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NASA CASE NO. MFS-28327-1

PRINT FIGURE 2

NOTICE

16 p

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MSFC

(NASA-Case-MFS-28327-1) SPACECRAFT COMPONENT HEATER CONTROL SYSTEM Patent Application (NASA. Marshall Space Flight Center) 16 p CSCL 22B

N89-28556

G3/18 Unclas 0229845

NASA Case No. MFS-28327

Technical Abstract

SPACECRAFT COMPONENT HEATER CONTROL SYSTEM

This invention relates generally to temperature control circuitry for a spacecraft component 42, and more particularly to such a circuit constructed into a single integrated circuit 64 that may be conveniently located proximate component 42 and which may be accessed by spacecraft central processor 59 to modify operation of the heater circuit or relay operational data relating to the heater circuit to spacecraft central processor 59.

A heater control circuit is constructed as a single integrated circuit 64 mounted proximate component 42. A pair of redundant temperature sensors 84, 86 disposed to sense temperature of component 42 provide an electrical signal that is digitized and fed to microprocessor 71 for comparison with set point temperature and deadband temperature range stored in memory 67. An error signal generated by this comparison is used by microprocessor 71 to instruct heater controllers 74, 76 to selectively provide power to electrical strip heaters 102, 104, heating component 42. Further, microprocessor 71 is coupled via bus 62 to central processor 59, which can access or interrogate microprocessor 71 to modify operation of integrated circuit 64 or to relay operational data relating to integrated circuit 64 back to central processor 59.

The novelty of this circuit resides in constructing the control circuitry in a single integrated circuit, which may be mounted proximate component 42, minimizing signal losses and degradation, and coupling the control circuitry to spacecraft central processor 59 for modifying the set point temperature and deadband temperature range, as well as relaying operational data back to the spacecraft central processor.

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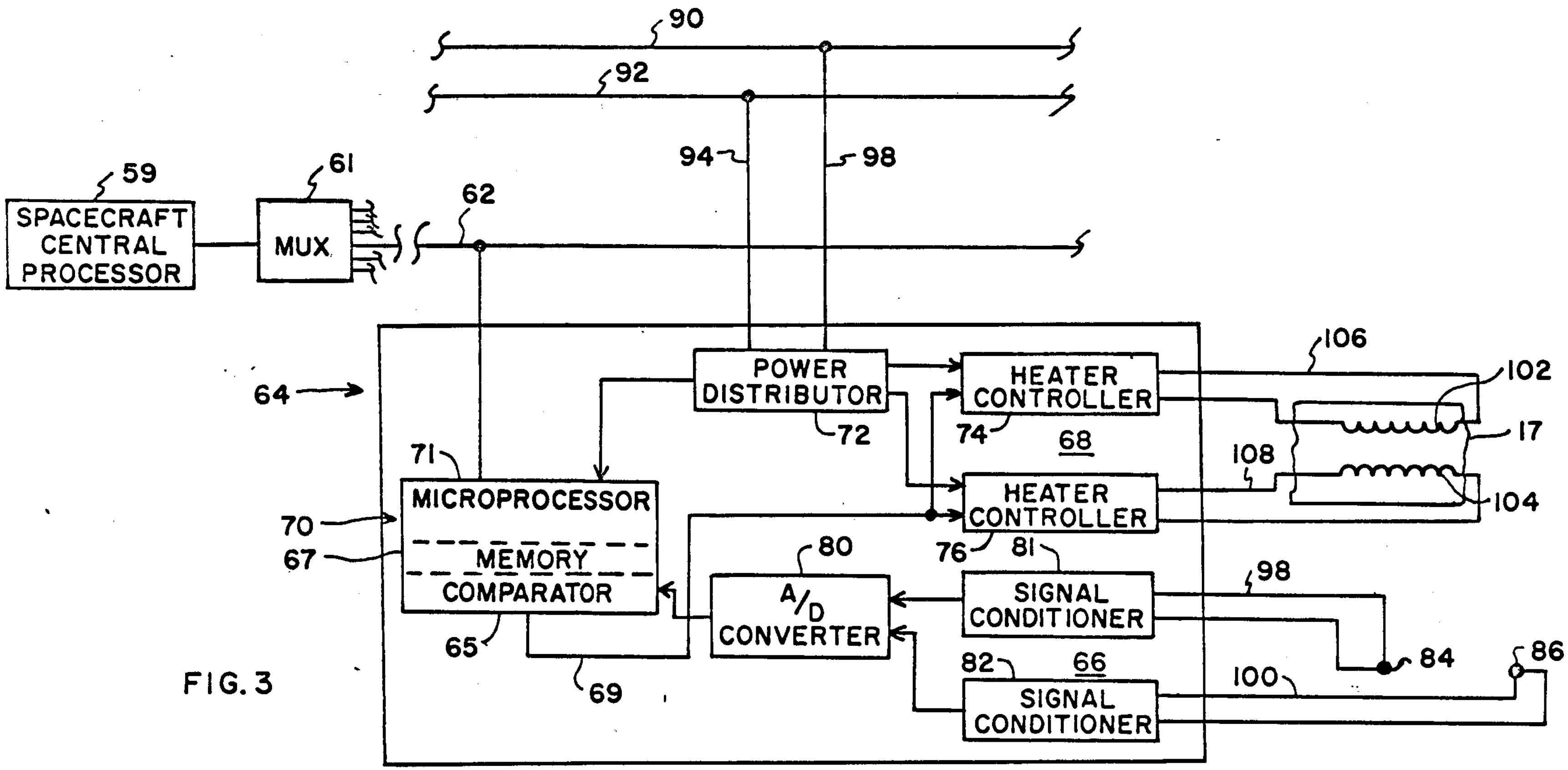

