CHAPTER 11
NORTHERN ILLINOIS UNIVERSITY

Department of Electrical Engineering
DeKalb, IL 60115

Principal Investigators:

Mansour Tahernezhadi (815)-753-8568
Xuan Kong (815)-753-9942

WIRELESS COMMUNICATION DEVICE

Designer: Lawrence D. Allen
Supervising Professors: Drs. M. Tahernezhadi, X. Kong
Department of Electrical Engineering
Northern Illinois University (NIU)
DeKalb, IL 60115

INTRODUCTION

A hand-held wireless remote controlled thermostat system was designed for the control of residential heating and air-conditioning (HVAC). Any person who can operate a telephone will be able to use the hand-held controller, which, for prototype purposes, is fashioned from a telephone handset with push-button and sliding switch controls. With this remote control, individuals with limited mobility are able to have complete HVAC control at their fingertips. The device is also configurable to remotely control multiple household appliances. The design project consists of a base unit, which is connected to the selected household appliances, as well as a hand-held unit that communicates and instructs the base-unit to perform a desired function on a selected device. The base unit can also relay the status of a selected device to the handheld unit on demand.

SUMMARY OF IMPACT

People with limited mobility require control over their home environment. If the temperature setting in a person's home is too hot or too cold for comfort, the wireless home's HVAC (heating/air conditioning system) control can be set to make the temperature more comfortable. However, for a person with limited mobility, getting to the HVAC control module to adjust the setting could be difficult or impossible.

This wireless design can be configured to turn on and off other household appliances, enabling individuals with limited mobility to control wirelessly multiple numbers of household appliances. The availability of the portable wireless device also provides the caretaker with a higher degree of effectiveness and flexibility, which in turn leads to a reduced healthcare cost for the patient.

TECHNICAL DISCRIPTION

The device displays ACTUAL TEMPERATURE with a green, 2-digit, 7-segment LED and SET TEMPERATURE with a red, 2-digit, 7-segment LED.

Figure 11.1. Wireless Remote Control Device (Base and Handheld Units).

The actual temperature and the setting temperature have a range from 00 to 99 °C. The device interfaces locally with the user via three push-button switches and two four-position slider switches with the following functions:

Push button 1	Device Circuit/Microcontroller Reset
Push button 2	Increment Temperature Setting
Push button 3	Decrement Temperature Setting
Slider switch 1	Function Selector Switch (Heater/OFF/FanON/Cooler)
Slider switch 2	Remote/Local ON/OFF Switch (RemoteON/OFF/OFF/LocalON)

With Local ON control selected, all local switches are functional. Device status and switch settings are displayed via 6 LEDs and the aforementioned 7-segment LED displays. Local ON is clear green,

RemoteON is clear red, Heater will be red when the Heater is ON, OFF/Standby will be amber, FanON will be green, and Cooler will be white green when the Cooler is ON. The device will determine actual temperature via interface with a DS1620 Digital Thermometer and Thermostat integrated circuit mounted on the exterior of the TCM (Thermostat Control Module) casing. With Heater selected, the TCM will turn on the heater when the actual temperature is below the set temperature and remain in OFF/Standby otherwise. With Cooler selected, the TCM will turn on the Cooler when the actual temperature is above the set temperature and remain in OFF/Standby otherwise. With FanON selected, the TCM will turn on the Fan regardless of temperature setting. With OFF/Standby selected, the TCM remains in OFF/Standby regardless of temperature setting.

The device interfaces with the HVAC components via the Relay/Demo box, which uses the micro-controller output to solid-state relays to turn on the Heater, Fan, or Cooler. It is powered by a Regulated 5VDC 500mA, 120V 60Hz AC adapter.

The device has three 240V25A solid-state relays with 5V TTL control to switch on three standard 125V/15A receptacles that power the heater, fan, and cooler. Each relay employs a heat sink, and an 8-watt 120VAC internal fan circulates cooling air into and out of the box.

There is a 125V15A power switch on the front of the box to energize the entire system. A fourth receptacle used to power the TCM AC adapter is on whenever the power switch is on. Total current at 125VAC 60Hz is specified not to exceed 15A as limited by the lowest rated internal components. The actual size of the casing is 5"h×2.75"w×2.25"d including switch, LED, and DS1620 protrusions.

The TCM case has two holes drilled on the rear for mounting screws. The microcontroller used to control all the processes of the TCM is the 8-bit Microchip PIC16C63/JW EPROM. The Peripheral Interface Controller (PIC) 16C63/JW is a 28-pin DIP microcontroller with 22 I/O pins, 4K EPROM, and 192 bytes of RAM. All internal component connections are all based on the I/O pins of the PIC.

Figure 11.2 shows the seven-segment LED Display circuitry. The theory behind this design is detailed in the Display Strobe Sequence Truth Table. Basically, the PIC controls selection (or non-selection) of the transistor switches to drive the common anode LED displays as well as the binary coded decimal required for the appropriate switch when on. Because the 74LS138 provides a LO (sink) output, the 74LS240 acts as an inverting driver to provide a positive voltage to the NPN transistors. Figure 11.3 shows the various subcircuits of the input switches, LEDs, and outputs to the Relay box. The truth tables are diagrammed for the various switch settings and output logic.

Section 1 is the Reset Switch (push-button grounds pin 1) with a 68Ω resistor between the switch and ground to prevent potential latch-up problems associated with excessive current. Section 2 is the Increment/Decrement Switches with the same basic circuitry as the Reset Switch. Section 3 is the Function Selector Switch with the appropriate pull-up resistors and ground for various logic combinations. Section 4 is the Local/Remote ON/OFF Switch with the appropriate configuration for its logic outputs to the PIC. Also included are the Local/Remote Indicator LEDs, which are a function of the switch position. Note that both the Function Selector and the Local/Remote ON/OFF Switches are four-position switches that change two poles at once. Section 5 details the Status LEDs and the output to the Relay box. Figure 11.4 shows the PIC Clock/Temperature Support Circuits as well as the Relay Box Circuit.

