thermally driven, nearly-random motions of electrons in an electrical conductor cause some of those electrons to pass through a rectifying diode (114), into a capacitor (116), where electric charge is accumulated. In some embodiments of this invention, a transformer (110) can be used to increase either the voltage or the current of the electricity that passes into the rectifying diode (114). A multiplicity of the capacitors can be wired in parallel to increase the total accumulated charge. Practical use can be made of the accumulated direct current electricity that is thus made available.

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TITLE: DEVICE FOR CONVERSION OF ENVIRONMENTAL THERMAL ENERGY INTO DIRECT CURRENT ELECTRICAL ENERGY

This application claims the benefit of US non-provisional application 10/112,655 filed on 03/29/2002, which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention.

The present invention relates to energy conversion devices, and in particular, to a specific device that converts nearly random thermal energy from the ambient environment into direct current electrical energy.

2. Brief Description of the Prior Art.

Many types of devices are known which can convert various energy sources into direct current electrical energy, a common example being a photovoltaic semiconductor diode (solar cell). However, in order to provide useful amounts of electricity, solar cells require a fairly powerful source of light, which is not always available.

Another known energy conversion device is the thermocouple, which can convert low intensity thermal energy into direct current electrical energy. An example is disclosed by Stachurski in U.S. Pat. No. 4,125,122, but such a device requires both a heat source which is at a relatively high temperature, and a heat sink which is at a relatively low temperature, and that situation is not always present.

It is known that a main conductor of electricity, which is at substantially the same temperature as the ambient environment, can spontaneously emit weak, nearly random pulses of electricity into wires that are attached to said main conductor. This is true, even if the average temperature measured by a slow means such as by an ordinary mercury thermometer is substantially the same at all places in the main conductor and the wires, so that a difference in average temperature is not required or present.

The weak pulses of electricity that are thus emitted are nearly random in both voltage and timing, and they are ordinarily considered to be "electrical noise." Various forms of electrical noise are known, some of which depend on an external source of electrical power passing through the conductor. Another form of electrical noise is known to be spontaneous, with no external electrical power being needed, and with its energy coming from the ambient thermal motion of electrons, atoms, and molecules in all materials at ordinary temperatures. This spontaneous, nearly random electron motion exists in all conductors, nonconductors, and somewhat resistive conductors ("resistors") which are at ordinary "room temperature," which is often assumed to be approximately 21 degrees Centigrade (Celsius).

Some of these electricity pulses go in opposite directions from each other, so they are not the "direct current" that would always go in the same direction. These pulses do not have the form of repeating sine waves, so they are not ordinary alternating current (ac), but they can be considered to be a special, nearly-random form of ac.

The effective voltage (similar to an average, but not quite the same) that is used to calculate the wattage of ac power is called the root mean square, or RMS voltage, when the ac electricity is in the form of sine waves. The RMS voltage is described in Shanefield, D.J. *Industrial Electronics for Engineers, Chemists, and Technicians.* N.Y., Noyes, 2001, p.156, which is hereby incorporated by reference. For convenience, the RMS concept can be applied to electrical pulses that are not in the form of sine waves, but then this concept only approximately follows the mathematics of sine wave ac.

Nearly-random pulses of electricity that are spontaneously emitted from a main electrical conductor, into wires that are connected to it, have RMS voltages that are dependent on the ambient temperature and also on the electrical resistance of the conductor. For a conductor that is somewhat resistive and is at a temperature of 17 degrees Centigrade (Celsius), a typical RMS voltage is approximately 0.002 volt according to Oliver, B.M. *Electrical Noise.* IEEE Press, New York, 1977. Edited by Madhu S. Gupta, p. 134.

An electrical resistor can be used as part of a thermometer, as disclosed by von Thuna in U.S. Pat. 3,937,086. The strengths of the spontaneously emitted electrical pulses emanating from the resistor are proportional to the ambient temperature according to known mathematical relationships. Because the emitted pulses at ordinary room temperature are usually quite weak, von Thuna's invention is mainly intended for use in measuring very high temperatures, as typically found inside nuclear reactors. The preferred embodiment cited by von Thuna measures temperatures of approximately 1500°C. The voltages of those pulses are increased by a 57:1 step-up transformer, before being used to resonantly exite a tuned circuit. They are then amplified by transistors in circuits requiring external power.

In van Thuna's thermometer, thermally driven electrical energy spontaneously goes from the resistor to the primary coil of the transformer, with no other source of electrical energy added to that part of the circuit. Although the electrical energy obtained from the resistor is weak, it is still strong enough to be used for a practical purpose, in this case to measure temperature. However, von Thuna does not accumulate the spontaneously emitted electricity until after it has been amplified using external power sources.

A thermally driven, spontaneously emitted electrical pulse only exists for a very short time. If that pulse were immediately and directly conducted into a potentially useful device, such as a resistive heating element or an electric motor, that device's own thermally emitted RMS voltage, being of a similar strength and duration, would, on average, oppose the pulse during the same short periods of time. No practical use would be likely, especially if the overall effect is averaged over a longer period of time. Also, the RMS peak voltages and currents are very small. Some method of accumulating the pulses is desirable, without having them act in opposition to each other. Preferably that accumulation should also result in higher available voltages and currents.

If the nearly-random emitted pulses of electricity could be rectified into the form of direct current (dc), then these coulombs of charge could be accumulated in a capacitor (condenser) or a storage battery, over a long period of time. The resultant larger amount of potential energy could become usable for heating, running a motor, and the like.

Another advantage of converting the electricity into the form of dc is that several capacitors or batteries could be switched into a series configuration, and more voltage could thus be obtained, without the necessity of synchronizing the pulse timing (phases) as would be necessary with sine wave ac or nearly-random pulse ac. Also, groups of these storage devices could later be switched into a parallel configuration, providing much greater electrical power, at least for limited periods of time. Integrated circuit technology might allow many thousands of these devices to be used together, in series and parallel.

