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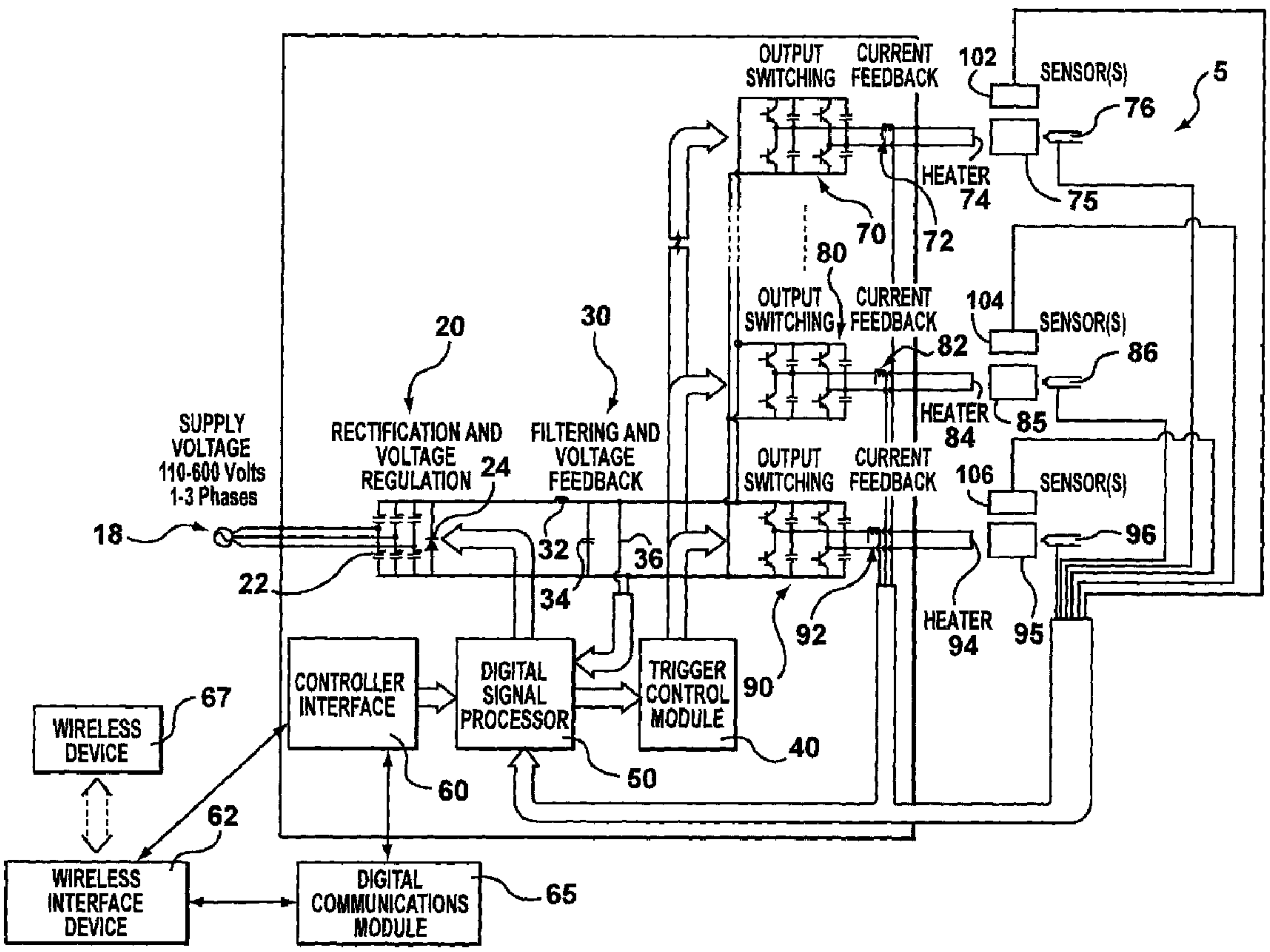
(54) Titre : DISPOSITIF DE COMMANDE DESTINE A AU MOINS UN DISPOSITIF DE CHAUFFAGE UTILISE DANS UN SYSTEME DE MOULAGE PAR INJECTION A CANAUX CHAUFFANTS ET UN PROCEDE D'UTILISATION ASSOCIE

(54) Title: CONTROLLER FOR AT LEAST ONE HEATER UTILIZED IN A HOT RUNNER INJECTION MOLDING SYSTEM AND AN ASSOCIATED METHOD OF USE



(57) Abrégé/Abstract:
A temperature controller for at least one heater being utilized in a hot runner injection molding system, the temperature controller comprising: a regulated voltage supply that is electrically connected to the at least one heater being utilized in the hot runner

(57) Abrégé(suite)/Abstract(continued):
injection molding system; at least one temperature sensor being positioned relative to the at least one heater being utilized in the hot runner injection molding system; at least one digital signal processor being operatively connected to: (i) the at least one heater being utilized in the hot runner injection molding system, (ii) the regulated voltage supply, and (iii) the at least one temperature sensor, the at least one digital signal processor being configured to regulate temperature of the at least one heater being utilized in the hot runner injection molding system based on feedback from the at least one temperature sensor; and at least one output switching stage being electrically connected to the at least one heater being utilized in a the hot runner injection molding system and the regulated voltage supply, wherein the at least one output switching stage varies at least one of voltage and frequency to the at least one heater being utilized in a the hot runner injection molding system through at least one of pulse width modulation and zero crossing detection.

ABSTRACT OF THE DISCLOSURE

A temperature controller for at least one heater being utilized in a hot runner injection molding system, the temperature controller comprising: a regulated voltage supply that is electrically connected to the at least one heater being utilized in the hot runner injection molding system; at least one temperature sensor being positioned relative to the at least one heater being utilized in the hot runner injection molding system; at least one digital signal processor being operatively connected to: (i) the at least one heater being utilized in the hot runner injection molding system, (ii) the regulated voltage supply, and (iii) the at least one temperature sensor, the at least one digital signal processor being configured to regulate temperature of the at least one heater being utilized in the hot runner injection molding system based on feedback from the at least one temperature sensor; and at least one output switching stage being electrically connected to the at least one heater being utilized in a the hot runner injection molding system and the regulated voltage supply, wherein the at least one output switching stage varies at least one of voltage and frequency to the at least one heater being utilized in a the hot runner injection molding system through at least one of pulse width modulation and zero crossing detection.

CONTROLLER FOR AT LEAST ONE HEATER UTILIZED IN A HOT RUNNER INJECTION MOLDING SYSTEM AND AN ASSOCIATED METHOD OF USE

TECHNICAL FIELD

The present invention relates to control of at least one heater utilized in a hot runner injection molding system, and particularly an improved controller utilizing a digital signal processor with feedback for fast and accurate control of at least one heater utilized in a hot runner injection molding system.