SPACECRAFT CENTRAL PROCESSOR
MUX
POWER DISTRIBUTOR
HEATER CONTROLLER
HEATER CONTROLLER
MICROPROCESSOR
MEMORY
COMPARATOR
A/D CONVERTER
SIGNAL CONDITIONER
SIGNAL CONDITIONER

FIG. 3

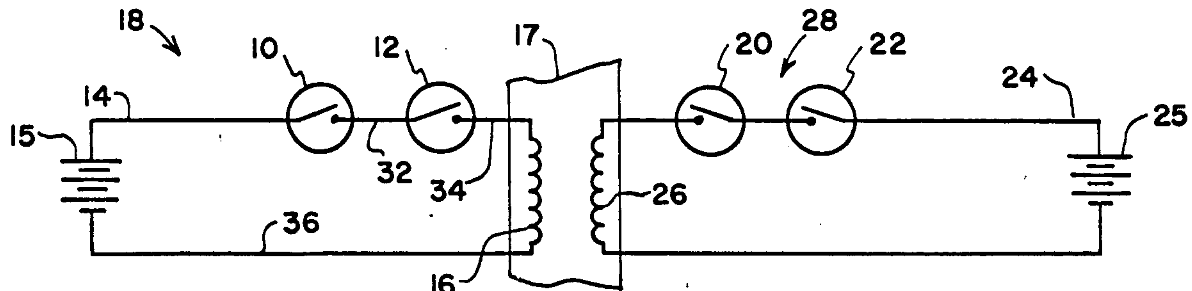

FIG. 1

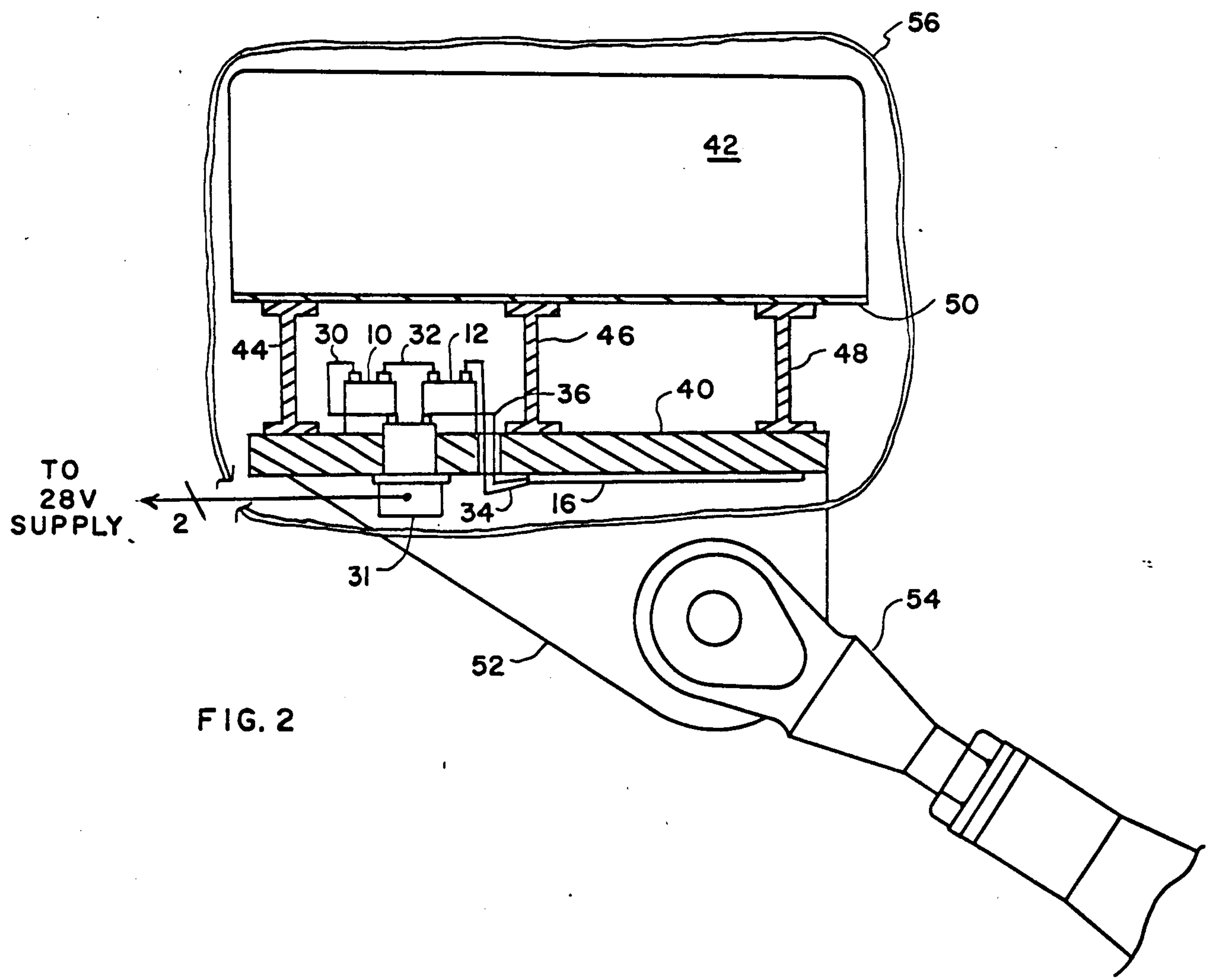

FIG. 2

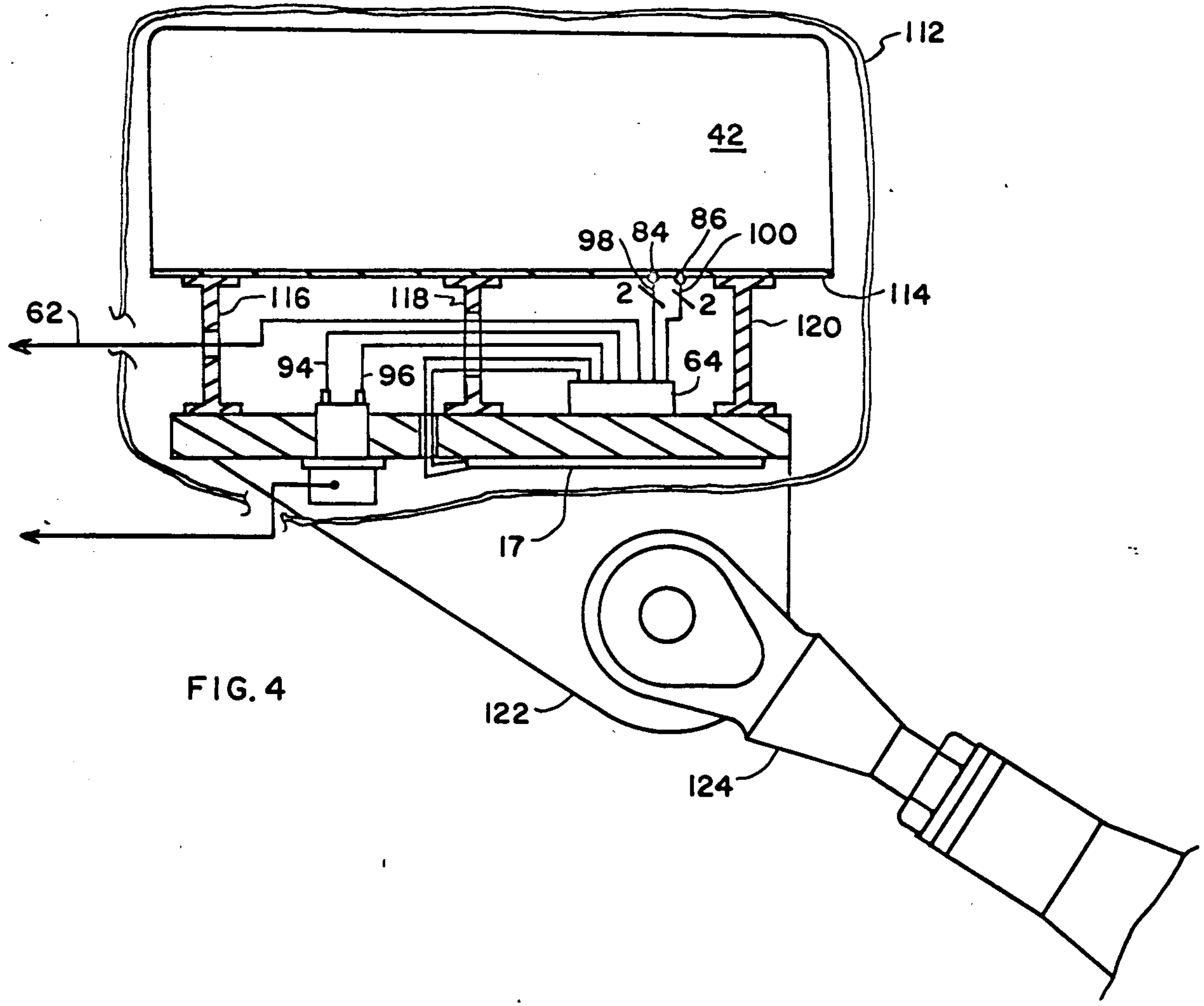

FIG. 4

[redacted]

NASA Case No. MFS-28327 PATENT

SPACECRAFT COMPONENT HEATER CONTROL SYSTEM

Origin of the Invention

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for Government purposes without the payment of any royalties thereon or therefor.

Field of the Invention

The invention relates generally to solid state, programmable control circuitry for active thermal control systems, and more specifically to such circuitry used in temperature monitoring and control of a spacecraft component or part.

Description of the Prior Art

Spacecraft component heater control systems have typically used thermostats to provide temperature control. As is well known, a thermostat is a mechanical device which makes or breaks electrical contact due to changes in temperature. This