The present invention relates to thermal computers and has particular reference to a new type of transducer.

By employing a radically different concept in the design of the transducer, the time constant has been reduced by a factor of 20 and the input power requirements have been reduced by a factor of 100. Also the size and weight have been reduced materially.

However, the circuit applications of the present transducer are identical with those used in the past for carrying out the mathematical operations of multiplication, integration, etc., by the mechanical transfer of thermal energy from one to another. Consequently, as before, the new unit is also constructed with three sets of wire pairs, viz., one heater pair and two sensor pairs.

The principle utilized in the new design, which is not embodied in the former units, is that the time constant is improved (made smaller) by reducing the thermal capacity of the various elements to the lowest amount physically possible. Further improvement is achieved both by increasing the rate of transfer of thermal energy from the heater to the sensors by using a greater proportion of the emitted energy (from the heater) to heat the sensors.

The thermal capacity is kept small by using extremely fine wires for each heater and sensor. The reduction in the diameter of the wire has a two-fold effect. Not only is the mass of the element reduced thereby, but the resistance, which increases as the square of any reduction in wire size, is increased. As a consequence, for a given impedance level, the length of the wire can be materially shortened, resulting in a still further decrease in the mass of the element. Thus, the total mass of the wire will be reduced as the cube of the diameter ratio. The wires are used with no insulation, since the short lengths permit mounting them firmly with but a small air gap between them. Thus, the heat capacity previously contributed by the wire insulation is now absent.

The rate of transfer of thermal energy from the heater to the sensors is increased in several ways. First, the heater wires are mounted in very close proximity to each other so that the thickness of the intervening layers of insulating atmosphere is reduced. The "heat" transported by conduction has a shorter distance to travel. Secondly, the transducer is mounted in an evacuated envelope with the result that a higher proportion of the thermal energy is transferred by the radiation process (rather than conduction process) than would be the case if wires were not in an evacuated envelope. The radiated power being proportional to the fourth power of temperature provides a much higher rate of heat transfer than the conduction process which is proportional to the first power of the temperature. The evacuation of the envelope has the added advantage of decreasing the heat capacity of the system contributed by the air surrounding the wires. Placing the wires close to each other effects the condition that the sensors directly intercept a greater portion of the energy being emitted by the heater due to the larger solid angle covered by the sensors as viewed from the heater when the wires are moved in closer.

A final refinement to the device is achieved by enclosing the space occupied by the fine wires with an infrared reflector to ensure that as much as possible of the energy emitted by the heater is effective in raising the temperature of the sensors and, thereby, producing a change in impedance which results in an output signal voltage. The reflector is placed as close to the sensitive wires as possible, taking into account the condition that the wires must not be shorted out when subjected to mechanical vibration or by the unavoidable slack produced in the wires when heated.

Besides the improvement in the time constant, the new design results in further advantages which are achieved as a by-product of the new parameters introduced. There is a considerable improvement in the overall attenuation and stability of the unit, the dimensions of the device become small enough to package in an envelope of about the size of a sub-miniature tube and, what is of considerable importance, the power required to drive the input is reduced drastically to the order of about 10 milliwatts.

For a more complete understanding of the invention, reference may be had to the accompanying diagrams, in which Figure 1 shows a preferred construction of the thermal element, Figure 2 illustrates a typical transducer using the element of Figure 1, Figure 3 is an alternative embodiment of the invention, and, Figure 4 is yet another embodiment of the invention.

Figure 1 of the drawings shows the preferred construction of a thermal element embodying the principles which have been found to be necessary and desirable for a unit having a low time constant. The element is constructed on an electrically insulating base 10 made preferably of a plastic material such as clear Lucite, for example, in which four pins or supports 11, 12, 13, 14 are held securely. Since some of the dimensions of the device of Figure 1 are extremely small, the pictorial representation there shown is distorted.

The distance between the facing surfaces of the pins 11 and 12 and pins 13 and 14 is one the order of one one-hundredth of an inch and these spacings are maintained within very close tolerances. The distance between pins 11 and 13 and pins 12 and 14 is on the order of two inches. One end of a sensor filament wire 15 is spot welded to a contact terminal 16 at the edge close to pin 11, then bent around pin 11, stretched taut between pins 11 and 13 and then spot welded to the terminal 17 at the edge close to pin 13. Similarly, the other sensor filament or wire 18 is bent around the pins 12 and 14 and is spot welded to the contact terminals 19 and 20 at the edges nearest the pins 12 and 14. In this fashion, the spacing between the sensor wires 15 and 18 may be accurately controlled to within the close tolerances and fine spacing found necessary without extensive assembly problems. The heater filament or wire 21, located midway between wires 15 and 18, is stretched between the contact terminals 22, 23 and is secured thereto by spot welding. The wires 15, 18 and 21 all lie in substantially the same plane. Although spot welding has been specified throughout, other securing or clamping means may be used if convenient. An infra-red reflecting surface or shield 24 of copper or aluminum is bonded to the base 10 and covers the area between the pins 11, 12 and 13, 14 under the wires 15, 18 and 21.