BACKGROUND OF THE INVENTION

In a typical injection molding system, molten resin is loaded into a tubular passage called a runner. The molten resin flows from the runner through a gate valve and into the cavity of the mold. The resin in the mold is then cooled and hardens into an article. The mold is opened and the article is ejected.

In a cool runner injection molding system, resin inside the runner and the cavity of the mold is cooled and ejected. In contrast, in a hot runner injection system, resin in the hot runner is kept molten and injected into the cavity during the next molding cycle. In order to keep the resin in the runner molten, the runner is heated. In addition, the resin at the gate valve is cooled to prevent molten resin from dripping out when the mold is opened. This process requires precise and fast temperature control to effectuate changes. In addition, in the hot runner injection molding system, a heater can be utilized with a number of components, including, but not limited to a barrel, a distributor, and a nozzle.

There are a number of different ways to heat the runner. These include: electric resistance heating; induction heating; and a combination of both types of heating. Induction heating consists of winding insulated, conductive wires around the area surrounding the runner near the gate. When the windings are supplied with high frequency power, the area around the runner is heated by electromagnetic induction.

U.S. Patent No. 4,726,751 to Shibata et al. discloses a temperature control system for a hot runner plastic injection molding system where the voltage frequency is varied that is applied to the heater windings. However, Shibata et al. only adjusts the power to the heaters in discrete, automatic steps with parallel resistors and/or capacitors rather than utilizing seamless frequency variations based on a sensed temperature. Furthermore, Shibata et al. is limited to only varying voltage frequency and not voltage amplitude. U.S. Patent No. 4,726,751 to Shibata et al. is incorporated herein by reference in its entirety.

U.S. Patent No. 4,788,485 to Kawagishi et al., U.S. Patent No. 5,136,494 to Akagi et al., U.S. Patent No. 5,177,677 to Nakata et al., U.S. Patent No. 5,504,667 to Tanaka et al., and U.S. Patent No. 5,663,627 to Ogawa disclose utilizing pulse width modulation to convert AC power to DC power and are directed solely to motor control and not heating systems. U.S. Patent No. 4,851,982 to Tanahashi discloses a system that uses pulse width modulation, conversion of AC power to DC power and then back to AC power, and then varying the voltage and the frequency for use with elevator motors.

U.S. Patent No. 5,285,029 to Araki, U.S. Patent No. 4,545,464 to Nomura, U.S. Patent No. 4,879,639 to Tsukahara, U.S. Patent No. 4,894,763 to Ngo, U.S. Patent No. 5,465,202 to Ibori et al., and U.S. Patent No. 5,694,307 to Murugan disclose converting AC power to DC power and then back to AC power but does not involve the field of temperature control. U.S. Patent No. 6,603,672 to Deng discloses conversion of DC current to AC current which is then converted from AC current to DC current and then controlling the output frequency. However, Deng does not disclose applying these methods to temperature control in the field of heaters that can be used in hot runner injection molding systems. U.S. Patent No. 6,009,003 to Yeo and U.S. Patent No. 4,816,985 to Tanahashi disclose current/voltage control for an elevator system.

U.S. Patent No. 3,881,091 to Day discloses a control for heating currents in a multiple cavity injection molding machine using a solid state, bidirectional conducting device for controlling current load, a phase shifting capacitor connected to the conducting device, a variable resistor connected in parallel to the conducting device and a switch to short out the variable resistor to maximize the flow of current. However, Day does not disclose utilizing a digital signal processor for controlling voltage frequency or amplitude. U.S. Patent No. 3,881,091 to Day is incorporated herein by reference in its entirety.

U.S. Patent Application No. 2005/0184689 to Maslov et al. discloses a microprocessor controller that alters the power supply based on current feedback. U.S. Patent No. 6,090,318 to Bader et al. discloses taking a mean of measured temperatures in individual hot runners and raising and lowering the measured melt temperatures together. This Reference also appears to teach away from the present invention by stating: "To prevent continuous fluctuation in the hot-runner temperatures, however, the new temperature set points for the various cavities are first compared with the measured actual temperatures and the old set points, and only after this comparison in stage 33 of the computer is it decided whether a command should be given to the hot-runner controller 17 to alter the set point for a cavity." (Column 5, Lines 38-45). Therefore, there is not a fast and efficient control of the heater but an analysis of a number of set points and then an alteration of the current set point.

Existing temperature controllers are not capable of fast and precise control of temperature. This lack of control allows temperature swings in the heater windings which causes heater failure creating a major problem. As shown in FIG. 1, a large temperature excursion is shown in the graph indicated by numeral 10. The temperature excursion ("dT") is 300° Celsius with duty cycle of 14 seconds on and 114 seconds off. The results for a first temperature sensor are indicated by numeral 76, the results for a second temperature sensor are indicated by numeral 86 and the results for a third temperature sensor are indicated by numeral 96. The heaters, measured by all three (3) temperature sensors 76, 86 and 96, failed prior to 8,000 cycles. In addition, existing control systems utilize either zero switching or phase firing for control of the voltage supplied to the windings of the heaters. Phase firing introduces the problem of electrical noise into the system which also makes it difficult to have a fast and precise control of temperature.

The present invention is directed to overcoming one or more of the problems set forth above.

SUMMARY OF THE INVENTION

In one aspect of this invention, a digital signal processor (DSP) that can utilize software algorithms, feedback signals, and output signals to provide temperature control is disclosed. The DSP has the ability to digitally control temperature with both accuracy and speed.

In another aspect of this invention, a digital signal processor that can utilize both zero switching and phase firing control methods for control of voltage for heating is disclosed. These control methods reduce heater temperature oscillations around a set point in order to extend the life of a heater as well as reduce noise generation. Maximum voltage and frequency will be applied to the windings of a heater for maximum heat generation without affecting the reliability of the heaters. The digital signal processor will use temperature feedback, set point control and monitoring, and open loop percentage control that will give a significant advantage in processing polymers with a hot runner injection molding system where direct temperature control at the hot nozzle tip is not always possible.

In still another aspect of this invention, a temperature controller for at least one heater being utilized in a hot runner injection molding system, the temperature controller comprising: a regulated voltage supply that is electrically connected to the at least one heater being utilized in the hot runner injection molding system; at least one temperature sensor being positioned relative to the at least one heater being utilized in the hot runner injection molding system; at least one digital signal processor being operatively connected to: (i) the at least one heater being utilized in the hot runner injection molding system, (ii) the regulated voltage supply, and (iii) the at least one temperature sensor, the at least one digital signal processor being configured to regulate temperature of the at least one heater being utilized in the hot runner injection molding system based on feedback from the at least one temperature sensor; and at least one output switching stage being electrically connected to the at least one heater being utilized in a the hot runner injection molding system and the regulated voltage supply, wherein the at least one output switching stage varies at least one of voltage and frequency to the at least one heater being utilized in a the hot runner injection molding system through at least one of pulse width modulation and zero crossing detection.

