

TITLE OF THE INVENTION

'Digital Electronic Control Unit For Domestic And Commercial Appliances'

FIELD OF THE INVENTION

5 This invention relates to a digital electronic control unit for controlling the functions of domestic and commercial appliances such as washing machines, refrigerators, dishwashers, electric ovens, and the like.

BACKGROUND

10 Many modern appliances incorporate control elements that are common in the nature of their control action as well as the parameters that are controlled. For example temperature control is a common requirement in several different appliances such as refrigerators, washing machines, dish-washers and electric ovens. Similarly, on-off control of fractional horse-power a.c. motors is also
15 common to all the appliances mentioned above, besides many others. Timer based control is yet another of the common requirements in many appliances. These requirements extend to several different commercial appliances also.

 The control mechanisms currently employed in each of these appliances are often widely different from each other. In addition, there are generally
20 several different control mechanisms employed in each appliances, often as many as one separate control device for each controlled parameter, with each of the control devices being wired together in a final circuit to perform the desired overall control function in a coordinated manner. This manner of implementation is inefficient and expensive when compared with the
25 capabilities that emerge with the use of an integrated system of control in which the advantages offered by modern electronics technology are utilised to the fullest to provide an integrated, miniaturised implementation that is both cost-effective and efficient in terms of operation, implementation and energy consumption.

Some of the common parameters for control in appliances are :

- 1) Temperature
- 2) Liquid Level
- 3) On-Off control of fractional horse-power ac or dc motors.
- 5 4) Time sequences
- 5) Events—such as switch closures / openings.

In addition, some common requirements are :

- 1) Audio output (e.g. to alert users when attention is required).
- 10 2) Push-button / rotary adjustments of control parameters by the user.
- 3) Display of user-selections / events / parameter values by visual means
--- indicators or displays.

An implementation of the various control functions in single-chip form
15 results in a flexible "electronic control element" that provides the maximum
advantages of low-cost, small size, ease of implementation and high reliability.
There are no known equivalent implementations available today.

Microcontroller based implementations for some control parameters,
such as temperature, are known. These come close to realising some of the
20 advantages but fall short in respect of optimal implementation of some of the
common requirements, such as triac-firing control, a.c motor protection controls
and interfaces to sensors. These requirements generally entail the incorporation
of additional external circuitry and interfaces that dilute the effectiveness of the
implementation.

25 The object of this invention is to provide a digital electronic control unit
that provides an efficient, miniature, reliable and cost effective control
mechanism for use in appliances intended for household and commercial
applications.

To achieve the said objective this invention provides a digital electronic control unit which comprises:

- 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
15 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
20 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,
- a digital de-multiplexer connected to the output of the said digital noise filter and controlled by the said central control unit for
25 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 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.

- a clock oscillator that provides the timing signals necessary for the operation of required circuits of the digital electronic control unit.

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

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

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

The user variable means are potentiometers or switches.

20 The said central control unit includes circuitry for defrost operation in the appliance, if required.

The said control unit also includes special circuitry for start relay operation, if required in the appliance.

25 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 unit for generating audio signals for user's attention using an external audio transducer.

The 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.

5 The entire digital electronic control 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.

10 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.

15 The central control unit and the linearity, offset and sensitivity correction circuit are digital logic circuits.

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

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

Fig - 1 shows the electronic control unit 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.

25 Fig - 3 shows an embodiment in which the entire electronic control circuit excepting 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 correct the sensed parameter. The said central control unit [6] includes circuitry for defrost operation (not shown) and for start relay operation (not shown), if required for the appliance. 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]. 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.

Fig.-3 shows an implementation of the electronic control unit 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 (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.

5 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
10 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 machines user-interface
15 panel [46] and when required, alarms are annunciated on the audio unit [47].

Fig-8 shows an application of the electronic control unit in a refrigerator [48]. A temperature sensing element [49] placed inside the freezer compartment senses the temperature near the cooling coils [50], another temperature sensing element [51] placed inside the main compartment senses the temperature inside
20 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 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],
25 refrigerator light [57] and door-open alarm [58] based on the signals received from each of the sensing elements and switches.

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 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. 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 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 the central control unit [6] to the input of the demultiplexer [7] alongwith 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.

The central control unit [6] also includes circuitry for defrost operation and start relay operation, if required for the appliance.

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

5 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
10 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 Clock Circuit [16] based on a quartz Crystal oscillator in the 32 KHz –
15 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.

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 connected,

25 - 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

- a clock oscillator that provides the timing signals necessary for the operation of required circuits of the digital electronic control unit.

2. A digital electronic control unit as claimed in claim 1 characterized in that the said sensing element are linear or non-linear transducers.

3. A digital electronic control unit as claimed in claim 1 characterized in that the said central control unit and the said linearity offset and sensitivity correction circuit are digital logical circuits.

4. A digital electronic control unit as claimed in claim 1 characterized in that the said central control unit contains defrost operation circuits in case of refrigeration appliances.

5. A digital electronic control unit as claimed in claim 1 characterized in that the said central control unit contains start relay circuitry in case of appliances using single phase AC motors.

6. 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

7. 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.



8. A digital electronic control unit as claimed in claim 1 characterized in that the user variable means are potentiometers or switches.

9. 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.

10. 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.

11. A digital electronic control unit as claimed in claim 1 characterized in that the 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.

12. A digital electronic control unit as claimed in claim 1 characterized in that the entire digital electronic control 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.

13. A digital electronic control unit as claimed in claim 12 characterized in 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.

14. A digital electronic control unit as claimed in claim 1 characterized in that 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.



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

16. A digital electronic control unit as claimed in claim 15 characterized in that the frequency of the clock oscillator is preferably 4 MHz.