At first sight, it might seem that there is a serious difficulty with rectifying the low voltage nearly-random pulses by using a PN junction semiconductor diode. Such a rectifying diode device is commonly thought to require a certain minimum voltage (called the forward voltage drop), in order to pass fairly large currents. For example, a typical silicon PN diode requires approximately 0.6 V to drive 1 mA through it, as described in Shanefield, D.J. *Industrial Electronics for Engineers, Chemists, and Technicians*. N.Y., Noyes, 2001, p. 153, which is hereby incorporated by reference. Some other rectifiers such as germanium PN or Schottky metal/semiconductor types have lower voltage requirements, as described on the same page of the same textbook, but these are still reported to need at least 100 times more than the 0.002 volt that is reported to be available from the noise pulses spontaneously emitted from a resistor at room temperature.

An electrical transformer might possibly be used to increase the available voltage of noise pulses. Transformers are explained in for instance, Shanefield, D.J. *Industrial Electronics for Engineers, Chemists, and Technicians*. N.Y., Noyes, 2001, p. 105, which is hereby incorporated by reference. The higher voltages might be imagined to go through a rectifying diode and then be accumulated in a capacitor, for later practical usage. However, the noise pulses tend to be of high frequency, and most transformers are inefficient at high frequencies, because of eddy current losses. Also, most transformers only increase the voltage by factors of approximately 10, and the resulting accumulated power in the capacitor might be imagined to be of only negligible practical use.

Yater in US Patents 4,004,210 discloses a device comprising two conductors at two different temperatures, separated by a thermal and electrical insulator, as the source of thermally driven electrons rectified by a diode and stored in a capacitor as a dc electricity. Yater et al in US patents 5,356,484, 5,470,395 and 5,623,119 discloses similar inventions all requiring the conductors to be thermally and electrically separated and incorporating other limitations or requirements such as the need for quantum well diodes.

SUMMARY OF THE INVENTION

The object of this invention is to provide useful direct current electrical energy that is generated from the ambient environmental heat energy present in air, liquid, or solid that is in contact with the novel device, said environmental heat being conducted into the novel device, and being converted to direct current electricity within the device.

The present invention accomplishes this energy conversion by having a source of thermally agitated electrons, which are exhibiting substantially random motion, coupled to an electron accumulator by some means of selectively transmitting some of the electrons from the source to the accumulator.

In one embodiment, the present invention provides the combination of an electrical conductor, a rectifying semiconductor diode with low leakage current in the reverse direction, and a capacitance to accumulate direct current pulses in the form of useful electric charge. This combination is a novel device that generates useful direct current electricity from the energy present in ambient environmental heat. In some embodiments of the present invention a low loss electrical transformer is also used.

That such a simple setup can be used to accumulate useful quantities of electricity is an unexpected result. The assumption in the art is that in such a circuit, the forward voltage drop of the diode far exceeds the thermally generated noise voltage, and therefore no accumulation in the capacitor will occur. However, it appears that at extremely low currents, some diodes require very small forward currents. Such diodes can be used to make the simple circuit of this invention function as an energy accumulator.

In some embodiments the electrical conductor has substantial electrical resistance, such as 470 ohms.

The advantage of this invention over prior art is that useful direct current electricity can be generated without the need for concentrated energy sources such as electrochemical batteries or light sources, and the like, and without the need for two different temperatures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram illustrating an embodiment of the energy conversion device in which an input resistor is attached across the primary of a transformer.

FIG. 2 is a schematic diagram illustrating the use of a conductive wire as the input.

FIG. 3. is a schematic diagram illustrating the use of an open circuit across the primary.

FIG. 4. is a schematic diagram illustrating the circuit without a transformer.

FIG. 5. is a schematic diagram illustrating a circuit for measuring the output current.

FIG. 6. is a schematic diagram illustrating a circuit without an input wire or transformer.

FIG. 7. is a schematic diagram illustrating a circuit with a full wave rectifier.

FIG. 8. is a schematic diagram illustrating a circuit with a voltage doubling rectifier.

FIG. 9 is a schematic cross section of an integrated circuit embodiment.

DETAILED DESCRIPTION OF THE INVENTION

During the course of this description like numbers will be used to identify like elements according to the different figures that illustrate the inventions.

A preferred embodiment of the present invention comprises a transformer 110 having a core 112 with a low eddy current loss, a rectifying diode 114 having low reverse leakage current, a capacitor 116 to accumulate the electric charge and a resistor 118, as shown in the schematic circuit diagram of FIG. 1. The resistor 118 attached across the primary coil 120 of the transformer 110 can have a resistance in the range of as low as 0.1 ohm if it is a point contact, up to as high as 100,000 ohms if it is a bulk resistor. The number of turns in the secondary coil 122 of the transformer can be in the range of from 5 times more than the number of turns in the primary coil 120, up to 500 times more than the number of turns in the primary coil.

A transformer 110 with ferrite ceramic cores (instead of iron cores) can be efficient for high frequency use, especially if designed to have high permeability and low eddy current loss as described in Shanefield, D.J. *Industrial Electronics for Engineers, Chemists, and Technicians*. N.Y., Noyes, 2001, pp. 105,114 and 268, which is hereby incorporated by reference. An inexpensive transformer 110 with low loss and high permeability can be made using a core 112 of manganese zinc ferrite. Typical manganese zinc ferrite rods, such as FR-33 ceramic rods supplied by Ocean State Electronics Corp., Westerly, RI, have a relative permeability of 800 at 1 MHz. In one exemplary embodiment of a transformer core 112, four pieces of FR-33 ceramic rod, each 1.5 inches long, were cemented together to form a closed square. The primary coil 120 of the transformer 110 of this exemplary embodiment consisted of a single turn of enameled 30 gauge copper wire. This arrangement produced sufficient electromagnetic field to provide a useful output in a secondary coil 122 consisting of 200 turns of the same enameled 30 gauge copper wire. The details of this particular transformer 110 are described by way of example only and as one skilled in the art will realize, usable results may be produced using a variety of other coils materials and turns ratios.