In yet another aspect of the invention, a method for controlling temperature of at least one heater being utilized in a hot runner injection molding system, the method comprising: receiving an input voltage with a regulated voltage supply that is electrically connected to the at least one heater being utilized in the hot runner injection molding system; obtaining at least one temperature value from at least one temperature sensor being located distal proximate to the at least one heater being utilized in the hot runner injection molding system; regulating temperature of the at least one heater being utilized in the hot runner injection molding system with at least one digital signal processor that is operatively connected to the at least one heater being utilized in the hot runner injection molding system, the regulated voltage supply and the at least one temperature sensor; and varying at least one of voltage and frequency to the at least one heater being utilized in the hot runner injection molding system through at least one of pulse width modulation and zero crossing detection with at least one output switching stage that is electrically connected to the at least one heater being utilized in the hot runner injection molding system and the regulated voltage supply.

In still yet another aspect of the invention, a temperature controller for a heater being utilized with an injection molding equipment being associated with an injection molding system, the temperature controller comprising: a voltage rectifier and regulator module being configured to: (i) rectify an AC supply voltage, (ii) regulate the AC supply voltage, and (iii) convert the AC supply voltage into a DC voltage supply; a voltage filtering and feedback stage being electrically connected with the voltage rectifier and regulator module, the voltage filtering and feedback stage being configured to output a filtered DC voltage supply; an output switching stage being electrically connected with the voltage filtering and feedback stage, the output switching stage being electrically connected with the heater, the output switching stage being configured to convert the improved DC voltage supply into a heater voltage supply to be applied to the heater; a trigger control module being electrically connected with: (i) the voltage rectifier and regulator module, and (ii) the output switching stage, the trigger control module being configured to control the voltage rectifier and regulator module and the output switching stage; a temperature sensor being positioned relative to the heater, the temperature sensor being configured to measure temperature of the heater; and a processor, including: inputs being electrically coupled with: (i) the temperature sensor, and (ii) a measured voltage being associated with the voltage filtering and feedback stage; and outputs being electrically coupled with the trigger control module, the processor being configured to: (i) generate a command signal in response to receiving and processing the inputs, (ii) issue the command signal to the trigger control module, and the trigger control module controlling the voltage rectifier and regulator module and the output switching stage in compliance with the command signal in response to receiving the command signal from the processor.

In an aspect of the invention, an injection molding system, comprising: an injection molding equipment; a heater being utilized with the injection molding equipment; and a temperature controller for the heater, the temperature controller comprising: a voltage rectifier and regulator module being configured to: (i) rectify an AC supply voltage, (ii) regulate the AC supply voltage, and (iii) convert the AC supply voltage into a DC voltage supply; a voltage filtering and feedback stage being electrically connected with the voltage rectifier and regulator module, the voltage filtering and feedback stage being configured to output a filtered DC voltage supply; an output switching stage being electrically connected with the voltage filtering and feedback stage, the output switching stage being electrically connected with the heater, the output switching stage being configured to convert the improved DC voltage supply into a heater voltage supply to be applied to the heater; a trigger control module being electrically connected with: (i) the voltage rectifier and regulator module, and (ii) the output switching stage, the trigger control module being configured to control the voltage rectifier and regulator module and the output switching stage; a temperature sensor being positioned relative to the heater, the temperature sensor being configured to measure temperature of the heater; and a processor, including: inputs being electrically coupled with: (i) the temperature sensor, and (ii) a measured voltage being associated with the voltage filtering and feedback stage; and outputs being electrically coupled with the trigger control module, the processor being configured to: (i) generate a command signal in response to receiving and processing the inputs, (ii) issue the command signal to the trigger control module, and the trigger control module controlling the voltage rectifier and regulator module and the output switching stage in compliance with the command signal in response to receiving the command signal from the processor.

These are merely some of the innumerable aspects of the present invention and should not be deemed an all-inclusive listing of the innumerable aspects associated with the present invention. These and other aspects will become apparent to those skilled in the art in light of the following disclosure and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention, reference may be made to the accompanying drawings in which:

FIG. 1 illustrates a graphical representation of a large temperature excursion and associated effect on the life of a heater such as that utilized in an injection molding system as found in the prior art;

FIG. 2 illustrates a schematic view of the temperature controller according to the present invention; and

FIG. 3 illustrates a graphical representation of a small temperature excursion and associated effect on the life of a heater such as that utilized in an injection molding system according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, and components have not been described in detail so that the present invention will not be obscured.

FIG. 2 illustrates a schematic view of a temperature controller according to the present invention that is generally indicated by numeral 5. In the present invention, the temperature controller 5 utilizes a digital signal processor ("DSP") 50, which is preferably but not necessarily embedded. The digital signal processor ("DSP") 50 handles all of the software programs, feedback signals, and output signals that are utilized in the control of what is preferably, but not necessarily, an injection molding system. The present invention accepts a wide range of supply voltages 18, e.g., 110 Volts AC to about 600 Volts AC, at any frequency, e.g., 50 Hz to about 400 Hz and with one to three phases.

The supply voltage 18 is then converted to a DC voltage by a voltage rectifier and regulator module 20. The voltage rectifier and regulator module 20 is electrically connected to a voltage filtering and feedback stage 30 to ensure the quality of the DC voltage supply to the heaters 74, 84 and 94, respectively, utilized with hot runner injection molding equipment 75, 85 and 95, respectively.

Preferably, but not necessarily, the voltage rectifier and regulator module 20 includes a series of thyristors 22 and at least one diode 24. Also, triacs, transistors, and other comparable types of electrical components can be utilized for the voltage rectification and regulation in the regulator module 20. Preferably, but not necessarily, the voltage rectifier and regulator module 20 can provide phase angle control, time proportioning and true power control. True power control can compensate for physical property changes in the heaters 74, 84 and 94 and/or voltage changes.

The voltage filtering and feedback stage 30 preferably, but not necessarily includes at least one inductor 32 and at least one capacitor 34. The rectified, regulated, and filtered voltage is then provided to the heaters 74, 84 and 94, respectively, utilized preferably, but not necessarily with the hot runner injection molding equipment 75, 85 and 95, respectively in one aspect of this invention where DC voltage is used for accurate set point maintenance. Understandably, the voltage filtering and feedback stage 30 will generate pulses of variable time base and variable amplitude proportionate with sensory feedback and communicate this to an output device, which in this illustrative, but nonlimiting, example is a heater. The rectified, regulated, and filtered voltage is also measured 36 with this measured voltage being fed back to the digital signal processor 50.

Moreover, the present invention is also optionally capable of generating control signals for controlling various hot runner injection molding equipment 75, 85 and 95, e.g., hot runner injection molding system components, including water, mold base heating/cooling,. cavity pressure and hydraulically operated material flow modulators in addition to mold temperature.

