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Intelligent Heating Towel Rack

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Abstract

The paper presents a novel heating towel rack control system capable to switch ON/OFF according to the wetness level of the towel. The wetness level affects the capacitance of the rack sensing part. The system is designed to control the towel rack heating by changing the capacitance to a voltage difference, which drives the switching part of the system. Principles of operation and technical parameters are presented. Results obtained from an experimental testing on a prototype are also revealed.

Keywords: towel rack, wetness level, capacitance to voltage converter, energy savings.

1 Introduction

The heating towel racks are widely used in New Zealand. They have been on the market for some time, and are manufactured using different shapes and materials. A typical heating towel rack, designed to produce heat from the electrical energy for drying a towel, is normally controlled by a mechanical switch. Consequently, the rack has to be switched manually.

This paper focuses on a control system which enables the heating towel rack switch ON when the towel is wet and switch OFF when the towel is dry. The system is to be used on the heating towel rack, which works under 230V AC power supply and have 60-65W power consumption. It is designed to operate in bathrooms, for home and hotel service.

During the design process several factors were taken into account, namely:

The size – the system should be easy to install on the existing heating towel rack. The size of the system is required to be 2cm (width)×10cm (height) ×15cm (length).
Power consumption requirements - The system should have lower power consumption compared to 60-65W, which is the power of the heating towel rack. The power consumption is decided to be under 5W.
Budget setting for the system - Assumptions have been made for money saving analysis. The amount of money saving on one heater can be up to $3 per month, and the budget of the system is set to be under 30 dollars.

2 Specifications and construction principles

The sensing system is based on the capacitance measurement. Therefore the physical structure of the towel rack should allow as large changes of the capacitance as possible. For this reason different shapes have been considered, to ascertain the largest capacitance difference between the dry bath towel and the wet towel. Figure 1 shows the structure of the rack.

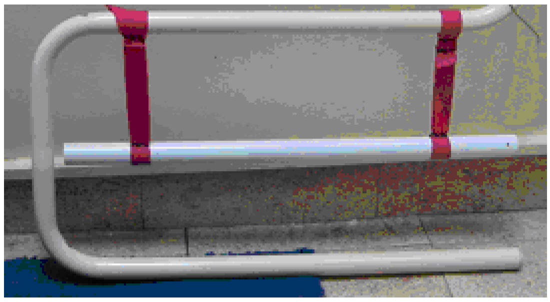

Figure 1. Capacitance sensing parts

A principle investigation was carried out to determine the relationship between the amount of water contained in the towel and the capacitance of the rack. Figure 2 shows this relationship obtained from the experiment.

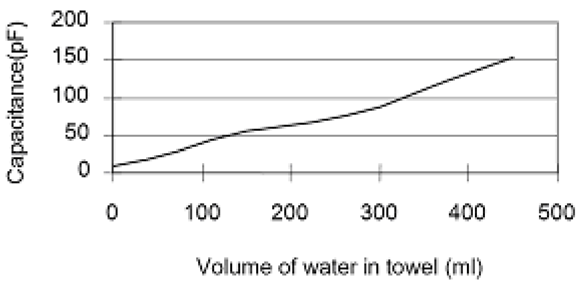

Figure 2. Volume of water in towel (ml)

The system must be able to distinguish between the wet and the dry towel. Therefore a capacity threshold was determined under which the towel is considered to be dry, and above which the towel is assumed wet. In this case the threshold is $C_{threshold}$ =17pF.

3 Switching system

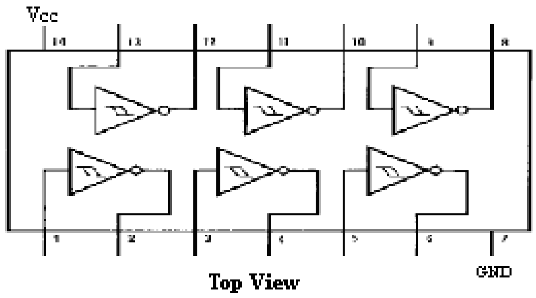

Figure 3. MM74c14 Hex Schmitt Trigger

The design of the switching system is based on a capacitance meter, which converts the capacitance to a voltage [1], [2], [3]. An oscillator is used to detect the charging and discharging of the capacitor represented by the rack. The MM74C14 Hex Schmitt Trigger is a monolithic complementary MOS (CMOS) integrated circuit constructed with N- and P-channel enhancement transistors. Figure 3 shows a top view of MM74c14 Hex Schmitt Trigger.

The reason for choosing MM74c14 Hex Schmitt Trigger was in relation to its operating parameters. It detects 2/3 of the rail voltage to change the state of the output. The linear relationship between the charging time and the capacitance simplifies the design. The whole circuit diagram of capacitance voltage converting system is shown in figure 4.