is usually accomplished by differential thermal expansion of a bi-metallic disk which changes shape and thus position with temperature. Since a thermostat can conceivably fail in the closed position, two thermostats are used in spacecraft operation and are wired in series so that the circuit breaks if either of the thermostats open. In addition, to provide the complete redundancy needed for space flight, two parallel circuits, each with two thermostats, are required as a safeguard against one of the thermostats in either circuit failing in the open position. Alternatives to the mechanical thermostat have generally been analog circuits in varying design using solid state devices to precisely control the temperature of critical spacecraft components.

Several disadvantages have been noted with these known prior systems. For the thermostatically controlled heater systems, the mechanical thermostat itself poses a great potential for failure. As mentioned, this generates a need for redundancy of both circuits and components, thus requiring additional volume of space for installation. Mechanical mounting of the thermostat on the component to be controlled is an added consideration, with not only space but also access being factors in location for the thermostats. Further, the thermostatic heater control circuit provides no feedback of temperature data for monitoring the status of the component. Thus, if component temperature monitoring is needed, separate temperature sensors must be installed. Another problem is that thermostats have pre-established set point (temperature) and dead band (control range) which cannot easily or readily be altered.

Although analog circuits eliminate the mechanically related problems associated with thermostats, they also have pre-established set point and dead band which cannot be altered once integrated in the spacecraft. The analog circuit also has no feedback or temperature data for monitoring the thermal condition of the component even though one or more of the temperature sensors are included in the circuit. Thus, if the component temperature requires monitoring, another sensor must be installed and integrated with the spacecraft data system.

