Building Temperature Control*

April 17, 2002

Abstract

This document describes the procedure to interface the building temperature control experiment to the DS1104 dSPACE data acquisition card. It also provides one simple example of distributed control system that could be implemented.

1 The Model building

The building temperature control experiment is a two floor model building with temperature sensors and heaters in each room that simulates diverse and realistic temperature control challenges encountered in multizone temperature control for buildings. The difficulty in modeling this system comes from the multitude of unique variations and the addition of different disturbances. What happens if we open a window? What if there is air blowing in or out? Figure 1 shows a layout of the two building levels in its basic configuration. All doors and windows can be opened or closed and there are 4 electronically controllable fans that can be used for disturbances (e.g. by putting the fans in the windows) or to simulate a heating system that uses forced air. The two floors can be segmented and studied in isolation or put together to consider interaction effects. In addition, the walls dividing rooms 3 and 4, and 5 and 6, can be pulled out to study temperature control for different floor layouts (or, you could change the material used for the wall which would result in different interaction effects).

2 Connecting the Experiment

In order to interface the experiment with dSPACE a general purpose Quanser DS1104 interface board is used. This board provides the interface between the internal dSPACE DS1104 data acquisition card and several connectors. This section describes how the plant inputs and outputs are connected to the Quanser

*Under the direction of K. Passino, this experiment was originally constructed by a group of undergraduates in an EE682P design project and it was later significantly improved by Todd Broceus and Tyson Rathburn. Jorge Finke added electrically controllable fans, interface cables, and implemented a controller in dSpace.

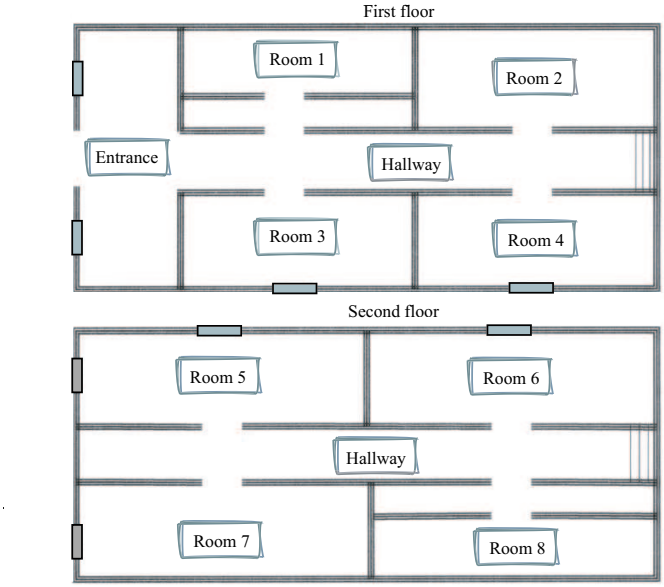

Figure 1: Building structure.

DS1104 interface board. For this experiment 8 analog inputs and 8 digital outputs are being used to sense the temperature and activate the heaters, respectively. In addition, 4 analog outputs control the airflow generated by the fans. The physical position of the fans is chosen by the user. Fans are mounted on a sliding base as seen in Figure 2, which allow them to replace doors or windows. Notice that there are two types of fan modules. The module shown at the left in Figure 2 blows air out of the room, while the one at the right blows air into the room. They allow for a stronger interaction between the temperatures in different rooms when they are operating at different temperatures than if we only had the heaters alone. Interaction between floor levels is also given by the thin floor between the two. The connection between the plant and the interface board should be done as follows:

- *Sensor inputs:* Analog inputs to the board are placed as described in Figure 3. For each floor, there is a white cable labeled "Temperature sensors" that ends with 4 RCA connectors, one for each room. The user should plug connectors 1 through 4 to the respective analog input channel in order to read the temperature values of these rooms. The color sequence for the connectors is yellow, blue, red and white. For the second floor, the white cable should be plugged into channels 5 through 8 in the same color sequence.

- *Heater outputs:* Digital outputs control the state of the heaters interfaced by an IDC connector. The user should connect the ribbon cable to the

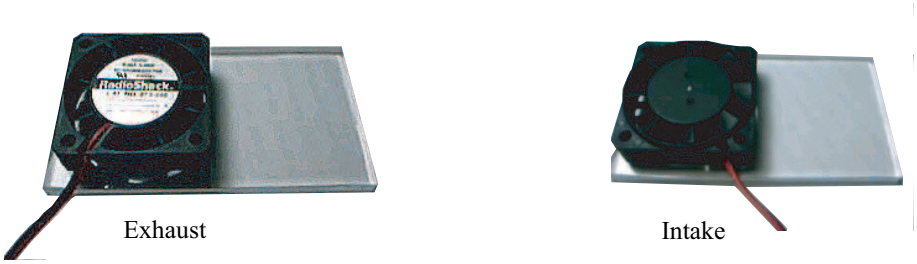

Figure 2: Fan modules.

digital outputs as specified in Figure 3.

