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TITLE OF THE INVENTION*'Digital Electronic Control Unit'***FIELD OF THE INVENTION**

This invention relates to a digital electronic control unit with real-time-
5 clock based control, remote control and networking capabilities for
controlling the functions of domestic and commercial appliances such as
washing machines, refrigerators, dishwashers, electric ovens, and the like.

BACKGROUND

10 //Many modern control systems that are used for industrial or
commercial applications incorporate the following features :

- 1) Real-time-clock (Time-of-day) based control actions.
- 2) Networking of various devices inorder to share resources or data,
as well as to provide remote access to a device over the network.
- 3) Remote control using a hand-held remote control device.

15 The use of computers in control systems has further increased the need
for such intercommunications. Finally, the rapid growth of the Internet and its
fast expanding reach into offices and homes in the movement towards the
"networked society" of the near future is expected to generate the demand for
internetworking the various. These developments have led to the need for
20 communication abilities even in the average devices of the home. It is
therefore expected that domestic appliances would also require such
capabilities.

Most designs of devices with such capabilities utilise microcomputers
or microcontrollers as the key component for control. While this approach
25 works very well, it is not the most cost-effective or efficient for many
applications. In particular, the cost-sensitive, mass-volume application area of
domestic appliances require special interface circuits, such as AC power
switching devices, for which additional hardware is needed when using
microcontrollers. This additional hardware can easily increase the cost and

size of the control for the appliance very significantly. The use of special custom hardware provides a better solution, but existing designs of such custom hardware are very specialised to a particular application or appliance. Each appliance product therefore needs its own dedicated design of custom hardware.

The most desirable solution is one in which a specially-designed hardware suitable for the entire range of appliances, is configured for use in each specific product. Such a design would provide the flexibility of microprocessor-based designs at significantly lower cost and size. //

The object of this invention is to provide a flexible, digital electronic control unit for use in domestic and commercial appliances, that provides the capabilities of real-time based control, remote control and networking.

To achieve the said objective this invention provides a digital electronic control unit characterized by:

- a plurality of sensor drive circuits each of which drives an external sensing element, the said sensing elements converts the sensed parameter to an electrical signal,
- an analog multiplexer that receives the signal from each of the external sensing elements, and selectively routes one of the signal to its output,
- an analog-to-digital converter connected to the output of the said analog multiplexer, that converts the multiplexer output to digital form,
- a linearity, sensitivity and offset correction circuit connected to the output of the said analogue-to-digital converter for correcting the digital values received from it, using sensor calibration data stored in non-volatile memory,
- a central control unit that receives the corrected output from the said linearity offset and sensitivity correction circuit, and generates the control signals necessary for operation of the appliance, as well as the

selection signals for controlling the said analog multiplexer, using control data supplied by the non-volatile memory,

- a digital noise filter connected to the output of the said central control unit, to eliminate spurious outputs,
- 5 - a digital de-multiplexer connected to the output of the said digital noise filter and controlled by the said central control unit for selecting the output to which the input from the said digital noise filter is to be connected,
- a plurality of control latches, each being connected at one output
10 of the said digital de-multiplexer, for storing the digital data received from it and actuating the necessary part of the appliance in order to correct the sensed parameter,
- a non-volatile memory that stores the data and control parameters required for the operation of the said central control unit, linearity
15 sensitivity and offset correction circuits, output drive and protection circuits.
- a clock oscillator that provides the timing signals necessary for the operation of required circuits of the digital electronic control unit,
- the said central control unit is further connected to at least one of
20 the following at its input:
 - a real-time clock that provides time-of-day data,
 - a remote control interface unit, that provides the ability to receive user input and provide responses to the user from/to a remote control device,
 - 25 - a network interface unit, that provides the capability for bidirectional transfer of data between the digital control unit and other devices.

The said remote control interface unit is an infra-red or ultrasonic or radio frequency remote interface units

The said network interface unit is is for a Transport Control Protocol / Internet Protocol (TCP/IP) based network such as for Internet connectivity.

The said network interface unit is is for a Controller Area Network (CAN) Bus based network.

5 The said sensing element are linear or non-linear transducers.

The said central control unit and the said linearity offset and sensitivity correction circuit are digital logical circuits.

