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Capacitive Touch User Interface and Implementation with Virtual Refrigerator

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Abstract
The proposed User Interface incorporates 14 Touch keys, including slider and wheeler functionality using self capacitance technology, 24 side throw LED with intensity controlled Fade-IN, Fade-OUT effects, Buzzer chime, Voltage regulator circuit, and communication circuitry for the control board. The major advantage that this User Interface is that the entire assembly is less than 10mm thick including PCB, components, light guide and graphics sticker. In this project the mentioned capacitive touch user Interface is interfaced with a Lab view system simulating a virtual refrigerator capable of responding to the commands from the User Interface.
Keywords—User Interface, self capacitance, Light guide, Lab view, LED driver, Buzzer, Human Machine Interface (HMI).

I. INTRODUCTION

The User Interface is the part of the system a consumer or intended operator has access to in order to control the various functions the product is capable.

Figure 1 Current trends in User Interface

As shown in figure 1 a good user Interface is an integral part of various products we see around us like Automobiles, phones, computers, television, music systems home appliances etc. The user interface may also provide the user with audio visual indications in order to convey different states and modes. The User Interface has gained increasing importance in the field of HMI (Human Machine Interface). In the field of home appliances HMI is enhanced in terms of flush finish boards, touch keys, gesture recognition, polyphonic tones, glass front aesthetics, Wi-Fi or NFC compatibility, Smartphone compatible etc to name a few notable feature. A good user interface providing functionality and aesthetics is one of the core ingredients to achieving optimum standards in HMI. A good user interface also aims at making the product more user friendly and thereby enhancing the user experience with the product.

Labview is a system developed by National Instruments which is widely used in the field of automation. Labview provides ease of creation of a virtual system that is completely programmable and capable of establishing via a wide range of protocols. Thus Labview system is capable of efficiently simulating system behavior and generating required control actions. Lab view can be used to generate. A virtual system provides a distinct advantage providing cadence to whole set of features.

II. LITERATURE SURVEY

A. *Market Survey*

The User Interface in this project is targeted for the refrigeration market in India. A range of refrigerators available in India by a variety of manufacturers were reviewed to have a comparative analysis. We can see that refrigerators on the whole lack in terms of user experience. Most models are pretty basic and are farfetched from the use of latest available technologies Thus from the range of products in India we have seen that these products do have a lot of features but lack in terms of User Interface experience. Traditional lighting systems are done using LEDs with either ON/ OFF modes. In order to enrich the aesthetics it is necessary to make use of varying light intensities. The products with the enhanced user Interface are mainly imported from U. S and European markets and therefore available only at a steep price. Hence when it comes to User Interface for refrigerators in India there is a significant scope of improvement.

The major road block hampering the introduction more enhanced Human machine Interface is the heavy cost that comes with it A system like a capacitive touch user Interface also faces technical challenges due to the space constraints on the refrigerator doors in India. The conventional touch assembly is pretty thick as shown in Fig 2 which could result in reduced cooling insulation at the respective position thereby causing cooling loses as well as result in condensation on the electronic board. Thus the proposed slim UI assembly as shown in Fig. 3 overcomes a lot a lot of manufacturing and performance issues. (Figures are taken from the software : Expedition PCB 3D viewer)