The digital signal processor 50 employs software control algorithms to generate control signals. Modifications, updates and new control features can be done in software thereby reducing cost compared to controls utilizing programmable controllers and/or analog microprocessors. The digital signal processor 50 is capable of automatic tuning by calculating optimum PID ("Proportional-Integral-Derivative") and other parameters required by the control scheme, e.g., feed-forward, PID control algorithm, slope control, differential inputs and other known methods. The most common control methodology is in process control. Preferably, this is a continuous feedback loop that keeps the process flowing normally by taking corrective action whenever there is any deviation from the desired value ("set point") of the process variable (rate of flow, temperature, voltage, etc.). An "error" occurs when an operator manually changes the set point or when an event (valve opened, closed, etc.) or a disturbance changes the load, thus causing a change in the process variable. The PID ("Proportional-Integral-Derivative") controller receives signals from sensors and computes corrective action to the actuators from a computation based on the error (proportional), the sum of all previous errors (integral) and the rate of change of the error (derivative).

The automatic calculation of PID parameters is accomplished by switching the output on and off to induce oscillations in the measured value. From the amplitude and the period oscillation, the PID parameters are calculated. This auto tuning is performed whenever the thermal load changes.

The present invention preferably includes a temperature controller interface 60 that interprets operator input and generates commands to the digital signal processor 50. The digital signal processor 50 is configured with the controller interface 60 to run the process. There could also be support for a portable processor, e.g., laptop, visualizations in addition to a standalone operation (not shown). The controller interface 60 can be set-up to provide user access levels with different associated rights for each particular category of user.

The controller interface 60 may also include a menu structure such that setup, operation, debugging, and data collection are grouped together in a logical manner. The controller interface 60 may contain clear visual cues to injection molding system conditions and actions. The input from a user is preferably minimized to run the controller interface 60 and respond to alarm conditions.

The present invention may include a digital communications module 65 that is capable of communicating with a wide variety of computer networks, e.g., WAN, LAN, a global computer network, e.g., the Internet, and so forth. A wide variety of output devices such as printers (not shown) can be electrically connected to the digital communications module 65.

This would allow for remote access and troubleshooting. The digital communications module 65 could also include a Serial Peripheral Interface ("SPI") port, which is a full-duplex synchronous serial interface for connecting low/medium bandwidth external devices using four wires. Serial Peripheral Interface ("SPI") port communicates using a master/slave relationship over two data lines and two control lines. The digital communications module 65 may also include an RS232 port, among other types of digital communication. In addition, the digital communications module 65 could be configured for local intra-module communication, e.g., Profibus, Ethernet, radio frequency ("RF") link (that is, a radio frequency link) over a power wire, and so forth.

In another embodiment of the invention, the digital communications module 65 is electrically connected to a wireless interface device 62. This wireless interface device 62 provides electronic communication with a wide variety of wireless interface devices 62 including, but not limited to, a hand-held unit; a radio frequency ("RF") controlled unit (that is, a radio frequency controlled unit); a wireless local area network ("LAN") connected unit; a personal digital assistant ("PDA"), among other types of portable digital, wireless devices.

Another aspect of the present invention is that the temperature controller 5 is utilized to control the temperature of the heaters 74, 84 and 94, that are typically in the form of resistive heaters, inductive heaters, or heaters that are a combination of both resistive heaters and inductive heaters.

The digital signal processor 50 handles all of the software programs and closed loop controls for temperature in addition to generating command signals to the trigger control module 40 for control of the voltage rectifier and regulator module 20 and the output switching stages 70, 80, and 90.

The output switching stages 70, 80, and 90 are responsible for producing variable frequency to each heater 74, 84 and 94 with voltage (power) pulses modulated by switching devices, e.g., IGBTs, MOSFETs, that allow for DC current to be applied to each of the heaters 74, 84 and 94 when the software program determines heater set point stability and long life are needed. Preferably, but not necessarily, the output from each of the output switching stages 70, 80, and 90 is a voltage with a frequency of up to 400 Hz at about 240 Volts AC. Moreover, in the alternative, the output switching stages 70, 80, and 90 could be configured to provide a frequency in the range of from about 0 Hz to about 200,000 Hz.

The digital signal processor 50 employs a PID temperature control algorithm that is configured to control the temperature of the heater windings with a high degree of accuracy, e.g., +/- .1° Celsius, in a wide temperature range, e.g., 0° Celsius through about 800° Celsius. This software platform is expandable to support multiple PID control loops for system voltage, current, and frequency. Voltage is controlled using zero crossing and phase control and preferably the PID control loop is applied to voltage amplitude control in a way that output from the heaters 74, 84 and 94 is proportional to device supplied voltage. In addition to control functions, the digital signal processor 50 is also configured to detect open circuits, reverse wires, pinched wires, and short circuit conditions in the feedback sensing circuits including the temperature sensors 36, 92, 96, as well as in heaters 74, 84 and 94. Furthermore, the digital signal processor 50 may detect when one of the heaters 74, 84, and 94 may be wet and apply an appropriate voltage to dry the heaters 74, 84, and 94, i.e., a bake-out function, utilizing moisture detection and moisture mitigation algorithms. Furthermore, the digital signal processor 50 may detect incorrect wiring connections to any heaters 74, 84, 94.

According to a non-limiting variant, in order for the digital signal processor 50 to implement control functions, the digital signal processor 50 is configured to accept various system measurements, e.g., injection molding system measurements. Preferentially, output signals are created by the digital signal processor 50 based on sensory input from sensors ("sensors") 102, 104 and 106. Sensors 102, 104 and 106 may include, but are not limited to: a material state change sensor; a pressure sensor; a resistance shift sensor; a capacitance sensor; an inductance sensor; a material phase change sensor; a permeability sensor; a density sensor; a viscosity sensor; a shear feedback sensor; a material flow sensor; a polymerization response sensor; a strain sensor; a stress sensor; and a transformation function sensor.

An illustrative, but nonlimiting, example of a sensor for monitoring a material state change sensor includes, but is not limited to, a fiber optic raman spectrometry (FORS) sensor that provides real time material state information. An illustrative, but nonlimiting, example of a sensor for monitoring pressure includes, but is not limited to, a transducer. An illustrative, but nonlimiting, example of a sensor for monitoring resistance shift includes, but is not limited to, a quartz crystal. An illustrative, but nonlimiting, example of a sensor for monitoring capacitance of a circuit includes, but is not limited to, a capacitance-to-digital conversion integrated circuit. An illustrative, but nonlimiting, example of a sensor for monitoring inductance of a circuit includes, but is not limited to, an inductance-to-digital conversion integrated circuit.

An illustrative, but nonlimiting, example of a sensor for monitoring material phase change includes, but is not limited to, a sensor that utilizes a hydrogel. An illustrative, but nonlimiting, example of a sensor for monitoring permeability includes, but is not limited to, a permeability sensor. An illustrative, but nonlimiting, example of a sensor for monitoring viscosity includes, but is not limited to, a viscosity sensor utilizing a cylinder and piston. An illustrative, but nonlimiting example of a sensor for monitoring shear feedback includes, but is not limited to, an integrated tactile/shear feedback array.