The output of each of the said control latches is connected to an output drive and protection circiut to drive a switching device to actuate the
10 necessary part of the appliance in order to correct the sensed parameter

To provide user-defined inputs and selections for defining the desired values of the control parameters, a plurality of user input means are connected to the said central control unit through said analog multiplexer, analog-to-digital converter, and linearity offset and sensitivity correction circuit.

15 The user variable means are potentiometers or switches.

A display drive unit is connected to the output of the said central control unit for the selective display of either the sensed parameter or the user-specified value from the user input means on an external display device.

An audio drive unit is connected to the output of the said central control
20 unit for generating audio signals for user's attention using an external audio transducer.

Power supply for powering the digital electronic control unit consists of a low loss capacitive voltage dropping network followed by a voltage clamping device, a rectifier and a filter network to provide a DC voltage.

25 Entire digital electronic control unit including the real-time clock, remote control interface unit and netwok interface unit except power supply, sensing elements, user variable means and external switching devices, is implemented as a custom Application Specific Integrated Circuit (ASIC), to provide a miniature and cost effective control element. The ASIC also

excludes non-volatile memory in order to provide larger capacities for storage of data, but includes a memory interface block for connecting to the external non-volatile memory.

The output drive and protection circuit includes a thermal protection circuit, an over-current protection circuit, over-voltage protection circuit and a soft start circuit for providing an effective reduced voltage start up to the load during the initial period of turn-on.

The frequency of the clock oscillator ranges from 32 KHz - 25 MHz, preferably 4 MHz.

The network interface unit, in one embodiment is for connecting to a TCP/IP protocol based network, such as for connecting to the Internet.

In another embodiment, the network interface unit is designed for connecting to a Controller Area Network (CAN) system.

In yet another embodiment, the network interface unit is designed for connecting to a cable network.

A digital electronic control unit has been described in our co-pending PCT application No. PCT/IN 99/00029. The instant application includes the facilities for networking, remote control and time-of-day based control using a real-time clock. These facilities have not been claimed or described in the said co-pending application.

The invention will now be described with reference to the accompanying drawings :

Fig - 1 shows the digital electronic control unit including real-time clock, remote control interface, and network interface, according to this invention, using potentiometers for providing user-variable input.

Fig - 2 shows an alternate embodiment of the unit, using switches for providing user-variable input.

Fig - 3 shows an embodiment in which the entire digital electronic control circuit including the real-time clock, remote control interface unit and

network interface unit except the power supply, external sensing elements, user variable means and external switching devices, is implemented as an Application Specific Integrated Circuit (ASIC).

Fig - 4 shows an alternative embodiment in the form of a ASIC in which the non-volatile memory is also external to the ASIC. This facilitates the use of larger capacities of non-volatile memory.

Fig - 5 shows the internal structure of the output drive and protection circuit.

Fig - 6 shows the transformerless power-supply used to provide power to the electronic control unit.

Fig - 7 shows an application of the electronic control unit in a washing machine.

Fig - 8 shows an application of the electronic control unit in a refrigerator.

Referring to the drawings, items [1a - 1d] show the external sensing elements. Sensor drive circuits [2a - 2d] provide the bias signals for the sensors. Analog multiplexer [3] selects the signal from one of the sensing elements based on the selection data from the Central Control Unit [6] which is then converted to digital form by analog-to-digital converter [4]. This digital output is adjusted for sensor linearity, offset and sensitivity by linearity, sensitivity and offset correction circuit [5] that receives the correction factor data in digital form from non-volatile memory [17]. This corrected digital output is supplied to central control unit [6] which stores the data. User input is received by means of external potentiometers [12a - 12c] and is used by the central control unit [6] alongwith the stored digital data received from the linearity, sensitivity and offset correction circuit [5] to generate the control signal for correcting the sensed parameter. This control signal is passed through digital filter [7] to remove noise and then applied to the input of digital demultiplexer [8] which routes it to one of the control

latches [9a – 9f] under the control of the central control unit [6]. The output of each control latch is connected to an output drive and protection circuit [10a – 10f]. Each output drive and protection circuit drives an external switching device [11a – 11f] to actuate the relevant part of the appliance to