- *Fan outputs:* Connectors for up to 4 fans are placed behind the building, over the power source. When connecting the fans BE CAREFUL that the first pin of the connector corresponds to the positive terminal (red wire) of the fan as seen in Figure 4. For an output voltage below 3 V the fans will not turn at all. For higher values, the fans start rotating, and increase the produced airflow up to 5.3 cfm for an output voltage of 12 V.

3 Distributed Temperature Control

The purpose of this section is to illustrate how signals are acquired using dSpace, and to implement a simple control algorithm to give an idea of how different control systems can be implemented on this plant.

For this example the first floor of the building will be used only. An exhaust fan is used to generate disturbances at the window of Room 3, and another intake fan is located at the door of Room 3 in order to allow air flow from Room 1 and the hallway. The overall program structure that manages the entire house temperature controller can be seen in Figure 5. In this case, the upstairs block, which controls the the second floor of the building, will be ignored. A uniform random number generator is used to randomly activate the disturbance fan.

Figure 6 shows the diagram corresponding to the first level of the building. All temperature measurements are acquired with a multiplexing analog to digital block, ADC-MUX, shown at the left of the diagram. The signal is then separated to different blocks (Rooms 1 to 4), where a simple ON/OFF controller is implemented independently (see Figure 7). Proper noise filtering is applied before sensor signals are passed to each room block to get a smooth temperature measurement.

An additional independent controller was developed in order to show the interaction and cooperation between rooms. The function of this controller is

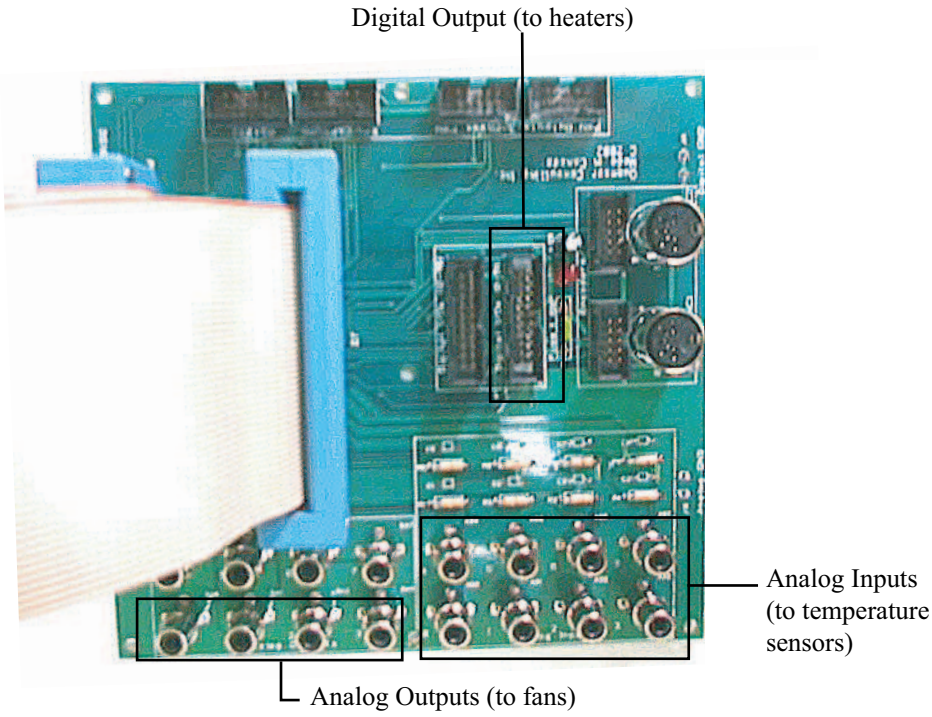

Figure 3: Quanser DS1104 interface board.

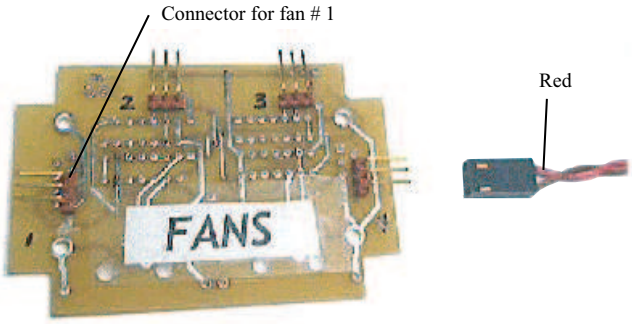

Figure 4: Fan connectors.