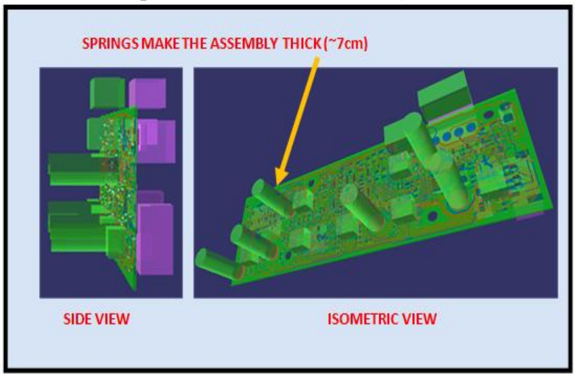

Figure 2 Conventional UI Assembly

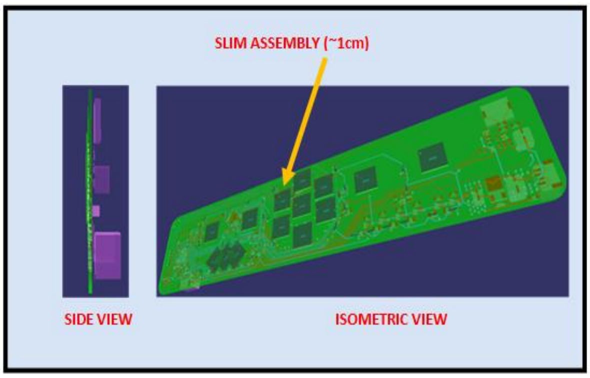

Figure 3 Proposed SLIM UI

B. *Current trends in User Interface test set-up*

In Whirlpool Corporation in order to test a user Interface and its interaction with the product currently it is required to have the specific control board that it would be used with an actual product capable of interfacing with the said control board as well as the user interface. With the number of different control boards available throughout the entire product range as well as different products available would make it an extremely large set of combinations to stock. Ideally a user Interface to be marketed in the North America would be tested by the software testing team in India. This would require them to not only ship the User Interface but also the specific control board as well as the product if the overall behavior needs to be ensured.

C. *Possible touch solutions*

1> A Touch Sensing Controller IC Adopting Differential Measurement

A touch sensor controller IC proposed by Stojanovic R et al. [1] with a novel touch sensing scheme is proposed for projected capacitive touch panel. The IC adopts the differential measurements to amplify the capacitance variation. By using the scheme, sensitivity to a touch object is increased and the immunities to power noise and display noise are improved.

2> FPGA Based Capacitive Touch Pad

A technique proposed by Siwei Zhana et al. [2] have introduced sensing principle and FPGA design of a capacitive touch pad/interface where the sensing pad is connected to the I/O pin via an external resistor. The circuit transforms the change in pad capacitance into voltage amplitude during charging, discharging and sharing phases. By using multiple pins and resistors, a multi touch system is achieved.

III. PROPOSED SYSTEM

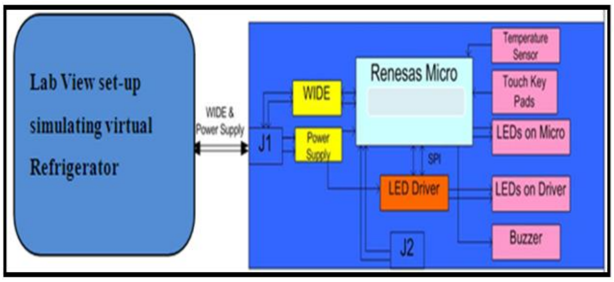

Figure 4 Block Diagram

D. *Labview Set-up.*

The Lab View set-up [6] would give a graphical representation of the entire refrigeration system consisting of the user Interface, Compressor Heater, Freezer temperature, Refrigerator compartment temperature. This system would be capable of handling and responding to commands sent by the user Interface.

E. *Micro controller*

The Touch panel microcomputer R8C/33T group contains a hardware peripheral (SCU: sensor control unit) that monitors the"touch" of the human body by measuring the stray capacitance generated between the touch electrode and the human. The Renesas R8C/33T Group [3] of single-chip MCUs incorporates the R8C CPU core, employing sophisticated instructions for a high level of efficiency. Renesas micro has 1 Megabyte of address space and it is capable of executing instructions at high speed. In addition, the CPU core boasts a multiplier for high-speed operation processing. Power consumption is low, and the supported operating modes allow additional power control.