5 correct the sensed parameter. The central control unit [6] drives a display drive unit [13] for displaying user input or sensed parameter value on an external display unit [14], and also an audio drive unit [15] for providing audio output through an external audio transducer [16]. The central control unit [6] receives time-of-day data from real-time-clock unit [C] which enables

10 it to perform control actions based on time-of-day requirements. A remote-control interface unit [R] connected to the said central control unit [6] provides the ability to receive user input data remotely from a hand-held remote control unit. A network interface unit [N] connects the said central control unit [6] to external devices, which may be other similar digital control

15 units or other devices such as computers, and enables the exchange of data between the various devices in the network. A Clock Circuit [18] and non-volatile-memory [17] are connected to various points in the circuit as indicated. /

In Fig-2, the user variable inputs originate from external switches [20a – 20c], instead of potentiometers.

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Fig.-3 shows an implementation of the electronic control unit including the real-time clock, remote control interface unit and network interface unit and excluding the external blocks [1a-1d], [11a-11f], [12a-12c], [14], [16], [19], and [20a-20c] in the form of an Application Specific Integrated Circuit

25 (ASIC) [21] to provide a solution that is both very miniature and cost-effective.

Fig-4 shows another embodiment using an ASIC [22] in which the non-volatile memory is external to the ASIC in order to provide for larger storage

capacity. A non-volatile memory interface block [23] is provided in the ASIC for connecting to the external non-volatile memory [24].

Fig-5 shows the internal structure of each output drive and protection circuit. Overcurrent protection [25], over-heat protection [26] and over-voltage protection [27] circuits inside each output drive and protection circuit monitor the electrical conditions at the output of each external switching device [11a-11f] and limit or cut-off the drive to it in case of overload conditions. Additionally, a soft-start drive circuit [28] provides a gradual start-up drive signal in order to minimise stress on the external switching device [11a-11f] as well as the load (appliance).

Fig.-6 shows the transformerless power-supply [29] of 2 to 8 volts, used to provide power to the digital electronic control unit. A capacitive voltage dropping network [30], with a voltage clamping zener diode [31] reduces the input high-voltage A.C. voltage to a low value. This low value a.c. voltage is then rectified and filtered by a diode [32] and then filtered by a capacitor [33] to produce a low voltage d.c. supply that feeds power to the circuit.

Fig-7 shows an application of the electronic control unit in a washing machine [34]. A water level sensing element [35] placed inside the wash tank senses the water level in the tank, a temperature sensing element [36] inside the wash tank senses the temperature of the water while. a detergent level sensing element [37] placed inside the detergent supply tank senses the detergent level. The water-fill valve [38], heating coil [39], detergent-fill valve [40], agitator motor [41], motor-reversing switch [42] and water-drain valve [43] are controlled by the electronic control unit [45] based on the signals received from the various sensing elements and from the user setting switches [44]. The status and user settings are displayed on the machine's user-interface panel [46] and when required, alarms are annunciated on the audio unit [47]. A handheld remote-control unit [RC] is also used to control

the user settings and receive status information, remotely. A real-time-clock [CL] on the front panel of the washing-machine displays time-of-day information and can be used to set control actions, e.g. turning-on or turning-off the washing-machine at programmed times during the day. A network

5 [NW] connects the washing machine to other appliances in the home and to home computer (not shown), to provide computer controlled operation from within the home. //

Fig-8 shows an application of the electronic control unit in a refrigerator [48]. A temperature sensing element [49] placed inside the freezer

10 compartment senses the temperature near the cooling coils [50], another temperature sensing element [51] placed inside the main compartment senses the temperature inside that compartment while a third temperature sensing element [52] senses the temperature of the compressor housing. A door switch [53] located on the door frame senses the open-close condition of the

15 refrigerator's door. The digital electronic control unit [54] receives the signals from each of these sensing elements and operates the compressor unit [55], circulating fan [56], refrigerator light [57] and door-open alarm [58] based on the signals received from each of the sensing elements and switches. In addition, the refrigerator has a real-time-clock [RCL] display on

20 the front-panel [FP] that is used to display the time-of-day as well as to define control actions at programmed times of day. The network interface inside the digital electronic control unit is also used to connect the refrigerator to a network [NET] in the home that connects the various appliances to a central home computer (not shown) for monitoring and control.