An illustrative, but nonlimiting, example of a sensor for monitoring material flow includes, but is not limited to, a sensor responsive to a material flow rate. An illustrative, but nonlimiting, example of a sensor for monitoring polymerization response includes, but is not limited to, a polymerization response sensor. An illustrative, but nonlimiting, example of a sensor for monitoring strain and/or stress includes, but is not limited to, a piezo-electric sensor element. An illustrative, but nonlimiting, example of a sensor for monitoring a transformation function includes, but is not limited to, a sensor whose output is modified via a transformation function.

A universal input with an advanced analog to digital converter can be utilized to sample the inputs during predetermined time intervals, e.g., 10 milliseconds or better at 120 Hz, and continuously to correct for drift. High noise immunity is achieved by rejection of pickup, e.g., 50/60 Hz, and other sources of noise. The resistance (impedance) of the heaters 74, 84 and 94 is measured to determine when one of the heaters 74, 84 and 94 might fail in order to perform scheduled maintenance. The temperature of the heaters 74, 84 and 94 is measured with the temperature sensors 76, 86, and 96 and these measured values are then provided to the digital signal processor 50. Illustrative, but nonlimiting, examples of temperature sensors include, but are not limited to, a thermocouple, a resistance temperature detector ("RTD"), and a pyrometer.

Moreover, the current to the heaters 74, 84 and 94 is also measured with feedback sensing circuits including temperature sensors 72, 82 and 92 and these measured values are also provided to the digital signal processor 50. The current is controlled with set point control and then open loop percentage control to control temperature around the set point. Leakage current is measured to identify a wet heater condition for at least one of the heaters 74, 84 and 94 to determine when to activate the bake-out function and apply suitably modulated output.

The result of utilizing the present invention with a small temperature excursion ("dT") of 30° Celsius, with 2 seconds on and 8 seconds off so that all heaters 74, 84 and 94 can cycle past 10,000 cycles as shown in FIG. 3. The results for a first temperature sensor are indicated by numeral 76, the results for a second temperature sensor are indicated by numeral 86 and the results for a third temperature sensor are indicated by numeral 96. As shown, this will provide a tremendous increase in reliability.

Thus, there has been shown and described several embodiments of a novel invention. As is evident from the foregoing description, certain aspects of the present invention are not limited by the particular details of the examples illustrated herein, and it is therefore contemplated that other modifications and applications, or equivalents thereof, will occur to those skilled in the art. The terms "have," "having," "includes" and "including" and similar terms as used in the foregoing specification are used in the sense of "optional" or "may include" and not as "required." Many changes, modifications, variations and other uses and applications of the present construction will, however, become apparent to those skilled in the art after considering the specification and the accompanying drawings. All such changes, modifications, variations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the claims that follow.

WHAT IS CLAIMED IS:

1. A temperature controller for at least one heater being utilized in a hot runner injection molding system, the temperature controller comprising:

a regulated voltage supply that is electrically connected to the at least one heater being utilized in the hot runner injection molding system;

at least one temperature sensor being positioned relative to the at least one heater being utilized in the hot runner injection molding system;

at least one digital signal processor being operatively connected to: (i) the at least one heater being utilized in the hot runner injection molding system, (ii) the regulated voltage supply, and (iii) the at least one temperature sensor, the at least one digital signal processor being configured to regulate temperature of the at least one heater being utilized in the hot runner injection molding system based on feedback from the at least one temperature sensor; and

at least one output switching stage being electrically connected to the at least one heater being utilized in the hot runner injection molding system and the regulated voltage supply, wherein the at least one output switching stage varies at least one of voltage and frequency to the at least one heater being utilized in the hot runner injection molding system through at least one of pulse width modulation and zero crossing detection.

2. The temperature controller for the at least one heater being utilized in the hot runner injection molding system according to Claim 1, further comprising:

at least one trigger control module that transmits command signals to the at least one output switching stage, wherein the at least one trigger control module is electrically connected to the at least one digital signal processor and the regulated voltage supply.

3. The temperature controller for the at least one heater being utilized in the hot runner injection molding system according to Claim 1, further comprising:

at least one controller interface that is electrically connected to the at least one digital signal processor.

4. The temperature controller for the at least one heater utilized in the hot runner injection molding system according to Claim 1, wherein:

the regulated voltage supply is capable of receiving alternating current voltage in a range from about 110 Volts to about 600 Volts in a frequency range from about 50 Hz to about 400 Hz in at least one phase.

5. The temperature controller for the at least one heater utilized in the hot runner injection molding system according to Claim 1, wherein:

the at least one digital signal processor utilizes zero crossing time proportioning control and phase fired voltage control.

6. The temperature controller for the at least one heater utilized in the hot runner injection molding system according to Claim 1, wherein:

the at least one digital signal processor utilizes control features selected from the group consisting of automatic tuning, PID feedback loop, feed forward, slope control, or cut back.

7. The temperature controller for the at least one heater being utilized in the hot runner injection molding system according to Claim 1, further comprising:

a voltage filtering and feedback stage that is electrically connected to the regulated voltage supply to smooth rectified the voltage coming from the regulated voltage supply.

8. A method for controlling temperature of at least one heater being utilized in a hot runner injection molding system, the method comprising:

receiving an input voltage with a regulated voltage supply that is electrically connected to the at least one heater being utilized in the hot runner injection molding system;

obtaining at least one temperature value from at least one temperature sensor being located distal proximate to the at least one heater being utilized in the hot runner injection molding system;

regulating temperature of the at least one heater being utilized in the hot runner injection molding system with at least one digital signal processor that is operatively connected to the at least one heater being utilized in the hot runner injection molding system, the regulated voltage supply and the at least one temperature sensor; and

varying at least one of voltage and frequency to the at least one heater being utilized in the hot runner injection molding system through at least one of pulse width modulation and zero crossing detection with at least one output switching stage that is electrically connected to the at least one heater being utilized in the hot runner injection molding system and the regulated voltage supply.

9. The method for controlling temperature of the at least one heater being utilized in the hot runner injection molding system according to Claim 1, further comprising:

transmitting command signals to the at least one output switching stage, wherein at least one trigger control module is electrically connected to the at least one digital signal processor and the regulated voltage supply.