It is, therefore, an object of the invention to enhance the responsiveness of a component heater control circuit through a solid state active programmable system.

Another object of the invention is to use the control circuit temperature sensors in a dual capacity to provide feedback data for monitoring of spacecraft components.

Yet another object of the invention is to provide a control circuit having the capability of reprogramming the heater control set point and dead band after it has been integrated into the spacecraft.

Summary of the Invention

The above and other objects and features of the invention are accomplished by a solid state, programmable spacecraft component heater control system. The system includes an integrated circuit to provide local temperature control signals and pass information on demand via a time multiplexed data bus to the central processor. The integrated circuit has a temperature sensing and conditioning circuit, a heater power and control circuit, and a microprocessor. The integrated circuit is quite small compared to a mechanical thermostat and can be located on the component near the strip heater with which it interfaces. The control system is entirely solid state and includes heater control logic in the microprocessor and temperature sensors on the component to generate temperature feedback data.

In typical operation, the set point temperature and dead band control range are programmed in the heater control logic of the microprocessor. Temperature sensors reference the component temperature through signal conditioners and an analog-to-digital converter. Based on the reference temperature, the microprocessor issues commands to the heater controllers to turn the heaters on or off. The integrated circuit, through the microprocessor, also interfaces with the central data bus. Upon interrogation by the spacecraft microprocessor via this bi-directional communication link, data relating to temperature status of the component is passed upon demand to the spacecraft central processor. Additionally, the on/off status of each heater and computed functions related to the heater duty cycle may be obtained and telemetered to operation control centers. The central processor of the spacecraft also has the capability of reprogramming the microprocessor's heater control logic if the need to do so arises.

Brief Description of the Drawings

The foregoing and additional objects, as well as the various novel features which are characteristic of the present invention, will be understood more clearly and fully from the following detailed description and from the recital of the appended claims taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic representation of prior art redundant mechanical thermostat control spacecraft heater system.

Fig. 2 is a cross-sectional view of the redundant mechanical thermostat control system of Fig. 1 shown mounted on a component within the spacecraft.

Fig. 3 is a schematic block diagram of the preferred embodiment of the present invention showing a programmable control circuit usable in a spacecraft thermal control system.

Fig. 4 is a cross-sectional view of the programmable heater control circuit shown mounted on a component within the spacecraft.

Description of the Preferred Embodiment

The mechanical prior art thermostat system referred to above is shown in the schematic of Fig. 1. In circuit 18, thermostats 10 and 12 are connected in series to switch power from a power bus 14 connected to a source of electrical power, such as 28-volt battery 15, to heater element 16. Thermostats 10 and 12 are connected in series as insurance against one of the two thermostats failing in the closed position. As long as one of the two thermostats 10 or 12 opens at the proper temperature, the system will respond effectively and break circuit 18, thus cutting off power from bus 14 to heater 16. For providing redundancy against either of the thermostats failing in the open position, a second, identical circuit 28 consisting of a set of series connected thermostats 20 and 22 control power from a second power bus 24 coupled to a second source of power, such as a second 28-volt battery 25, to a second heater element 26. The circuits 18 and 28 are shown side-by-side to indicate like circuits providing redundancy required for spacecraft heater control systems. As long as one of the control circuits 18 or 28 responds properly by having both of its thermostats 10 and 12 or 20 and 22 closed simultaneously, the respective heater elements will be supplied power from either bus 14 or 24.

In practice, and as shown in Fig. 1, heater elements 16 and 26 are embedded within a Mylar™ strip 17, with these elements being powered by redundant circuits 18 and 28. Connecting leads between the electrical components of circuit 18 are numerically identified as 14, 32, 34, and 36 to assist in understanding the relation between Fig. 1 and Fig. 2. As shown in Fig. 1, power or bus lead 14 is connected to power supply 15 to thermostat 10. Thermostat 10 is connected in series to second thermostat 12 via lead 32. Lead 34 connects thermostat 12 to heater 16, which in turn is connected back to power supply 15 by lead 36.