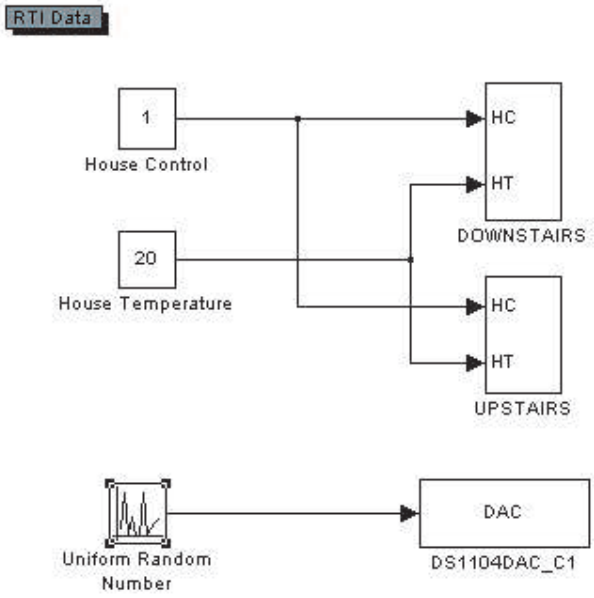

Figure 5: Program Structure.

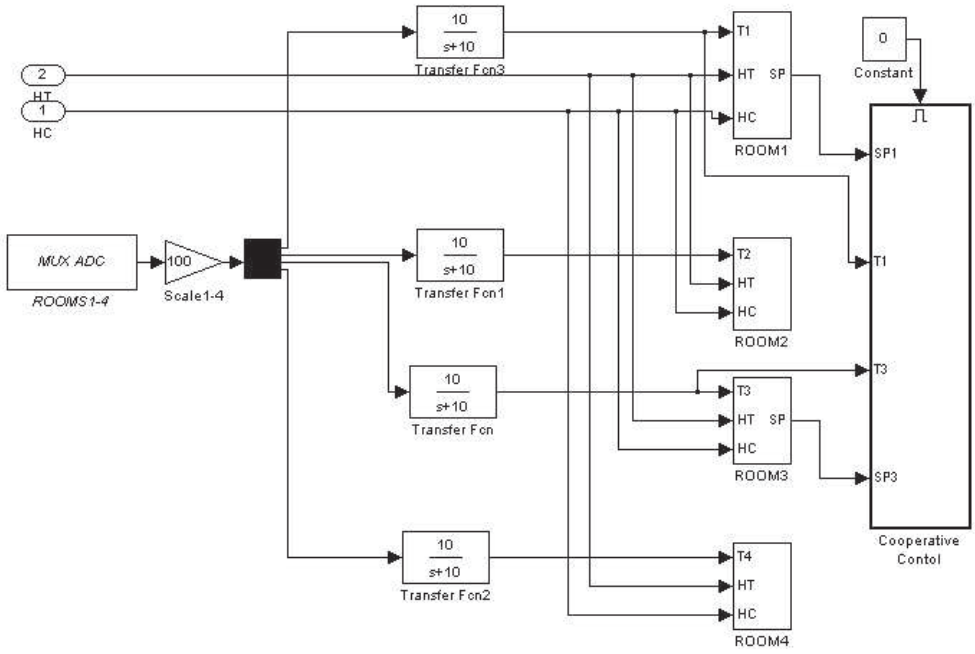

Figure 6: First level.

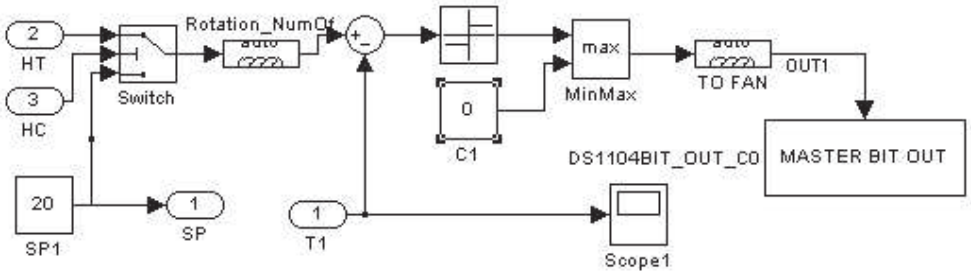

Figure 7: Room block.