In the preferred embodiment, diode 114 was a silicon PN diode with a peak inverse voltage (PIV) rating of 400 volts and useful charge accumulated in capacitor 116. The silicon PN diode had a reverse current of less than 0.1 microampere at 1 reverse volt.

In the embodiment of the invention illustrated in FIG. 1, the resistor 118 is for instance of the "carbon composition" type, made from graphite particles mixed with clay and covered with epoxy insulation, having a resistance of 470 ohms and a tolerance rating of ± 10%. Such carbon composition resistors are described in Shanefield, D.J. *Industrial Electronics for Engineers, Chemists, and Technicians.* N.Y., Noyes, 2001, p.28, which is hereby incorporated by reference.

The charge accumulating capacitor 116 in the embodiment of the invention illustrated in FIG.1 may for instance be a 1 microfarad capacitor made of metallized polypropylene film.

To measure the accumulated charge in the energy conversion device of this invention, the output terminals 124 in FIG. 1 may be attached to a digital voltmeter (not shown) such as, but not limited to, a Model 860 GMM digital voltmeter supplied by the Fluke Corp., Everett, WA. Such a meter has an input resistance higher than 10 MΩ, and therefore wastes very little of the accumulated electricity when measuring.

To demonstrate the energy conversion of the device of this invention, a series of measurements were made.

In each of the measurements, the entire apparatus (including the meter) was enclosed in copper metal screen or aluminum metal boxes, all attached to a water pipe ground connection, in order to isolate the circuits from electromagnetic fields. Because of the presence of radio waves from TV transmitters, cellular phones, and the like, various voltages appeared at the output terminals whenever the shielding was accidentally disrupted or the ground connection had a high resistance. Evidently the transformer and other circuit elements can operate as receiving antennas for radio waves, but that was preventable by shielding.

At the beginning of each of the measurements the output terminals 124 attached to the capacitor 116 and the voltmeter (not shown) were short circuited for 10 seconds in order to discharge any electricity left over from previous measurement. The short circuiting wire (not shown) was then removed, after which the capacitor 116 was disconnected from the voltmeter for 10 minutes or longer, in order to accumulate electric charge. Then the voltmeter was re-attached to the output terminals 124 and the voltage was measured within 2 seconds. The voltage readings slowly decreased after the initial measurement, because the voltmeter drained electric charge out of the capacitor 116 slightly faster than the energy conversion device of this invention was charging the capacitor 116.

Typical voltages accumulated in the capacitor 116 were approximately 0.001 V at 23°C, but these output voltages were lower when the temperature was decreased. At 21° C. the typical output voltage accumulated in the capacitor was 0.0005 V (0.5 mV). In each of the experiments reported below in the present patent application, the entire apparatus (including the meter) was at a temperature in the range of 20°C to 22°C.

Given the relatively simple nature of the circuit described above, the fact that a measurable, useful voltage accumulated in capacitor 112 was an unexpected result. One experienced in the electronic arts, looking at the circuit described above would be inclined to opine that PN rectifying diodes require a forward voltage of about 0.6 V in order to operate. Typical thermally produced noise voltages at around room temperature have RMS values of only about 0.002 V. Even allowing for an increased voltage step up due to the 200 to 1 coil ratio of the transformer, the voltage appearing across the diode would be about 0.4V, well short of that required to operate it.

One experienced in the electronic arts would also likely opine that that germanium or Schottky (metal/silicon) rectifying diodes require slightly lower forward currents to operate, typically around 0.2V. Therefore, if the circuits of this invention do function, they will function even better with these types of rectifying diode 114.

However, contrary to such expectations, neither a germanium PN rectifying diode nor a Schottky (metal/silicon) rectifying diode gave good results when used as the rectifying diode 114 in the embodiment of the invention illustrated in FIG. 1, in spite of low voltage drops of both these types of diode. The reason, in both cases, was deduced to be that, even though the forward voltage drop across the diode 114 was low, the leakage current in the reverse direction (going back into the transformer 110's secondary coil 122) was too high, and consequently a useful charge did not accumulate in the capacitor 116. Possibly germanium or Schottky silicon diodes of better quality could give good results. However, when diode 114 was a silicon PN diode with a peak inverse voltage (PIV) rating of 400 volts useful charge accumulated in capacitor 116. The silicon PN diode had a reverse current of less than 0.1 microampere at 1 reverse volt.

Silicon PN diodes turn out to be useful for rectifying noise pulses because a very small minimum forward voltage can drive a very small current forward through these diodes when fast pulses are involved, possibly because of capacitance effects. This unexpected property becomes even more evident when the currents involved are significantly smaller than 1 mA. For instance, at 1 μA of forward current, some substantially random noise pulses pass through the diode 114. If the substantially random noise pulses are first amplified by a transformer 110, they are even more apt to pass through a silicon PN diode 114. Although diodes 114 made of silicon PN were found to function better than diodes 114 made of germanium or the Schottky type in the embodiment of the present invention illustrated by the circuit of Fig. 1, the manufacture of diodes produces significant variability and different specimens of the same type of diodes may produce significantly different results.

Other types of resistors 118 such as metal film and wire-wound nichrome resistors gave similar output voltages, although resistances both lower and higher than 470 ohms yielded slightly lower output voltages. Substantially lower output voltages were obtained when a laminated silicon-steel core transformer 110 was used, and when an oxidized aluminum electrolytic capacitor 116 was used.