10. A temperature controller for a heater being utilized with an injection molding equipment being associated with an injection molding system, the temperature controller comprising:

a voltage rectifier and regulator module being configured to: (i) rectify an AC supply voltage, (ii) regulate the AC supply voltage, and (iii) convert the AC supply voltage into a DC voltage supply;

a voltage filtering and feedback stage being electrically connected with the voltage rectifier and regulator module, the voltage filtering and feedback stage being configured to output a filtered DC voltage supply;

an output switching stage being electrically connected with the voltage filtering and feedback stage, the output switching stage being electrically connected with the heater, the output switching stage being configured to convert the improved DC voltage supply into a heater voltage supply to be applied to the heater;

a trigger control module being electrically connected with: (i) the voltage rectifier and regulator module, and (ii) the output switching stage, the trigger control module being configured to control the voltage rectifier and regulator module and the output switching stage;

a temperature sensor being positioned relative to the heater, the temperature sensor being configured to measure temperature of the heater; and

a processor, including:

inputs being electrically coupled with: (i) the temperature sensor, and (ii) a measured voltage being associated with the voltage filtering and feedback stage; and

outputs being electrically coupled with the trigger control module,

the processor being configured to: (i) generate a command signal in response to receiving and processing the inputs, (ii) issue the command signal to the trigger control module, and the trigger control module controlling the voltage rectifier and regulator module and the output switching stage in compliance with the command signal in response to receiving the command signal from the processor.

11. The temperature controller of claim 10, wherein:

the processor increases reliability of the heater by: (i) increasing a duty cycle associated with the heater, the duty cycle being a ratio of active time that the heater is on to a total time that the heater is on and off, and (ii) reducing a temperature excursion associated with the duty cycle of the heater.

12. An injection molding system, comprising:

an injection molding equipment;

a heater being utilized with the injection molding equipment; and

a temperature controller for the heater, the temperature controller comprising:

a voltage rectifier and regulator module being configured to: (i) rectify an AC supply voltage, (ii) regulate the AC supply voltage, and (iii) convert the AC supply voltage into a DC voltage supply;

a voltage filtering and feedback stage being electrically connected with the voltage rectifier and regulator module, the voltage filtering and feedback stage being configured to output a filtered DC voltage supply;

an output switching stage being electrically connected with the voltage filtering and feedback stage, the output switching stage being electrically connected with the heater, the output switching stage being configured to convert the improved DC voltage supply into a heater voltage supply to be applied to the heater;

a trigger control module being electrically connected with: (i) the voltage rectifier and regulator module, and (ii) the output switching stage, the trigger control module being configured to control the voltage rectifier and regulator module and the output switching stage;

a temperature sensor being positioned relative to the heater, the temperature sensor being configured to measure temperature of the heater; and

a processor, including:

inputs being electrically coupled with: (i) the temperature sensor, and (ii) a measured voltage being associated with the voltage filtering and feedback stage; and

outputs being electrically coupled with the trigger control module,

the processor being configured to: (i) generate a command signal in response to receiving and processing the inputs, (ii) issue the command signal to the trigger control module, and the trigger control module controlling the voltage rectifier and regulator module and the output switching stage in compliance with the command signal in response to receiving the command signal from the processor.

13. The injection molding system of claim 12, wherein:

the processor increases reliability of the heater by: (i) increasing a duty cycle associated with the heater, the duty cycle being a ratio of active time that the heater is on to a total time that the heater is on and off, and (ii) reducing a temperature excursion associated with the duty cycle of the heater.

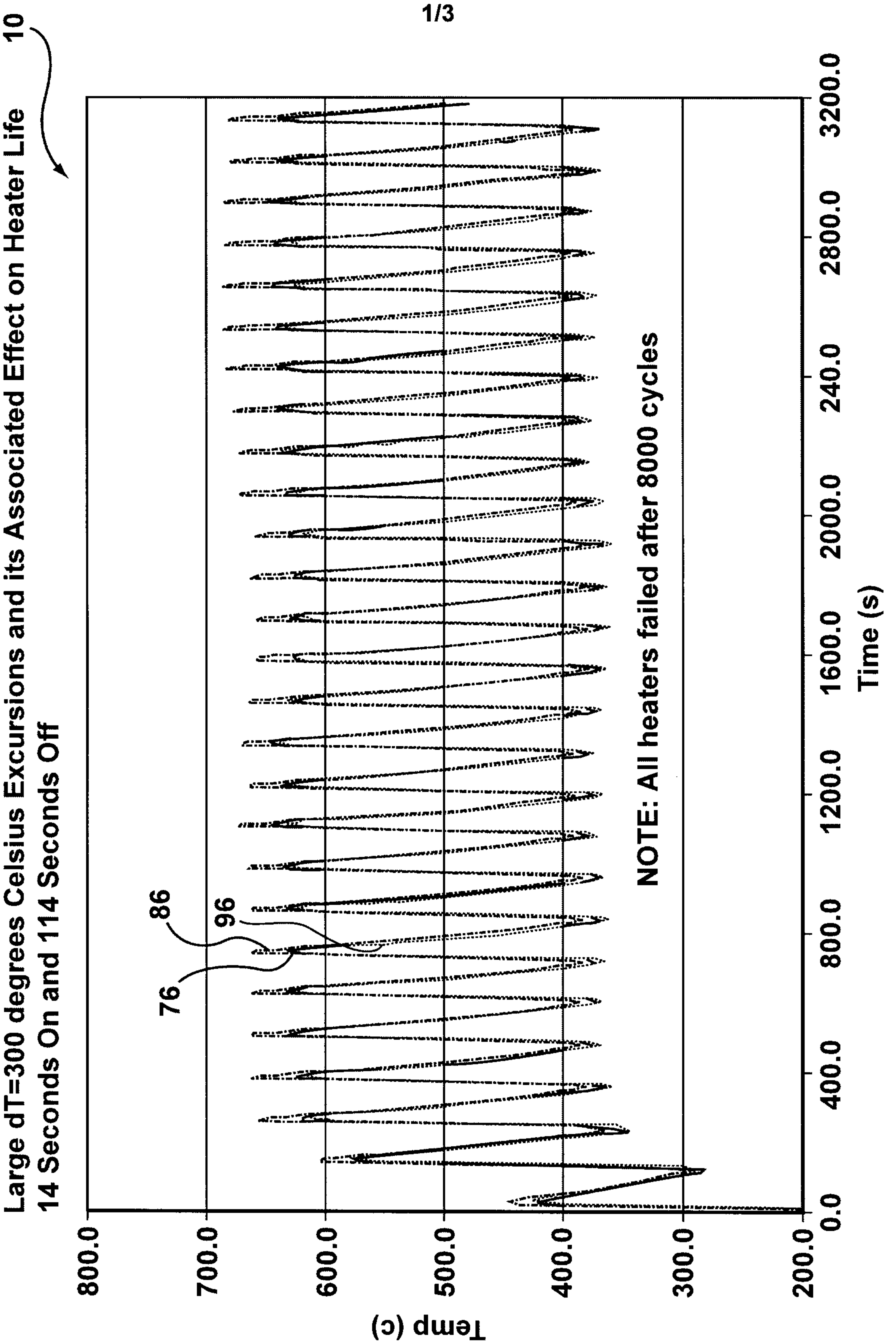


FIG. 1(PRIOR ART)