Fig. 2 is a pictorial representation of a prior art thermostatic heater control system of Fig. 1 integrated with a spacecraft component 42, which may be any orbital component requiring temperature maintenance for proper operation. In this example, strut attachment fitting 52 and strut clevis connector 54 securely mount component 42 to the spacecraft (not shown). For clarity purposes, only heater circuit 18 is shown. In practice, the second heater circuit 28 would be positioned adjacent heater circuit 18 to provide the required redundancy. Using like numbers to indicate the same parts, thermostat 10 is connected on one side by lead 30 to electrical connector 31, which is coupled to power supply 14 (not shown) and on the other by lead 32 to series thermostat 12. Heater strip 16 is connected to connector 31 by lead 36 and to thermostat 12 by lead 34. Heater strip element 17 is fastened to the bottom surface of lower supporting structure 40 of spacecraft component 42 by any means suitable for use in space, such as epoxy glue or cement. Between component 42 and the lower supporting structure 40 are shelf support members 44, 46, and 48 providing spaced support for shelf 50 on which component 42 is fastened. A multilayer insulation 56, consisting of 10 to 20 layers of aluminized Mylar™, insulates component 42 from extreme temperature conditions in space.

Contrasting the mechanical thermostat control of temperature is the programmable solid state heater control circuit of Fig. 3 which is incorporated into a single integrated circuit 64. The spacecraft central processor 59 is coupled to the control circuit through multiplexer 61, which is a time multiplexed device receiving data from bi-directional data bus 62 coupled to various systems on the spacecraft, including integrated circuit 64. Integrated circuit 64 provides local temperature control of component 42 and consists of redundant temperature sensing and conditioning circuits 66, redundant heater power and control circuits 68, and a control circuit consisting of microprocessor 70, which communicates with central processor 59 when interrogated thereby. Microprocessor 70 generally includes a plurality of random access memories (RAM) 67 in which is stored digital representations of desired set point temperature, or temperature at which heaters 102 and 104 are operated "on," and data representative of the dead band temperature range, or the range of temperature that the temperature of component 60 is allowed to fluctuate within without eliciting a response from the control circuitry. Additionally stored in memory 67 is routine operational data relating to operation of the thermal control system, which may be transferred to central processor 59 upon demand thereby. Stored values of set point temperature and dead band temperature range are compared by comparator 65 in microprocessor 70 with the signal from temperature sensors 84 and 86 mounted to component 42 and a control signal generated from the difference of these two signals. This control signal is then fed via lead 69 to either of controllers 74 and 76, which apply current to heaters 102 and 104 as directed. The integrated circuit 64 is solid state, and its physical size should be similar to several "redundant" thermostats, or on the order of two cubic inches. This permits convenient location of the integrated circuit 64 adjacent component 42, as shown in Fig. 4. Additionally, locating integrated circuit 64 as close as possible to sensors 84 and 86 keeps signal losses due to noise and signal degradation to a minimum.

Within the heater power and control circuit 68 is a power distributor 72 consisting of a D.C.-D.C. regulator, isolation diodes, and solid state switches that provide electrical power to heater controllers 74 and 76 and to microprocessor 70. Distributor 72 may be a conventional unit, such as that manufactured by Omega Engineering, Inc., of Stamford, Connecticut, Omega Model OMX-1302-DC-input. Heater controllers 74 and 76 are basically solid state switches using simple on/off control states to provide power to heaters 102 and 104 and may also be conventional units, such as a heater controller manufactured by Cyber Research, Inc., of New Haven, Connecticut, Model No. CY-ODC5Q. Spacecraft heater strips require 20 to 40 watts of electrical power which, with a 28-volt D.C. power bus, draws 1 to 2 amps of current, all within the specifications for the solid state switches as well as the power capabilities of the spacecraft.

Microprocessor 70 may be any suitable conventional model having an appropriate central processing unit (CPU), read only memory (ROM), random access memory (RAM), into which the temperature data is downloaded, and comparison means for comparing data stored in the random access memory with data obtained from the temperature sensors. Microprocessor 70 would also be reprogrammable to accomplish the specific mission requirements. One such microprocessor is the Omega Engineering Model 6000. Analog-to-digital converter 80 may also be a conventional unit having digital conversion compatibility with microprocessor 70 and, for example, may be one manufactured by Cyber Research, Inc., Model No. TD2141.

Signal conditioners 81 and 82 are generally used to amplify the signal provided by sensors 84 and 86, prior to digitizing, and will depend on the specific temperature sensors used in the control circuit. Sensors 84 and 86 could be of several different types, such as thermocouples, thermistors, resistance temperature detectors (RTD), and integrated circuit temperature transducers, with the selection again being dependent on specific mission requirements. For example, if an integrated circuit temperature transducer is used as the temperature sensor, a suitable signal conditioner would be Cyber Research INST 467-2. These signal conditioners amplify the analog signal provided by the temperature sensors and provide the amplified signal to analog-to-digital converter 80.