25 **WORKING :**

Sensing elements [1a – 1d] (which may be linear or non-linear transducers) are driven by sensor drive circuits [2a – 2d] and produce analog voltage signals in response to sensed parameters. These analog voltage signals are applied to the inputs of analog multiplexer [3]. Analog multiplexer [3]

outputs the signal from one of the sensing elements to analog-to-digital converter [4] under control of channel-select signals received from the central control unit [6]. Analog-to-digital converter [4] produces a digital output that is the equivalent of the analog voltage supplied at its input. This digital output
5 corresponding to the signal received from the selected sensing element, is received by linearity and sensitivity and offset correction circuit [5] and modified by it, using data stored in non-volatile memory [17] at the time of manufacture of the digital electronic control unit, to correct for non-linearities, offsets and sensitivity deviations in the sensing element's output.
10 This produces a corrected, digital sensed parameter value. The central control unit and the linearity and sensitivity and offset correction circuit are digital logic circuits.

The corrected sensed parameter value is stored by the central control unit [6] which receives these values for each of the sensing elements. In
15 addition, the central control unit [6] also receives user-supplied inputs from potentiometers [12a – 12c] or switches [20a – 20c]. The values of these inputs and the stored parameter values are evaluated by the central control unit [6] in accordance with control data that is supplied by the non-volatile memory [17]. The result of the evaluation is in the form of a digital value that is output from
20 the central control unit [6] to the input of the demultiplexer [7] along with selection signals that determine the output to which the result is routed. The sequence of evaluation is repeated for each output of the demultiplexer in a repetitive manner.

In addition, the central control unit [6] also outputs digital signals for
25 driving the display drive unit [13] and audio drive unit [15] in accordance with control data supplied by non-volatile memory [17].

The output from the demultiplexer is stored in one of the control latches [9a – 9f] based on the selection control signals generated by the central control unit [6], and is used to enable / disable the corresponding

output drive and protection circuit [10a – 10f]. Each output drive and protection circuit [10a – 10f] when enabled by its corresponding control latch [9a – 9f] generates the signals necessary to drive the external switching device [11a – 11f] in order to actuate the relevant part of the appliance to correct the sensed parameter. The output drive and protection circuit [10a – 10f] also monitors the load conditions continuously and deactivates the drive to the external switching device [11a – 11f] if overload conditions are encountered.

A real time clock unit [C] provides time-of-day input to the central control unit [6] for enabling control actions based on time-of-day values. A remote control interface unit [R] connected to the said central control unit [6] makes it possible for the user to input data remotely, instead of from the front panel of the digital control unit, with the help of a hand-held remote control device, which may be an infrared, ultrasonic or radio-frequency remote control transceiver. A network interface unit [N] connected to the said central control unit [6] provides the facility to connect the digital control unit to other devices, such as other similar digital control units or computers, in order to exchange information.

Clock Circuit [16] based on a quartz Crystal oscillator in the 32 KHz – 25 Mhz frequency range generates all the timing signals necessary to operate each circuit block. while a Power Supply [18] supplies the necessary voltage and current to each circuit block of the electronic control unit.

A digital electronic control unit has been described in our co-pending PCT application No. _____. The instant application includes the facilities for networking, remote control and time-of-day based control using a real-time clock. These facilities have not been claimed or described in the said co-pending application.

We claim :

1. A digital electronic control unit characterized by:

- 5 - a plurality of sensor drive circuits each of which drives an external sensing element, the said sensing elements converts the sensed parameter to an electrical signal,
- an analog multiplexer that receives the signal from each of the external sensing elements, and selectively routes one of the signal to its output,
- 10 - an analog-to-digital converter connected to the output of the said analog multiplexer, that converts the multiplexer output to digital form,
- a linearity, sensitivity and offset correction circuit connected to the output of the said analogue-to-digital converter for correcting the digital values received from it, using sensor calibration data stored in non-volatile memory,
- 15 - a central control unit that receives the corrected output from the said linearity offset and sensitivity correction circuit, and generates the control signals necessary for operation of the appliance, as well as the selection signals for controlling the said analog multiplexer, using control data supplied by the non-volatile memory,
- 20 - a digital noise filter connected to the output of the said central control unit, to eliminate spurious outputs,
- a digital de-multiplexer connected to the output of the said digital noise filter and controlled by the said central control unit for selecting the output to which the input from the said digital noise filter is to be
- 25 connected,
- a plurality of control latches, each being connected at one output of the said digital de-multiplexer, for storing the digital data received from it and actuating the necessary part of the appliance in order to correct the sensed parameter,

- a non-volatile memory that stores the data and control parameters required for the operation of the said central control unit, linearity sensitivity and offset correction circuits, output drive and protection circuits.