A cover 25, made of Lucite or other material, for example, is a channel shaped piece having bonded to its central portion a reflecting surface or shield 26 as seen where the cover material is broken away. When the cover 25 is fastened to the base 10, as by screws (not shown) which...
pass through the holes 27 in cover 25 and into tapped holes 28 in the base 10, the wires 15, 21, 18 are surrounded entirely by an infra-red reflecting surface.

The heater wire 15 and 21 is made of a material having a high temperature coefficient of resistance drawn to an extremely small diameter, on the order of \( \frac{1}{2000} \) inch. The heater wire, of substantially the same size wire, is made of a material having a low temperature coefficient of resistance. This is in accordance with the principles considered which earlier thermal units, such as that described in co-pending patent application Serial No. 261,255, now Patent No. 2,841,329, filed December 12, 1951, operate. However, it will be seen that the long thin wires constitute members of low thermal capacity. In earlier thermal units the thermal capacity was relatively high and no attempt was made to reduce the thermal capacity in order to lower the time constant, other more complicated means being used for this purpose. Added rigidity and strength is given to the wire 15, 18 and 21 to prevent short circuiting during vibration or elongation of the wires under heating by placing several small drops of or blocks with the same principles in mind, the wires 15, 18 and 21. If further protection against vibration is required, the ceramic material may be deposited between the wires for their entire length without departing from the invention.

The shield 24, 26 is an infra-red reflector which ensures that as much as possible of the energy emitted by the heater 21 is effective in raising the temperature of the sensors 15, 18. For further increase in the rate of transfer of heat, the thermal element is preferably enclosed in an evacuated envelope such as shown in Figure 2. In this figure, a pair of elements 38, 31 are shown encased in the glass envelope 32, since in practice a pair of elements connected as members of bridge circuits must nearly always be used. In Figure 2 the common terminal 33 of the two elements 30, 31 are connected to the lead in wires 34, one set of terminals 35 are connected to lead in wires 36 and the other set of terminals 37 are connected to lead in wires 38. A thermal insulator or barrier 39 separates the two thermal elements 30 and 31. It is known that in an evacuated enclosure the transfer of energy is mainly by radiation rather than conduction, and since the radiated power is proportional to the fourth power of temperature the rate of transfer of heat energy between the heater 21 and the sensors 15 and 18 will be greater than it would be in an evacuated atmosphere, thereby assisting in reducing the time constant of the device.

Figure 2 is merely illustrative and it will be realized that the evacuated envelope may take other forms, the glass envelope there shown.

The principles shown in Figures 1 and 2 depict a preferred embodiment at the present time. However, it is visualized that many devices embodying the principles of the invention but physically unsimilar to the devices of Figures 1, 2 may be made. For example, Figure 3 shows an apparently different device which, however, is constructed on the same principles as shown in Figure 3 includes a stack of substantially T-shaped conductors 40, 41, 42 and two stacks of L-shaped conductors 43, 44, 45 and 46, 47, 48 all of which are separated from each other by an insulting material 49 shown in black in Figure 3.

Heater wires 50 and 51 are stretched between the outer ends of conductors 44 and 41 and the conductors 47 and 41 respectively and are secured thereto by welding for example. One pair of sensor wires 52, 53 are similarly attached to conductors 40, 43 and 42, 45 respectively and are located on either side of the heater wire 50. Another pair of sensor wires 54, 55 located on either side of heater wire 51 are attached to the outer ends of conductors 40, 46 and 42, 48 respectively. The entire structure of Figure 3 may be enclosed in an evacuated envelope, and electrical connections to the external circuit will be made through leads connected to the lower legs of the conductors 41, 48 as seen in Figure 3. Infra-red reflectors or shields, 56, 57 are located in the space behind the heater and the sensor conductors, i.e., between the extremities of conductors 40, 41, 42 and conductors 43 through 48.

Figure 4 shows yet another possible embodiment of the invention. Here a pair of electrically non-conducting discs 60, 61 are separated by a supporting bar 62 which is faced on both sides by infra-red reflecting surfaces 63, 64.

Two sensor wires 65, 66 and one heater wire 67 are stretched between discs 60, 61 opposite surface 64 and similarly two sensor wires 68, 69 and one heater wire 70 are stretched between discs 60, 61 opposite the surface 63. Additional reflecting surfaces which surround the wires 65 through 70 are provided, as by the semi-cylindrical shells 71, 72 shown in Figure 4 which may be attached to the discs 60, 61 or by a tube (not shown) into which the assembly of discs and wires may be inserted. Connections to the external electrical circuit may be made through the ends of the wires 65 through 70 which pierce the discs 60, 61. The entire thermal device of Figure 4 may be mounted in an evacuated envelope, if desired.