Various other voltmeters were used in measurement performed by the inventor, to replace the Fluke digital meter. High quality digital meters gave the same results as the data reported in the present patent application, but lower quality meters with lower input resistances gave lower voltage readings, possibly because they drained electricity from the capacitor 116 of FIG. 1 faster than it was replenished through the rectifying diode 114.

To the surprise of the inventor, approximately 0.0003 volt (0.3 mV) of output was accumulated in the capacitor when the above experiment was repeated with no resistor 118 attached to the primary coil, either with a short circuiting wire 126 as the input feeding to the primary coil as in FIG. 2, or with an open circuit as the input as in FIG. 3. Evidently, electrons in the primary coil 120 itself move randomly at room temperature, making enough magnetic field to generate a small voltage output from the secondary coil 122, and therefore a useful voltage passes through the diode 114 and into the capacitor 116.

The present invention is a new use of the electrical circuit illustrated in FIG. 3. In the present invention the electrical circuit illustrated in FIG. 3 is used to convert ambient thermal energy that exists in an electrical conductor into dc electrical energy. The present invention is different from prior art that uses a similar circuit to convert externally obtained alternating current electrical energy into dc electrical energy. An example of said prior art is illustrated by, for instance, the well known half and full wave rectifiers shown in Shanefield, D.J. *Industrial Electronics for Engineers, Chemists, and Technicians*. N.Y., Noyes, 2001, p.154, which is hereby incorporated by reference.

To the further surprise of the inventor, approximately 0.0002 volt (0.2 mV) of output was accumulated in the capacitor 116 when the above experiment was repeated with a step-down transformer, using 200 turns in the primary coil 120 and 1 turn in the secondary coil 122 of FIG. 1. Many other ratios of turns were also tried, with varying results in output voltage.

Another unexpected finding was that approximately 0.0002 volt (0.2 mV) of output was accumulated in the capacitor 116 when the above experiment was repeated with no transformer, but with a short circuiting wire 126 as the input used to feed nearly-random pulses of electricity to the rectifying diode 114 as illustrated in FIG. 4.

Experiments were conducted by the inventor using the circuit of FIG. 5, with no transformer, and with a plain wire 128 input to the diode 114. A load resistor 130 was attached across the output terminals, having a resistance of 10 million ohms (10 MΩ). The measurement at the output terminals was 0.00002 volt (0.02 mV). This proves that electric current is being generated by the circuit, and the voltmeter is not just detecting a static electric field from the diode, or an electret effect. A voltage drop of 2×10^{-5} V across a $10^7\ \Omega$ resistor indicates a current of 2×10^{-12} A, according to the standard formula in Shanefield, D.J. *Industrial Electronics for Engineers, Chemists, and Technicians*. N.Y., Noyes, 2001, p.13, which is hereby incorporated by reference. (More than that amount of output current was indicated by the circuit of FIG. 1 and also by other embodiments of the present invention, when a 10 M Ω resistor was connected across the output terminals.)

When the circuit of FIG. 6 was used from time to time in the inventor's experiments, measurements of zero volts were usually obtained, although measurements ranging from +0.01 mV to -0.01 mV were also occasionally obtained. Other experiments using no diode 114 or no capacitor 116 yielded output voltage measurements ranging from +0.01 mV to -0.01 mV.

In another embodiment, the single rectifying diode was replaced by a four-diode full wave rectifier bridge 132 , as illustrated in FIG. 7 and explained in Shanefield, D.J. *Industrial Electronics for Engineers, Chemists, and Technicians.* N.Y., Noyes, 2001, p. 157, which is hereby incorporated by reference. The output was 0.5 mV with a 470 Ω input resistor.

Voltage multiplier circuits with multiple diodes can also be used, as described in Shanefield, D.J. *Industrial Electronics for Engineers, Chemists, and Technicians.* N.Y., Noyes, 2001, which is hereby incorporated by reference. An example is the circuit of FIG. 8, which generated 1 mV in the inventor's experiments, using a 470 Ω input resistor.

In another embodiment of the invention, two circuits such as are described by FIG. 1 were assembled, and the outputs were connected in series. The total output voltage measured was 1 mV, using components substantially as described above in connection with previous embodiments of the circuit illustrated by FIG. 1.

When thermal energy is taken from an electrical conductor, accumulated in a capacitor, and then conducted through a pair of wires to a resistance heater at another location, a temperature difference is generated. This might appear to be an unusual occurrence, but analogous results from prior research that accumulated thermal energy via mechanical and chemical devices (not electrical) has been reported in the article by Astumian, R.D. "*Making Molecules Into Motors*". *Scientific American,* July 2001, pp. 57-64.

In the measurements described above, the electron accumulator is a capacitor. It is appreciated that in all instances a suitable battery could also have been used.

In alternate embodiments of the invention, the individual conversion units may be miniaturized using well known semiconductor manufacturing techniques such as lithography on well known semiconductor materials, including but not limited to, silicon, germanium and suitably doped variants of silicon and germanium as illustrated in FIG. 9. In such constructions, the source of thermally agitated electrons may for instance be suitable doped regions of the base material 142. Similarly the rectifying means may be a PN junction 144 integrated into the design and the accumulator may be a capacitor formed by depositing conducting material 146 on either side of the base material, as shown in FIG. 9. Such a design would lend itself to making in a grid containing many individual energy converters. Such an array of energy converters could be discharged in series for maximum voltage or in parallel for maximum current, or some combination.

One useful embodiment of the apparatus for converting thermal energy to electrical energy is assembled by attaching the individual components to each other by the well-known means of temporarily melting and then solidifying solder metal alloy, according to the configuration of FIG. 1, in which said components include a resistor 118, a transformer 110, a rectifying diode 114, a and a capacitor 116, all joined by suitable conductors.