F. Touch Interface

As shown in Figure 5 there are different forms of touch keys, Touch screens

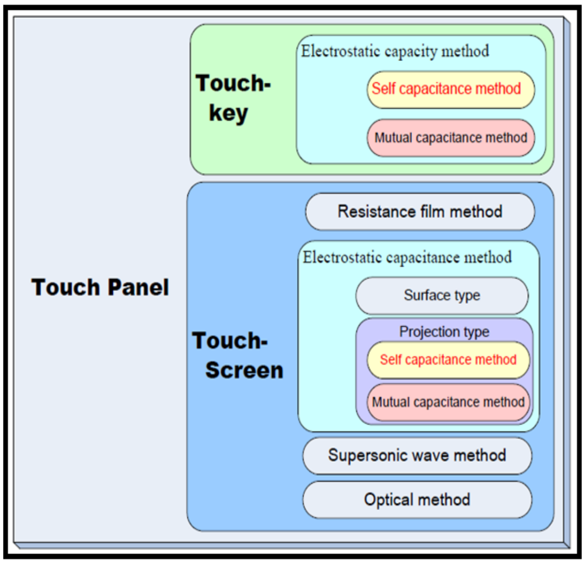

Figure 5 Types of Touch Interface

The touch pad principle used for this project makes use of electrostatic capacitance method is the general principle used in “Touch” measurements. The touch electrode is formed with materials such as PCB (printed circuits board), ITO (Indium Tin Oxide) films and electro conductive rubbers. The electric capacitance generated between the touch electrode and the human body is measured and a key ON or OFF judgment is made. When a lot of keys are necessary, the matrix configuration is used. The touch key matrix is like the key scanning matrix used with mechanical switches. When detection of movement of the finger that is the top to bottom or right and left is desired, the slider is used, and when the detection of movement around the circumference is desired, the wheel is used.

G. Touch Interface

The LED driver is basically used to control the LEDs without loading the micro-controller. The LED driver needs to have smooth Pulse Width Modulation control in order to have smooth control over LED intensity. The driver would typically have I2C protocol for communication with the micro-controller.

H. Touch Interface

The power to the User Interface would typically be delivered by the control board. The user Interface is required to have onboard voltage regulator provision to be compatible over a wide voltage range.

I. Touch Interface

Wide communication is a whirlpool proprietary communication protocol used for Inter-board communication. This interface carries signals coming from standard microcontroller asynchronous port (SCI or UART) and is designed to connect boards in a single line wired-OR bus. This interface has capability to carry up to 9600 baud.

IV. HARDWARE IMPLEMENTATION

A. Touch Implementation.

The self capacitance method [3] of touch detection is used by the Renesas R8C/33T controller. Figure 6 shows the principle of the self capacitance detection method. When not touched, a parasitic capacitance exists in touch electrode between the GND pattern and metallic frame of the PCB around the electrode. The electric capacitance is generated between the touch electrode and the finger because the human body is a conductor which is grounded to virtual GND so when the finger approaches the capacitance increases. The self-capacitance detection method perceives the approach of the finger by measuring an increase in the electric capacitance between non-touch and touch conditions. The self-capacitance method structure is simple, but because wiring to the electrode and the measurement IC cannot be protected by the GND pattern, the noise tolerance is low.

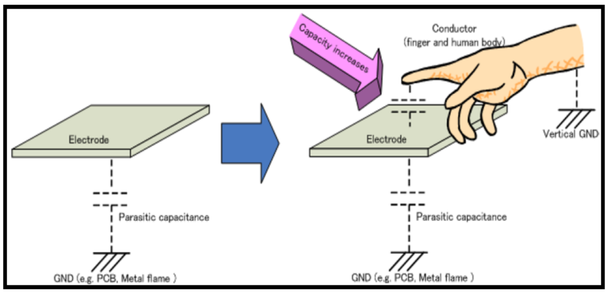

Figure 6 Self Capacitance Method

J. Touch sensing Within The Renesas Controller

Figure 7: shows the method of voltage division by series capacitance (OMRON method). This method measures the electric capacitance of Cx by the following methods.

Capacitor Cc is charged then is gradually discharged through resistance Rc. The charge of Cc is moved to the comparison capacitor Cr and the electric capacitance Cx. The divided voltage of Cr and Cx is measured. A detailed measuring method is as follows. SW1 is assumed turning on and Cc is charged. (SW2,SW3 is OFF) SW1, SW2, and SW3 are turned off. The charge of Cc is maintained. SW2 and SW3 are turned on for a fixed time. Cc is partially discharged through resistance Rc while all the charge on Cx and Cr are discharged.

SW1, SW2, and SW3 are turned off. The charge of Cc moves to Cx and Cr. The voltage of Cx is compared with Vref with a comparator. The relationship of voltages Vr, Vc,,Vx and capitances, Cc, Cr, and Cx are as follows.