In operation, and referring to Fig. 3, all circuit elements are powered by 28-volt D.C. power bus 90 or redundant bus 92 via leads 94 and 96 supplying power to power distributor 72. Integrated circuit 64 receives temperature data via leads 98 and 100 from temperature sensors 84 and 86 positioned to sense the appropriate temperature related to component 42. For example, sensors 84 and 86 may be mounted on a housing or case to sense conducted temperature therein, or closely proximate operating equipment in component 42 to sense radiant temperature therefrom, or, if component 42 is provided with a gaseous environment, such as is sometimes required by photographic equipment, to sense the temperature of the gas. In any case, when the sensed temperature fed back through signal conditioners 81 and 82 and A-D converter 80 is outside the programmed range of temperatures stored in memory 67 of microprocessor 70, the microprocessor instructs heater controllers 74 and 76 to adjust power applied to heaters 102 and 104 through leads 106 and 108, respectively. This effectively increases or decreases the heat supplied by heater elements 102 or 104 to component 42 and appropriately modifies this temperature. When it becomes necessary to alter the set point temperature or dead band temperature range, or both, the central processor of the spacecraft may be used to interrogate microprocessor 70 via multiplexer 61 and provide new temperature information to its associated RAM memory 67, which overrides prior temperature data stored therein. This new temperature data is then used by the microprocessor to provide local temperature control. If a failure occurs in one of heater controllers 74 and 76, signal conditioners 81 and 82, sensors 84 and 86 or heaters 102 and 104, spacecraft central processor unit 59 may instruct microprocessor 70 to ignore data from the failed unit or shut that portion of the system down. Further, microprocessor 70, as instructed by spacecraft central processor 59, may transmit data regarding status of any component under its direction back to central processor 59 where it may be telemetered back to ground control as needed.

In Fig. 4, a typical spacecraft installation for the programmable solid state heater control circuit is demonstrated. Using like numbers to indicate the same parts, heater circuit elements are powered by redundant 28-volt sources from leads 94 and 96. Integrated circuit 64 receives temperature data through leads 98 and 100 from temperature sensors 84 and 86 positioned as described with respect to component 42. When sensed temperature fed back to integrated circuit 64 is outside the range of temperature programmed in memory 67, power supplied to strip heater 17 through leads 106 and 108 is adjusted to increase or decrease the output of the heater. In Fig. 4, the heater strip 17 is of the type referred to above wherein two separate and distinct film heaters are contained within a single Mylar™ strip 17, one heater being powered by the primary circuit and the other heater powered by the redundant circuit. The structural and support components are the same as shown in Fig. 2 but are identified by different numbers to avoid confusion. Specifically, multilayer insulation 112, shelf 114, shelf support members 116, 118, and 120, strut attachment fittings 122, and strut clevice connector 124 are substantially identical to their counterparts shown in Fig. 2.

Thus, novel control circuitry has been described wherein operational data is derived from heater control instrumentation to eliminate the need for separate monitoring circuitry. Obviously, other modifications, additions, and variations of the specific embodiment disclosed herein can be constructed or proposed without departing from the true scope and spirit of the invention, as set forth in the following claims.

Abstract of the Disclosure

A heater control circuit is disclosed as being constructed in a single integrated circuit (64), with the integrated circuit conveniently mounted proximate to a spacecraft component (42) requiring temperature control.

Redundant heater controllers (74, 76) control power applied to strip heaters (102, 104) disposed to provide heat to a component (42) responsive to sensed temperature from temperature sensors (84, 86). Signals from these sensors (84, 86) are digitized and compared with a dead band temperature and set point temperature stored in memory (67) to generate an error signal if sensed temperature is outside the parameter stored in memory (67). This error signal is utilized by a microprocessor (71) to selectively instruct the heater controllers (76, 76) to apply power to the strip heaters (102, 104).

If necessary, the spacecraft central processor (59) may access or interrogate the microprocessor (71) in order to alter the set point temperatureand dead band temperature range to obtain operational data relating to operation of an integrated circuit (64) for relaying to ground control, or to switch "off" faulty components.