Another useful embodiment of the invention is assembled by attaching the components by the well-known means of spring-actuated clips that connect pairs of conductor wires together.

Still another useful embodiment of said apparatus is assembled by means of integrated circuit technology in which several components are fabricated simultaneously, and several other components are later fabricated on top of the first components, so that conductors, resistors, semiconductors, and insulators all become a single mass of material. One possible implementation of such an embodiment is shown by way of example in Fig. 9, comprising an N-doped silicon wafer 142, with P-doped regions 144 on which metal regions 146 have been deposited and to which metallic conductors 148, which may be but are not limited to wires, have been attached. In general terms, integrated circuits and their advantages are described in Shanefield, D.J. *Industrial Electronics for Engineers, Chemists, and Technicians*. N.Y., Noyes, 2001, pp. 249 and 257, which are hereby incorporated by reference. Among the well-known advantages of integrated circuits are miniaturization and the ability to manufacture millions of devices within a single unit at low cost.

More specifically, one useful embodiment of the integrated circuit technology is fabricated by starting with a one millimeter thick sheet of single crystal silicon commonly called a "wafer." This can be lightly doped with boron to cause it to be a P-type semiconductor during its growth as a single crystal by slowly cooling and "pulling" a cylinder of the silicon upwards from a larger pool of melted silicon. After cooling, the cylindrical "boule" of silicon is commonly cut into one millimeter thick sheets by the use of a rotating metal saw that has sharp diamond particles embedded in its active edge.

After suitable cleaning, a "wafer" sheet of silicon is heated in the presence of water vapor to form 0.1 micrometer thick silicon dioxide films on both sides. Controlled holes are etched in said silicon dioxide films by means of "photolithography," in which a 0.1 micrometer thick film of photosensitive organic polymer is coated onto the silicon dioxide film, and said polymer is later exposed selectively to ultraviolet light, which causes said polymer to become selectively more soluble in a liquid "developer." Controlled holes are etched in said polymer film by washing the coated wafer in a liquid solvent that selectively dissolves the UV light exposed regions of the polymer film but does not dissolve the selectively unexposed regions of said film. Controlled holes are then etched in said silicon dioxide film by immersing the coated wafer in an alternating current plasma of fluorocarbon vapor, which plasma selectively removes the silicon dioxide but selectively does not remove the polymer film.

After a "stripping" step to remove the polymer film by means of immersing the coated wafer in a heated liquid organic solvent, and after suitable cleaning, the coated wafer is immersed in a heated vapor of an arsenic compound such as arsine, causing elemental arsenic to diffuse selectively into regions of the silicon sheet that are not covered by silicon dioxide. This process forms rectifying PN junctions where the original P-type silicon is in contact with the heavily N-type doped silicon that contains arsenic.

After suitable cleaning, aluminum metal is evaporated or sputtered in a vacuum and deposited onto the coated wafer. Photolithograhy is performed as above, with photosensitive organic polymer coating and selective UV exposure and selective development, followed by selective etching of the aluminum by means of plasma, followed by stripping removal of the polymer. The UV exposure of the polymer is done in a manner that leaves lines of aluminum metal after the above steps, and said lines comprise conductors for the apparatus.

Capacitors 116 can be fabricated by the above means, wherever two conductors are separated by thin insulating material or reverse-voltage PN junctions.

Holes in the silicon dioxide film can be filled with said aluminum metal conductors in order to selectively connect one end of an aluminum conductor line to one end of another line that is above it and is insulated from it elsewhere, away from the hole.

Transformers 110 can be fabricated from spirals of aluminum metal. Said spirals are fabricated by stacking up aluminum metal films which are in the shape of incomplete circles, each separated from each other by interposed insulating silicon dioxide films, said films selectively having holes in them that are filled with deposited aluminum metal.

The spiral transformers 110 can alternatively be fabricated by using screen printed and sintered nickel metal instead of aluminum, and sintered ferrite ceramic instead of single crystal silicon. Instead of photolithography, screen printing can be used to selectively fabricate layers of magnetic ferrite ceramic and conductive nickel spirals with suitable shapes including holes and fillings. Magnetic ferrite ceramic and sintering are described in Shanefield, D.J. *Industrial Electronics for Engineers, Chemists, and Technicians*. N.Y., Noyes, 2001, pp. 268 and 275, which are hereby incorporated by reference. Integrated circuit transformers of both spiral types described above are commonly used in military and other miniature electronic equipment. Capacitors are also commonly fabricated by screen printing followed by sintering for use in military and other miniature electronic equipment.

Two or more types of integrated circuit, silicon and ferrite and can be combined by placing them in contact with each other. In some cases, layers of one type of integrated circuit can be fabricated directly on top of a different type, in which the whole unit is fabricated sequentially, one layer at a time, and this is commonly done for use in cellular telephones and military equipment.

While the invention has been described with reference to the preferred embodiment thereof it will be appreciated that various modifications can be made to the parts and methods that comprise the invention without departing from the spirit and scope thereof.

I Claim:

1. An apparatus for converting thermal energy to electrical energy, comprising:

a source of thermally agitated electrons, said electrons exhibiting substantially random motion;

an electron accumulator; and

means for selectively transmitting some of said electrons from said source to said accumulator.

2. The apparatus of claim 1 wherein:

said source of thermally agitated electrons is an electrical conductor;

said electron accumulator is a capacitor; and

said selectively transmitting means is a rectifying diode.

3. The apparatus of claim 2 wherein:

said electrical conductor is substantially at room temperature;

the direct current (DC) resistance of said capacitor is more than 10 M Ohms at 1 Volt; and

the reverse resistance of said rectifying diode is more than 10 M Ohms at 1 Volt.