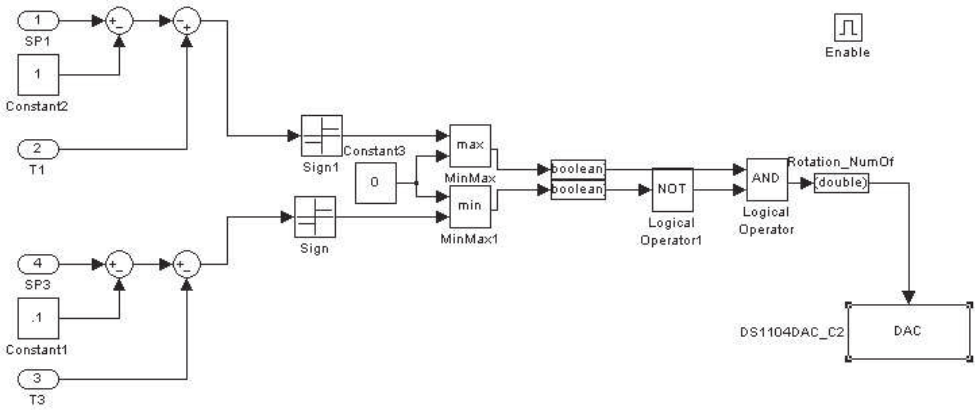

Figure 8: Cooperation between rooms.

described next: The temperature in Room 3 shall track a certain set point with variation no greater than 0.2 degrees. The fan at the window blowing air out of the room disturbs the room temperature and makes it difficult to maintain its set point accurately. The ON/OFF controller controls room 1 and 3 actuators (heaters). However, temperature variation for Room 1 is allowed, by specifications, to be $\pm$ 1 degree. For example, if a set point is specified to be 20 degrees C, any value between 19 and 21 degrees will fulfill its requirement. Thus, Room 1 will be able to contribute in heating and maintaining the room temperature in Room 3. A fan is placed between the two rooms attached to the doorframe of room 3 for proper airflow. The block diagram representing this algorithm is shown in Figure 8.

In order to test the controller, you are encouraged to measure the time to achieve specific set points with and without engagement. You can also test the ability of maintaining constant temperatures, even in presence of stronger disturbances. Figure 9 shows the layout created in the "Control Desk" of dSpace.

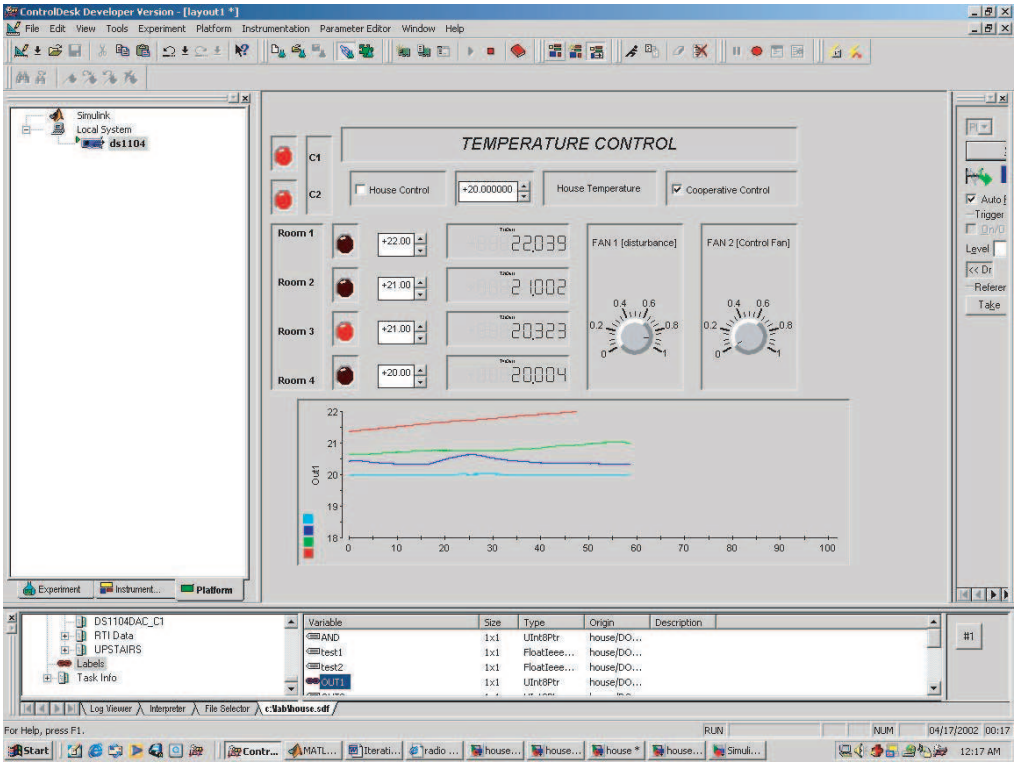

Figure 9: Program layout.