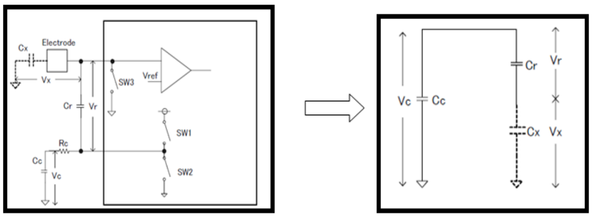

Figure 7 Fundamental Touch sensing circuit

Figure 8: shows a typical wave outline when touch detection operates. The rectangular shape waves shows changing voltage of Cx, and a mountain shape of waves is changing voltage of Cc. Voltage Vc decreases gradually as above-mentioned steps (3), (4), and (5) are repeated. Voltage Vx is the voltage shown by equation (c) in step (4), and 0V in step (3) since switch SW3 is closed. The number of cycles to reach Vx<Vref decreases when the capacitance of Cx increases by touch. The number of cycles is used to judge non-touch or touch.

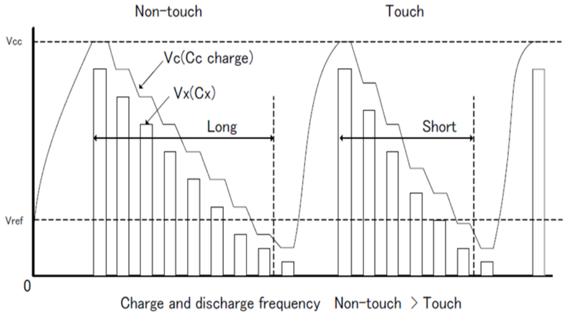

Figure 8 Touch Sensing cycles

The electric capacitance generated in man's finger and electrode is a few pF. A large value will provide an accuracy improvement of the touch detection if it is possible to improve it. However, the electrode surface area is related to the touch area of the finger and it is not effective to increase the area past some value. The inter electrode distance depends on thickness of the material with which the surface of the touch key is covered. Table 1 shows the relative permittivity of some common materials. It is different according to each material. The glass has the best relative permittivity excluding water. Acrylic and plastic are also often used

Dielectric Material	k
Acrylic	2.4-4.5
Glass	4.5-7.5
Nylon Plastic	3.0-5.0
Flexible Vinyl Film	3.2
Air	1.0
Water	80

Table 1 : Relative Permittivity of materials.

V. PROPOSED GRAPHICS

The proposed graphics is illustrated in Figure 7

Figure 9: Proposed Graphics

The product is capable operating in the following modes.

- Quick Ice
- Bottle cool
- Garden Fresh
- Vacation
- Low, Mid, High & Auto

Each user mode has a specific temperature set point, Compressor run time best suited for each of the particular applications. The exact product level temperature set-points and timing details are yet to be confirmed.

VI. LIGHT GUIDE AND LED PLACEMENT

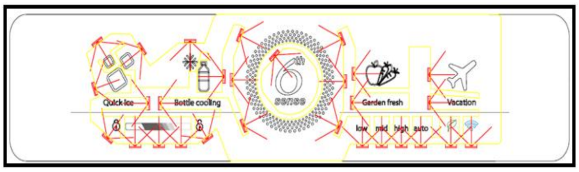

Figure 10: Light Guide and LED Placement.

For this particular project we would be using side fire LEDs in an attempt to accomplish the overall slim design. As shown in Figure 8 we can see the LED placement and the light rays shown as segments from the LED. The boundaries between icons show the final placement of light guide assembly. The Light guide contains light refracting particles at desired locations to refract light in order to illuminate the icons.

VII. RESULTS

The touch User Interface works as desired but an few software tweaks are required to adjust the sensitivity and touch response. The adjustment is to be made so as to accommodate the variations introduced by touch from different people. The LEDs driven by the LED driver, work with the required Fade-IN and Fade- OUT effect. The Buzzer chime is also a functional part of the User Interface.

Minimal Labview setup is done in order to simulate the virtual environment. The User Interface model is functional as an Individual model on the virtual system. At present work is in progress to communication between the User Interface and the Labview set-up.

VIII. Conclusion

The intended capacitive touch User Interface includes the Touch module, LED driver, Buzzer module, Communication circuitry and the on board voltage regulator within the estimated target costing. The Overall thickness of the complete assembly is expected to be less than 10mm. The product only requires a small cavity for the board to fit in and has sufficient room for the foam. This helps the installation without any loss in cooling.

The Virtual refrigerator will be able to simulate a host of control boards with minor changes. Thus the virtual system significantly improves the flexibility of the test equipment.

IX. Acknowledgment

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