4. The apparatus of claim 1 wherein said source of thermally agitated electrons is an electrically conducting wire; said electron accumulator is a battery and said selectively transmitting means is a rectifying diode.

5. The apparatus of claim 4 wherein:

said electrically conducting wire is substantially at room temperature;

the direct current (DC) resistance of said battery is more than 10 M Ohms at 1 Volt; and

the reverse resistance of said rectifying diode is more than 10 M Ohms at 1 Volt.

6. The apparatus of claim 2, further comprising a transformer, each of the primary and secondary coils of said transformer having between 1 and 200 turns of wire and wherein said electrical conductor is said secondary coil of said transformer.

7. The apparatus of claim 6 wherein the eddy current loss of said transformer is less than 1% at more than 1 KHz.

8. The apparatus of claim 6 wherein the number of turns of wire in said secondary coil is in the range from 10 to 200 times greater than the number of turns of wire in said primary coil.

9. The apparatus of claim 6 wherein the number of turns of wire in said secondary coil is in the range from 190 to 200 times greater than the number of turns of wire in said primary coil.

10. The apparatus of claim 6 wherein the number of turns in said primary coil is in the range of from 1 to 5.

11. The apparatus of claim 6 wherein the input to said primary coil is an open circuit.

12. The apparatus of claim 6 further comprising:

a second electrical conductor, said second electrical conductor being connected across the terminals of said primary coil.

13. The apparatus of claim 12 wherein the resistance of said second electrical conductor is in the range from 0.0001 to 100,000 ohms.

14. The element of claim 12 wherein the resistance of said second electrical conductor is in the range from 10 to 600 ohms.

15. The element of claim 12 wherein the resistance of said second electrical conductor is in the range from 600 to 4,000 ohms

16. The element of claim 12 wherein the resistance of said second electrical conductor is in the range from 4,000 to 10,000 ohms.

17 . The apparatus of claim 1 wherein:

said source of thermally agitated electrons is an electrical conductor;

said electron accumulator is a capacitor; and

said means for selectively transmitting said electrons is a full wave bridge rectifier.

18. The apparatus of claim 1 wherein:

said source of thermally agitated electrons is an electrical conductor;

said electron accumulator is a capacitor; and

said means for selectively transmitting said electrons is a voltage multiplier arrangement of rectifier elements.

19. An apparatus for converting thermal energy to electrical energy, comprising:

a plurality of sources of thermally agitated electrons, said electrons exhibiting substantially random motion;

a plurality of electron accumulators; and

means for selectively transmitting some of said electrons from said plurality of sources to said plurality of electron accumulators.

20. The apparatus of claim 19, further comprising means for connecting said electron accumulators in series.

21. The apparatus of claim 19, further comprising means for connecting said electron accumulators in parallel.

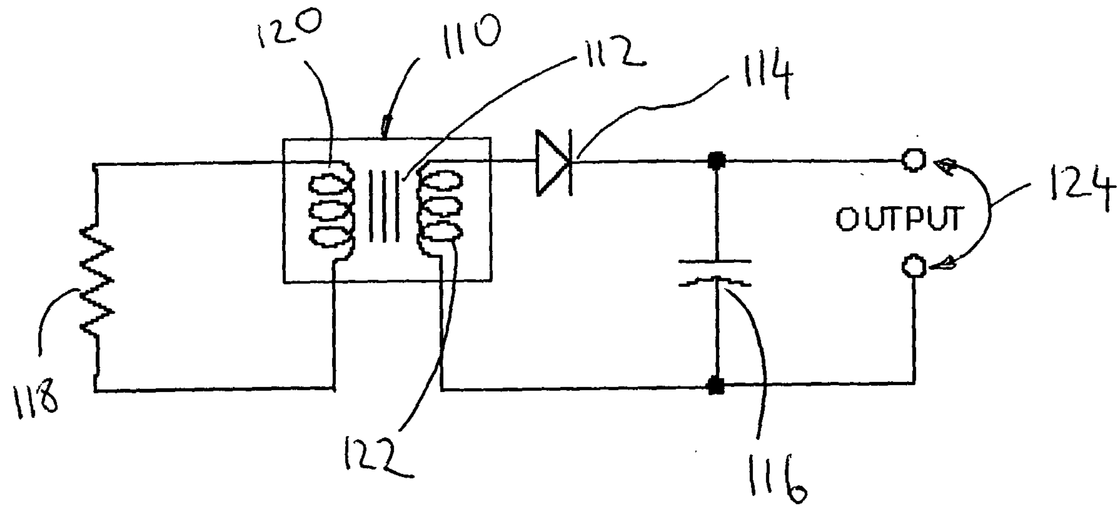
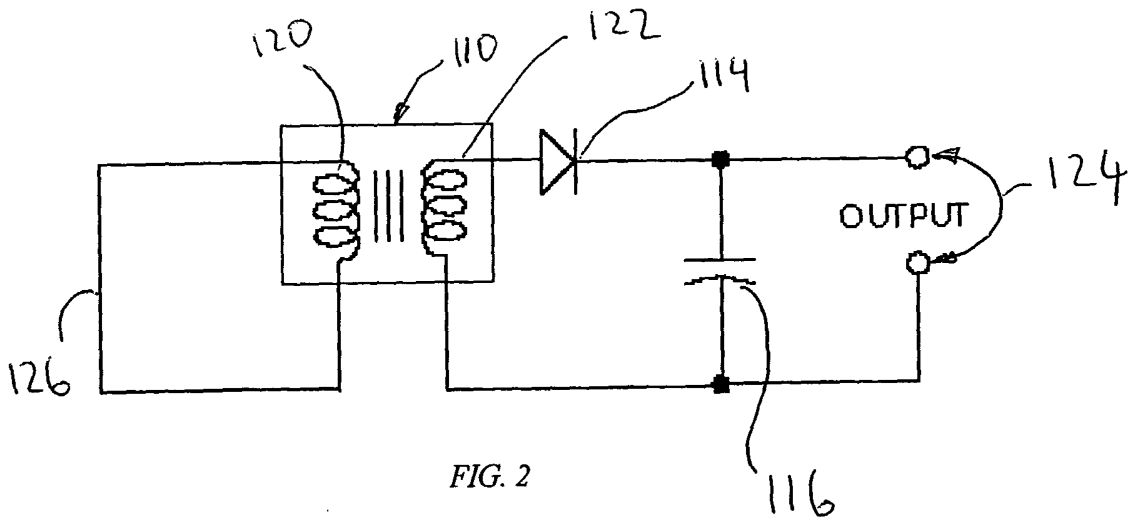