Properties of the specific components which are used in the construction of the physical devices will be enumerated:

The heater wire must have a temperature coefficient of resistance nearly equal to zero, should have high resistivity and low specific heat. The commercially available wire called "Evanohm" having a diameter of .0009" has been found satisfactory for this purpose.

The sensor wire must have as high a temperature coefficient of resistance as possible consistent with high resistivity, a low product of specific heat and density, low noise of constant resistance at any temperature, and moreover must be ductile to allow drawing into extremely thin wires. For this purpose "Balox," ballast nickel or platinum have been found to be eminently suitable.

The infra-red reflecting surfaces are made of beryllium copper alloy, although other metals such as aluminum or copper may be used.

It will be seen that in each of Figures 1, 3, and 4 the heater and sensors are suspended out of contact with anything which might absorb the heat given off by the heater 21 and thereby add to thermal capacity. There is no insulation, 18, 21 to require heating and the dimensions are such that they have minimal mass and therefore minimal thermal capacity. It should be noted that for a time constant of \( \frac{1}{20} \) of a second, the diameter of the wires should not be greater than one mil. The spacing between the wires should not be greater than 3 mils in order to keep the attenuation below 15. Variation of these parameters will give different values of time constants and attenuation.

The rate of transfer of energy is increased by the infra-red reflector and by mounting in the evacuated envelope.

We claim:

1. In a thermal transducer, an uninsulated heater filament, an uninsulated sensor filament, said sensor and heater filaments being in close proximity but not in engagement, said filaments being suspended between electrically insulated supports and an infra red reflector adjacent said filaments for increasing the heat transfer between said heater and sensor filaments.

2. A heater sensor in the form of a, an uninsulated heater filament, an uninsulated sensor filament, said sensor and heater filaments being in close proximity but not in engagement, said filaments being suspended between electrically insulated supports and an infra red reflector surrounding said filaments for increasing the heat transfer between said heater and sensor filaments.

3. In a device of the character described, a thermal transducer including an uninsulated heater filament, an uninsulated sensor filament, said sensor and heater filaments being in close proximity but not in engagement,
said filaments being suspended between electrically insulated supports and an infra red reflector adjacent said filaments for increasing the heat transfer between said heater and sensor filaments, said thermal transducer being enclosed in an evacuated envelope.

4. In a device of the character described, a thermal transducer including an uninsulated heater filament, an uninsulated sensor filament, said sensor and heater filaments being in close proximity but not in engagement, said filaments being suspended between electrically insulated supports and an infra red reflector adjacent said filaments for increasing the heat transfer between said heater and sensor filaments, said thermal transducer being enclosed in an evacuated envelope.

5. In a thermal transducer, an uninsulated heater filament, an uninsulated sensor filament, said sensor and heater filaments being in close proximity but not in engagement, said filaments being suspended between electrically insulated supports and an infra red reflector adjacent said filaments for increasing the heat transfer between said heater and sensor filaments, said heaters and sensors being in spaced parallel relation.

6. In a thermal transducer, an uninsulated heater filament, an uninsulated sensor filament, said sensor and heater filaments being in close proximity but not in engagement, said filaments being suspended between electrically insulated supports and an infra red reflector adjacent said filaments for increasing the heat transfer between said heater and sensor filaments, said heaters and sensors being in spaced parallel aligned relation.

7. In a thermal transducer, first spaced supports, a heater filament stretched taut between said first spaced supports, a plurality of second spaced supports adjacent but electrically insulated from said first spaced supports, a sensor filament stretched taut between said second supports and positioned parallel to said heater filament, and an infra red reflector adjacent said heater and sensor filaments for increasing the heat transfer between said heater and sensor filaments.

8. In a thermal transducer, first spaced supports, a heater filament stretched taut between said first spaced supports, a plurality of second spaced supports adjacent but electrically insulated from said first spaced supports, a sensor filament stretched taut between said second supports and positioned parallel to said heater filament, and an infra-red reflector surrounding said heater and sensor filaments for increasing the heat transfer between said heater and sensor filaments.

9. In a thermal transducer, an uninsulated heater filament, a plurality of uninsulated sensor filaments, said sensor and heater filaments being in close proximity but not in engagement, said filaments being suspended between electrically insulated supports and an infra red reflector adjacent said filaments for increasing the heat transfer between said heater and sensor filaments.

10. In a thermal transducer, first spaced supports, a heater filament stretched taut between said first spaced supports, a plurality of second spaced supports adjacent but electrically insulated from said first spaced supports, a plurality of sensor filaments stretched taut between said second supports and positioned parallel to said heater filament and an infra-red reflector adjacent said heater and sensor filaments for increasing the heat transfer between said heater and sensor filaments.

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