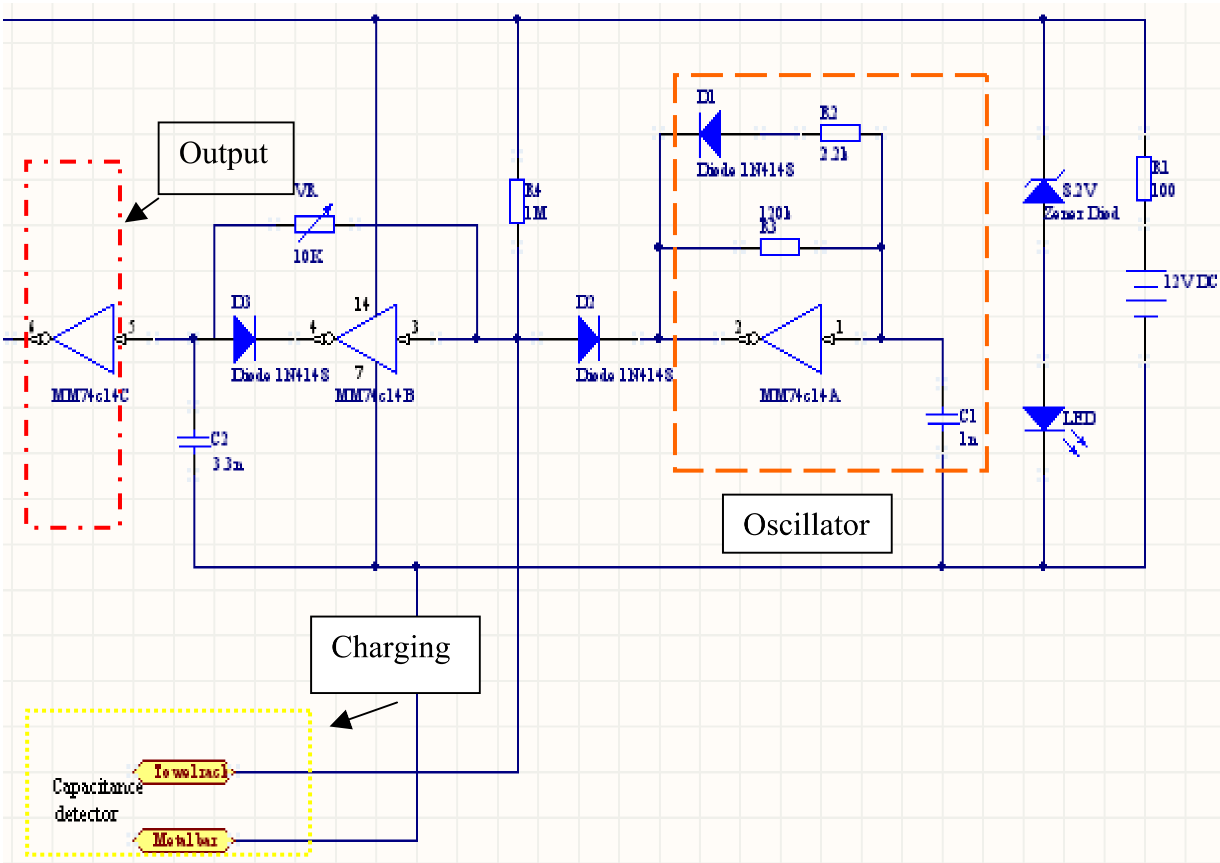

Figure 4. Capacitance to voltage converter

The output of the capacitance-sensing system controls the gate of the triac (BTA10-600) based-switch (figure 5). When the triac conducts, the heating is ON and the wet towel on the rack is dried. When the process finishes, the capacitance-based sensing system ascertains the change, and interrupts the triac gate current, stopping the heating.

To prevent triac conduction without gate current, snubber circuits are applied. The RC series one aims at avoiding dv/dt voltage change and the RC parallel one has to prevent di/dt current change.

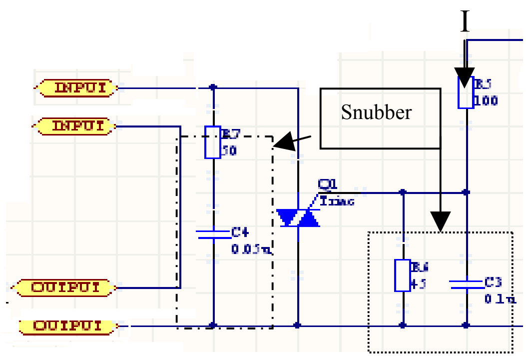

Figure 5. Switching circuit

As per the BTA10-600 datasheet [4] the trigger current I is within the range of 25 – 50 mA. The snubber value is also chosen in accordance to the component datasheet.

4 Cost of components

A cost estimation is presented in Table 1 along with the power consumption of the chosen components. The design parameters are observed and the system is well within the proposed limits.

Table 1: Cost of components

Components	Price (NZ$)
MM74c14 (1 W)	2.00
BTA10-600 (1 W)	4.90
Resistors, diodes, capacitors (2 - 3 W)	1.00
Zener diode & led	1.50
Transformer	5.00
Metal bars	10.00
Total cost	NZ$24.40

5 Conclusions

The purpose of the project was to develop a system capable to control a heating towel rack, and switch it ON or OFF according to the wetness of the towel. The presented system delivers the convenience and energy saving attributes. The total cost of the system (NZ$25) as well as its power consumption (5 W) are within the proposed design limits. On the global scale the system could offer a significant improvement to the energy consumption level within a country. Experiments on the prototype showed its reliability and consistency in power switching processes.

6 References

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