120
110
112
114
124
OUTPUT
118
122
116

FIG. 1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OUTPUT
126
116

FIG. 2

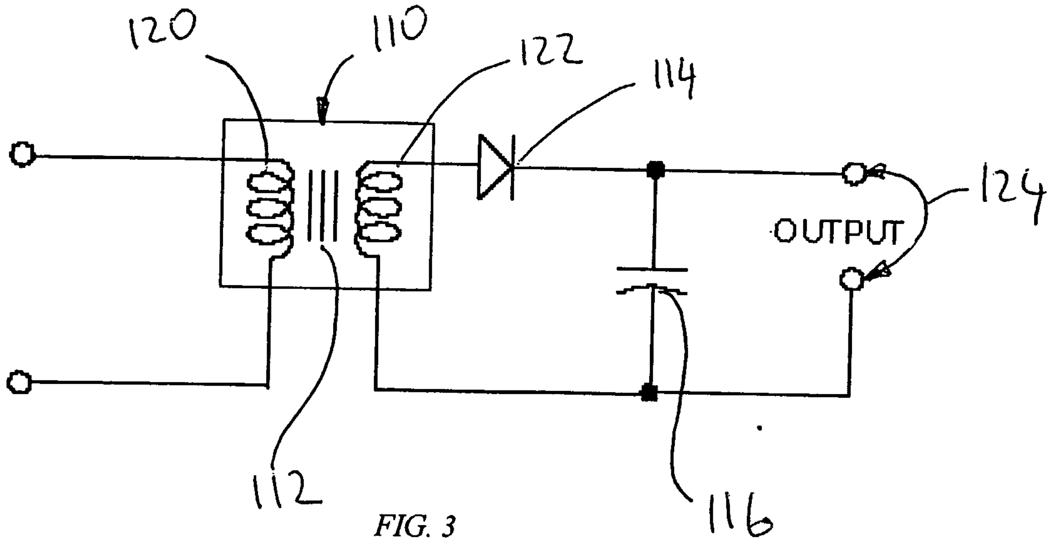

FIG. 3

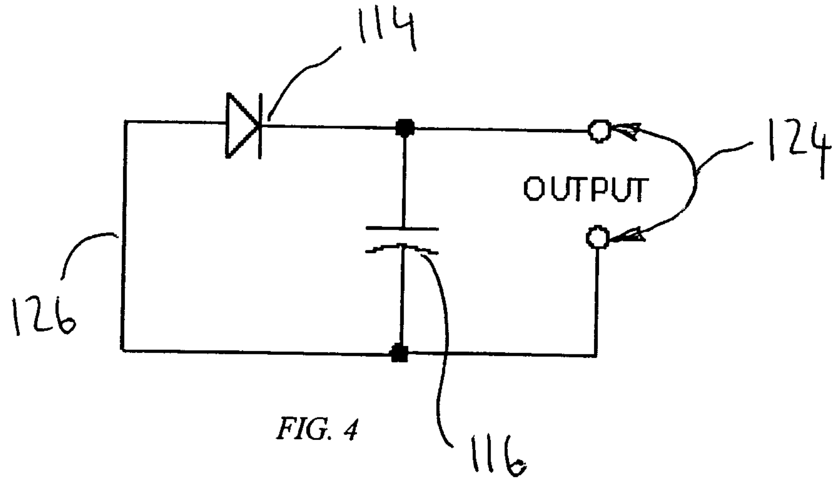

FIG. 4

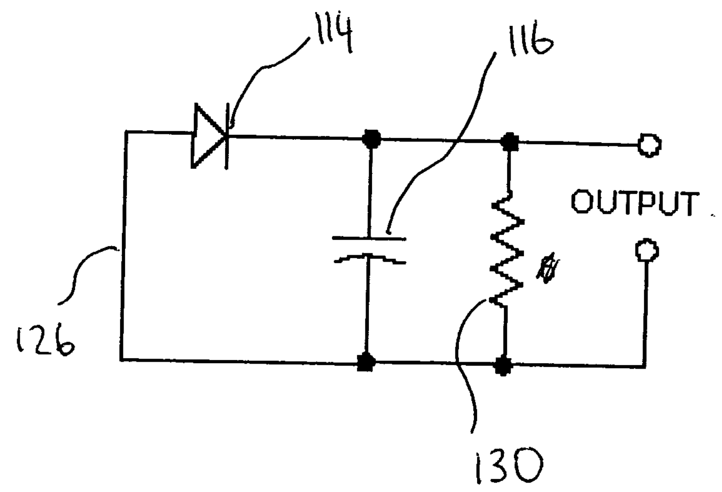

FIG. 5

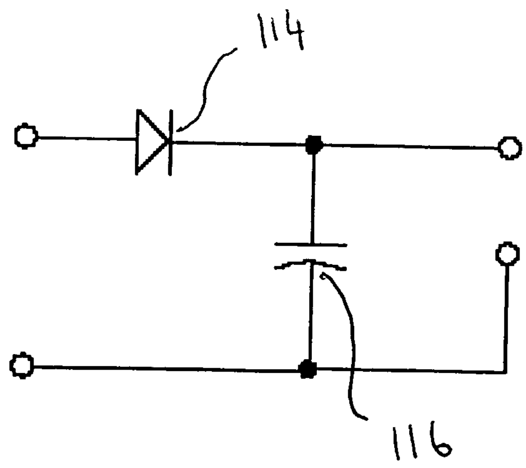

FIG. 6

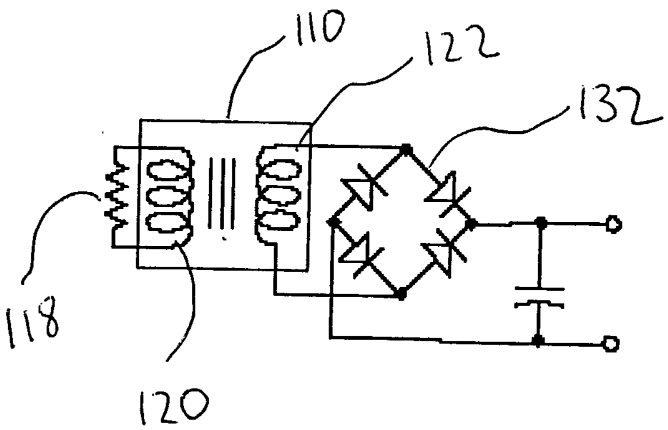

FIG. 7

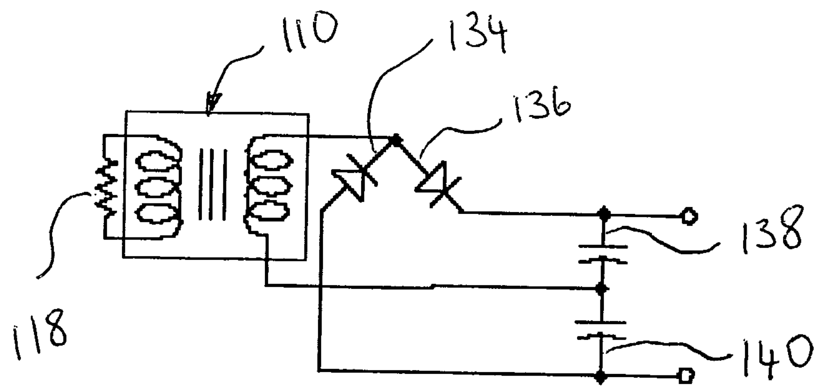

FIG. 8

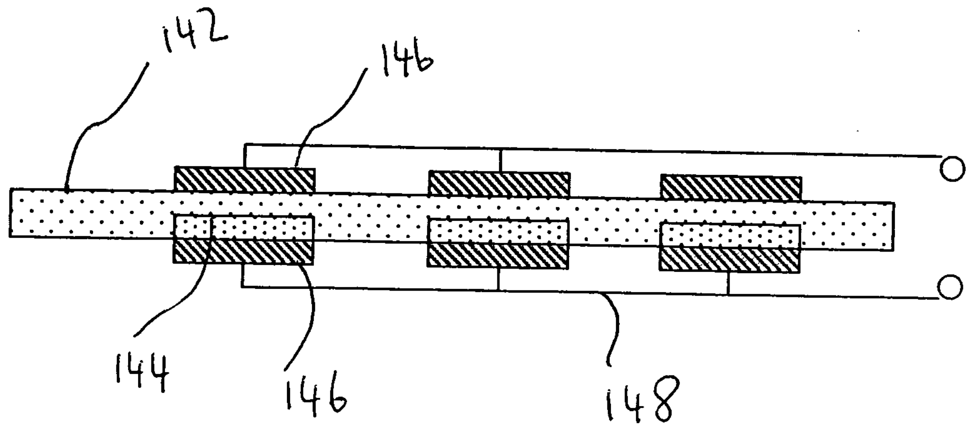

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US02/26269

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H01L 35/30, 35/00, 35/28, 35/02
US CL : 136/205, 206, 211, 212, 242
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 136/205, 206, 211, 212, 242

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,384,259 A (CAPEWELL) 17 May 1983 (17.05.1983), col. 1: 41-col. 6: 9.	1-21
Y	US 4,204,147 A (LARRABEE) 20 May 1980 (20.05.1980), col. 3: 16-col. 10: 5.	1-21
Y	US 3,860,863 A (LAMPRECHT) 14 January 1975 (14.01.1975), col. 6: 38-col. 9: 10.	1-21
A	US 5,770,911 A (CHENG) 23 June 1998 (23.06.1998), col. 3: 59-col. 8: 48.	1-21
A	US 5,491,399 A (GREGORY et al.) 13 February 1996 (13.02.1996), col. 2: 29-col. 4: 67.	1-21
A	US 5,204,586 A (MOORE) 20 April 1993 (20.04.1993), col. 2: 49-col. 6: 8.	1-21
A	US 5,084,664 A (GALI) 28 January 1992 (28.01.1992), col. 2: 32-col. 3: 59.	1-21
A	US 4,644,256 A (FARIAS et al.) 17 February 1987 (17.02.1987), col. 2: 30-col. 4: 22.	1-21

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 13 December 2002 (13.12.2002)	Date of mailing of the international search report 03 JAN 2003
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Thomas Parsons Jean Proctor Paralegal S. Telephone No. (703) 308-0661

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US02/26269

Continuation of B. FIELDS SEARCHED Item 3:
East, West
search terms: resistor, transformer, rectifying diode, capacitor