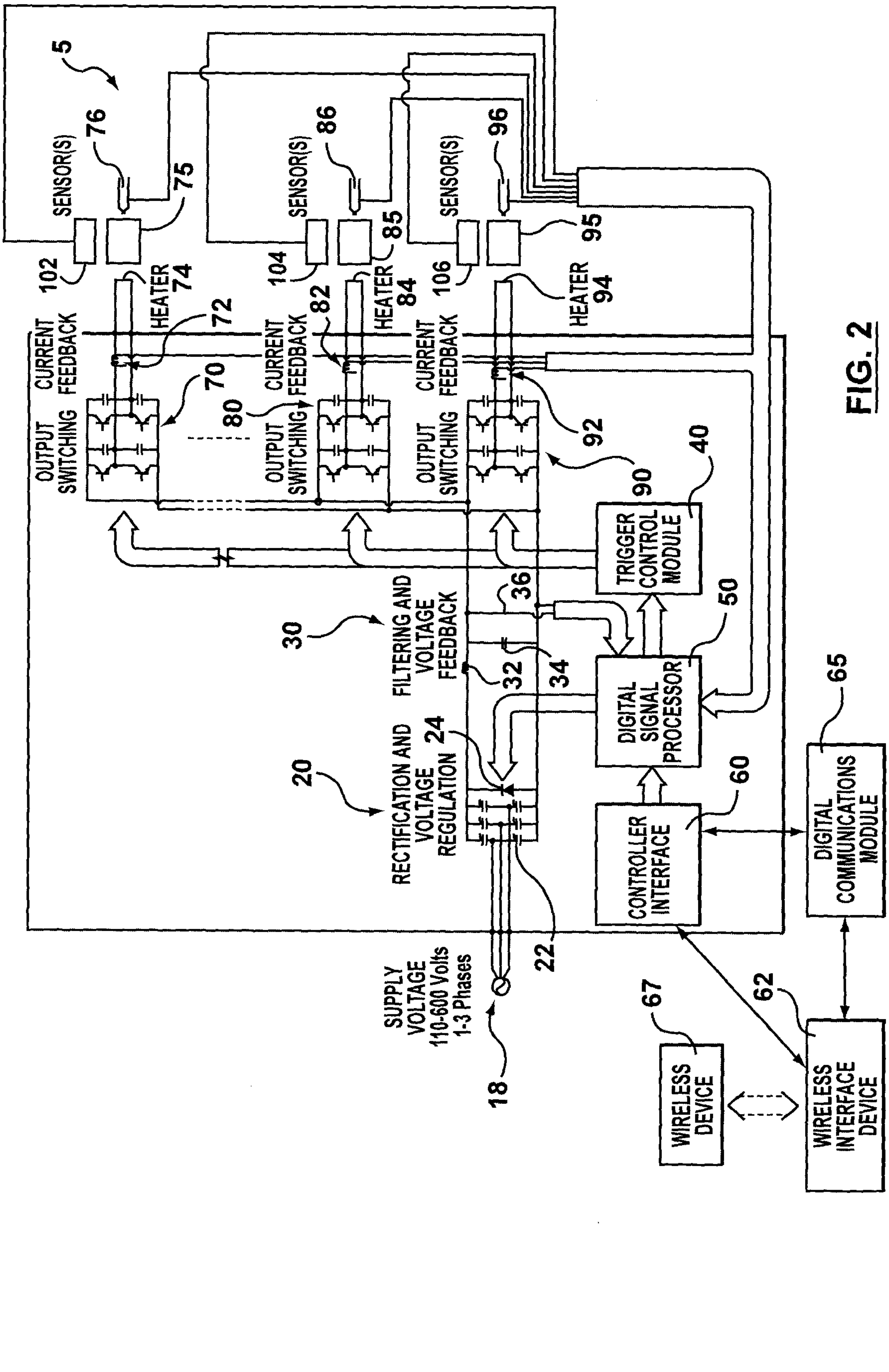

5
SENSOR(S)
76
75
102
SENSOR(S)
86
85
104
SENSOR(S)
96
95
106
HEATER 74
HEATER 84
HEATER 94
72
82
92
CURRENT FEEDBACK
CURRENT FEEDBACK
CURRENT FEEDBACK
OUTPUT SWITCHING
OUTPUT SWITCHING
OUTPUT SWITCHING
70
80
90
TRIGGER CONTROL MODULE
40
36
FILTERING AND VOLTAGE FEEDBACK
30
32
34
DIGITAL SIGNAL PROCESSOR
50
RECTIFICATION AND VOLTAGE REGULATION
20
24
22
CONTROLLER INTERFACE
60
DIGITAL COMMUNICATIONS MODULE
65
SUPPLY VOLTAGE 110-600 Volts 1-3 Phases
18
62
WIRELESS DEVICE
67
WIRELESS INTERFACE DEVICE