5 - a clock oscillator that provides the timing signals necessary for the operation of required circuits of the digital electronic control unit, /
 (- the said central control unit is further connected to at least one of the following at its input:

10 - a real-time clock that provides time-of-day data,
 - a remote control interface unit, that provides the ability to receive user input and provide responses to the user from/to a remote control device,
 - a network interface unit, that provides the capability for bidirectional transfer of data between the digital control unit and other devices.]



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2. A digital electronic control unit as claimed in claim 1 characterized in that said remote control interface unit is an infra-red or ultrasonic or radio frequency remote interface units

3. A digital electronic control unit as claimed in claim 1 characterized in
 20 that said remote control interface unit is a radio-frequency remote interface unit

4. A digital electronic control unit as claimed in claim 1 characterized in that said remote control interface unit is an ultrasonic remote interface unit.

5. A digital electronic control unit as claimed in claim 1 characterized in
 25 that said network interface unit is is for a Transport Control Protocol / Internet Protocol (TCP/IP) based network such as for Internet connectivity.

6. A digital electronic control unit as claimed in claim 1 characterized in that said network interface unit is is for a Controller Area Network (CAN) Bus based network..



7. A digital electronic control unit as claimed in claim 1 characterized in that said network interface unit is for a cable network..
8. A digital electronic control unit as claimed in claim 1 characterized in that said sensing element are linear or non-linear transducers.
- 5 9. A digital electronic control unit as claimed in claim 1 characterized in that said central control unit and the said linearity offset and sensitivity correction circuit are digital logical circuits.
- 10 10. A digital electronic control unit as claimed in claim 1 characterized in that the output of each of the said control latches is connected to an output drive and protection circuit to drive a switching device to actuate the necessary part of the appliance in order to correct the sensed parameter
11. A digital electronic control unit as claimed in claim 1 characterized in that to provide user-defined inputs and selections for defining the desired values of the control parameters, a plurality of user input means are connected to the said central control unit through said analog multiplexer, analog-to-digital converter, and linearity offset and sensitivity correction circuit.
12. A digital electronic control unit as claimed in claim 1 characterized in that the user variable means are potentiometers or switches.
13. A digital electronic control unit as claimed in claim 1 characterized in that a display drive unit is connected to the output of the said central control unit for the selective display of either the sensed parameter or the user-specified value from the user input means on an external display device.
14. A digital electronic control unit as claimed in claim 1 characterized in that an audio drive unit is connected to the output of the said central control unit for generating audio signals for user's attention using an external audio transducer.
15. A digital electronic control unit as claimed in claim 1 characterized in that power supply for powering the digital electronic control unit consists of a



low loss capacitive voltage dropping network followed by a voltage clamping device, a rectifier and a filter network to provide a DC voltage.

16. A digital electronic control unit as claimed in claim 1 characterized in that entire digital electronic control unit including the real-time clock, remote
5 control interface unit and network interface unit except power supply, sensing elements, user variable means and external switching devices, is implemented as a custom Application Specific Integrated Circuit (ASIC), to provide a miniature and cost effective control element.

17. A digital electronic control unit as claimed in claim 16 characterized in
10 that the ASIC also excludes non-volatile memory in order to provide larger capacities for storage of data, but includes a memory interface block for connecting to the external non-volatile memory.

18. A digital electronic control unit as claimed in claim 1 characterized in that output drive and protection circuit includes a thermal protection circuit,
15 an over-current protection circuit, over-voltage protection circuit and a soft start circuit for providing an effective reduced voltage start up to the load during the initial period of turn-on.

19. A digital electronic control unit as claimed in claim 1 characterized in that frequency of the clock oscillator ranges from 32 KHz - 25 MHz.

20. A digital electronic control unit as claimed in claim 19 characterized in
20 that frequency of the clock oscillator is preferably 4 MHz.