FIG. 2

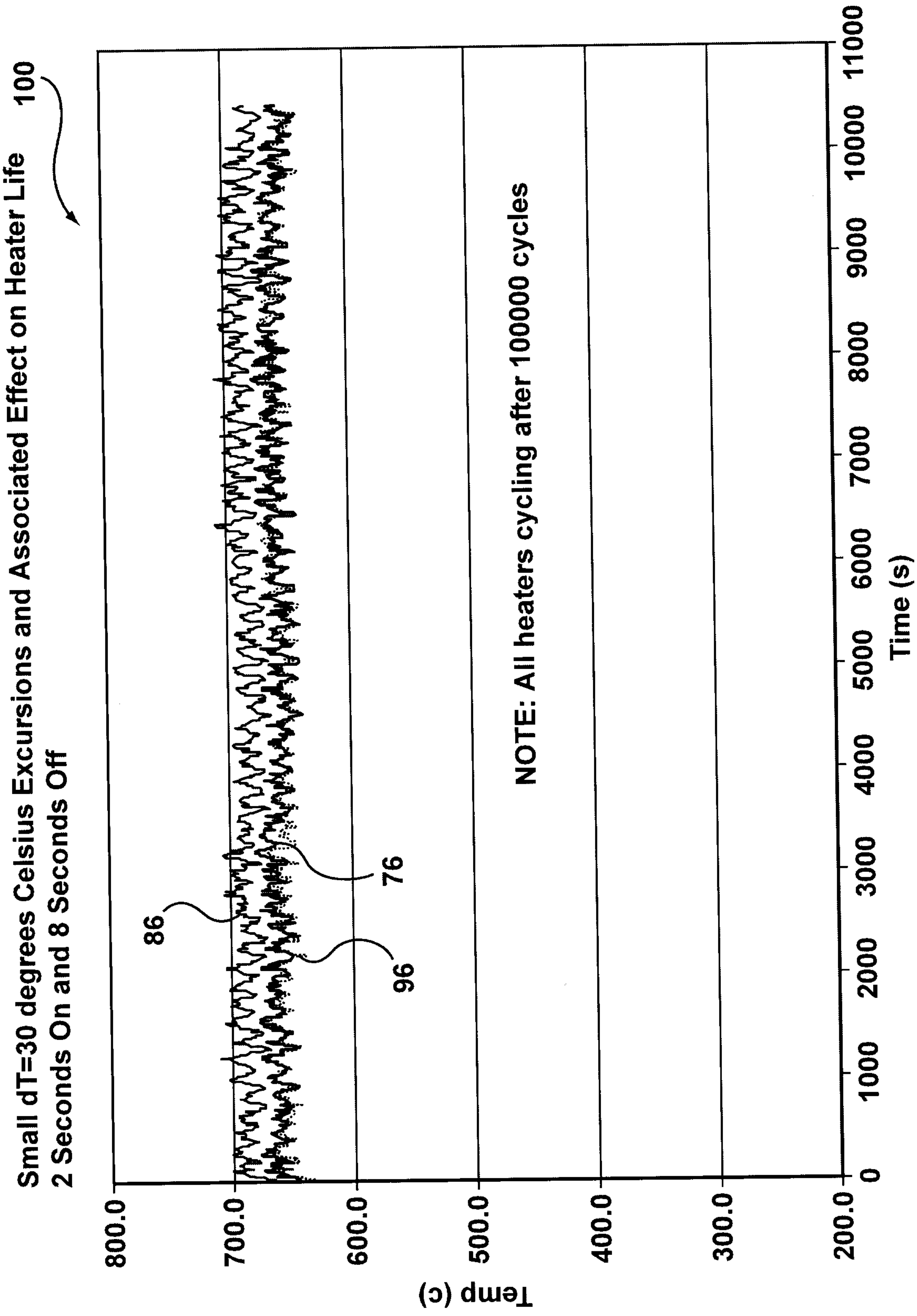
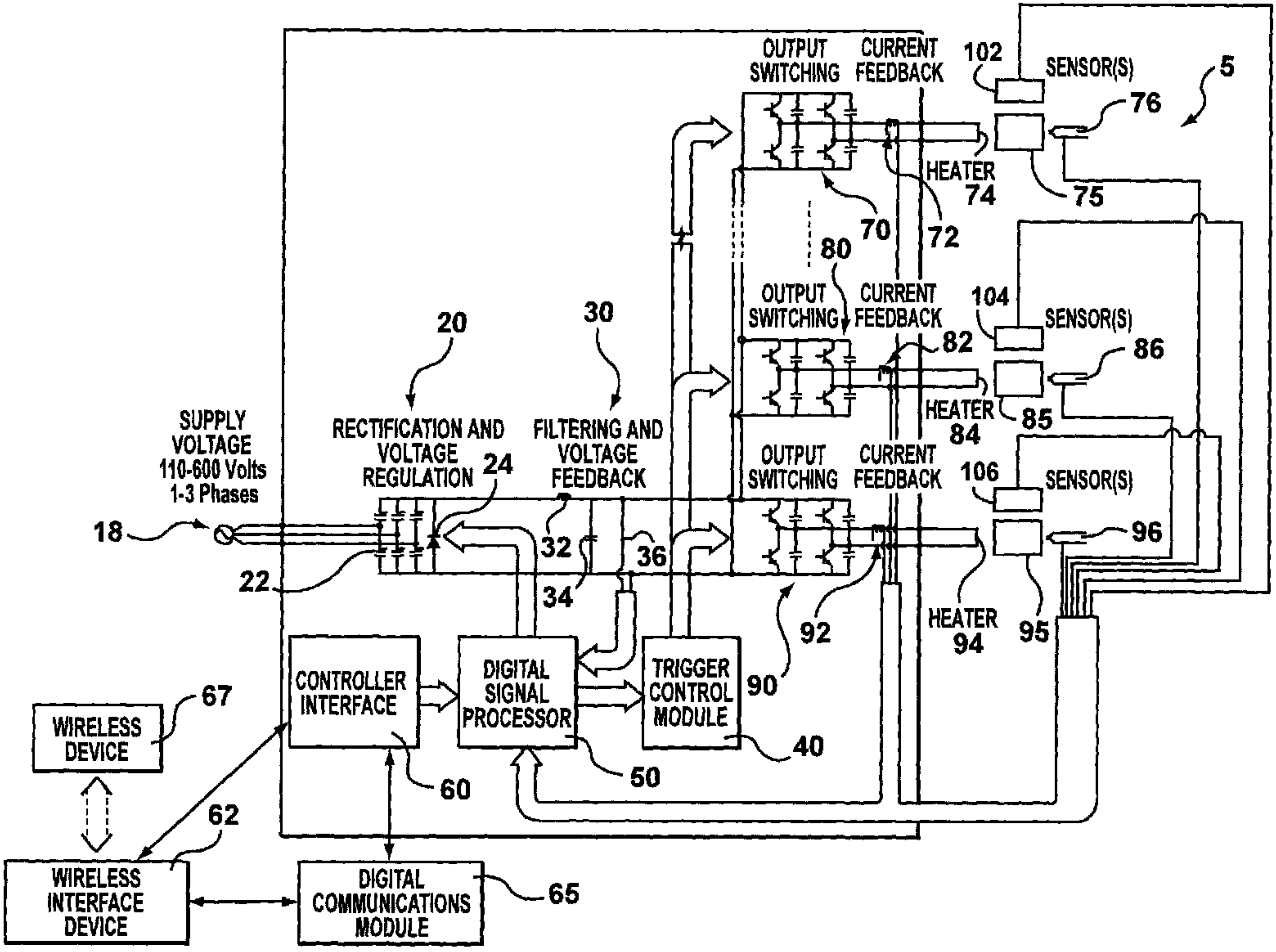

Small dT=30 degrees Celsius Excursions and Associated Effect on Heater Life
2 Seconds On and 8 Seconds Off
100
86
96
76
NOTE: All heaters cycling after 100000 cycles
Temp (c)
800.0
700.0
600.0
500.0
400.0
300.0
200.0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
Time (s)

FIG. 3



OUTPUT SWITCHING
CURRENT FEEDBACK
102
SENSOR(S)
5
76
HEATER 74
75
70
72
80
OUTPUT SWITCHING
CURRENT FEEDBACK
104
SENSOR(S)
82
86
HEATER 84
85
20
30
SUPPLY VOLTAGE 110-600 Volts 1-3 Phases
RECTIFICATION AND VOLTAGE REGULATION
24
FILTERING AND VOLTAGE FEEDBACK
OUTPUT SWITCHING
CURRENT FEEDBACK
106
SENSOR(S)
18
32
36
96
22
34
HEATER 94
95
92
90
CONTROLLER INTERFACE
DIGITAL SIGNAL PROCESSOR
TRIGGER CONTROL MODULE
67
WIRELESS DEVICE
40
60
50
62
WIRELESS INTERFACE DEVICE
DIGITAL COMMUNICATIONS MODULE
65