The PIC was programmed using the PIC Start Plus programmer and associated MPLAB Integrated Development Environment (IDE). The DS1620 uses a simple three-wire interface to communicate 9-bit temperature readings of the temperature of the device. The device must be initialized and controlled via this three-wire interface. While the Reset and Clock pins of the device can be interfaced easily with the PIC, the DS1620 sends and receives data via the third wire of the interface. The PIC's Serial Peripheral Interface (SPI) protocol requires two separate data lines: one to send and one to receive. The second issue involves the data transfer itself. The SPI interface protocol is limited to an 8-bit word data transfer with MSB first. The DS1620 sends 9-bit temperature reading, LSB first. The final issue is that the Reset must be high from the beginning of a transfer to the end of the last (9th) bit when reading the temperature value.

The Handheld Unit Wired Remote Control

The handheld unit (HHU) displays ACTUAL TEMPERATURE with a green, 2-digit, 7-segment LED and SET TEMPERATURE with a red, 2-digit, 7-segment LED. The device interfaces locally with the user via a 12-button keypad, one 4-position slider switch, and 2 push-button switches with the functions described below.

12-button keypad: Temperature Reset, Numerical Setting, and Transmitting

Slider-switch 1: Function Selector Switch (Heater/OFF/FanON/Cooler)

Push-button 1: TCM Device Circuit/Microcontroller Reset

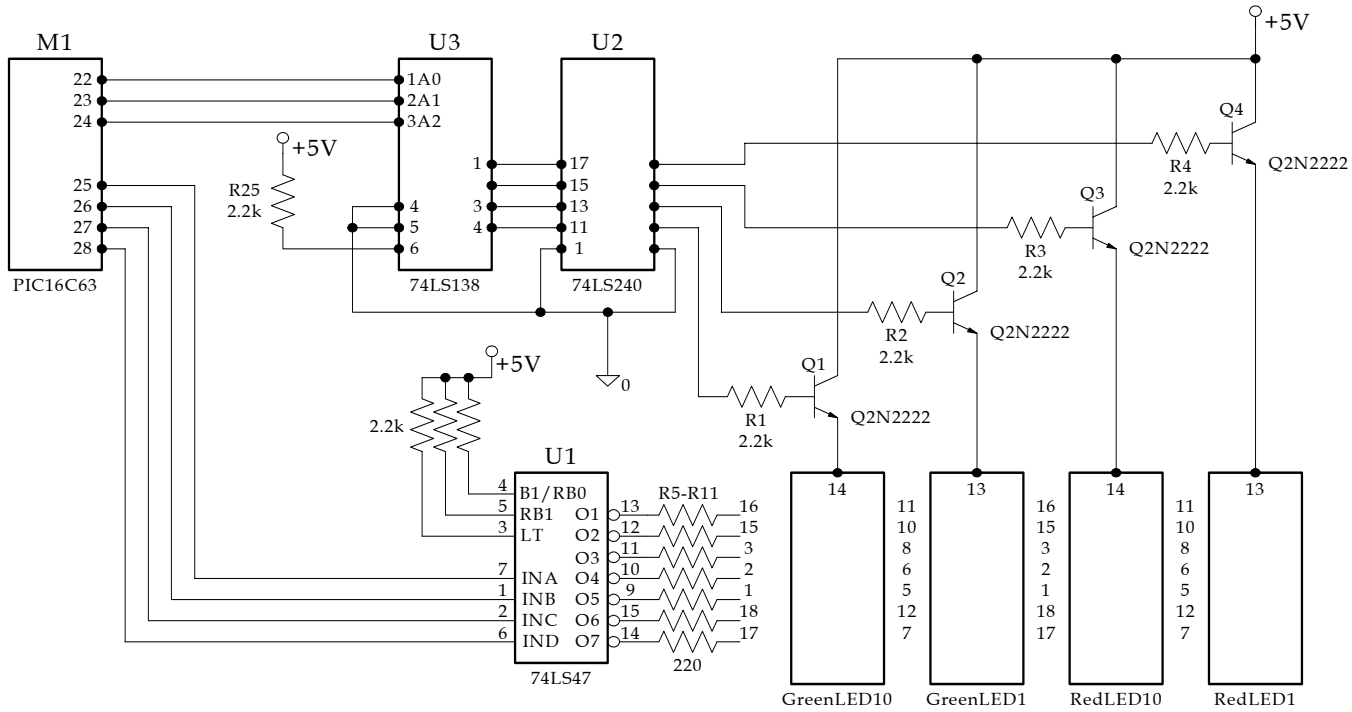
Push-button 2: HHU Device Circuit/Microcontroller Reset

Power is supplied via a 9VDC Alkaline battery and switched on via a lever switch that is held open (OFF) when the HHU is set face down on a flat surface and held closed (ON) when handled by the user.

The TCM device status is transmitted by the TCM, received by the HHU, and then displayed via four LEDs matching those on the TCM. The following status lights will match the TCM status lights: Heater will be red when the Heater is ON, an OFF/Standby condition will be amber, FanON will be green, and Cooler will be clear green when the Cooler is ON. There will be no LocalON or RemoteON LEDs as the HHU display will be blank when the TCM is on LocalON control or OFF and fully functioning when the TCM is on RemoteON control.

The TCM/HHU RF Transceiver uses two RF Micro Devices monolithic integrated circuits for transmission and reception of serial digital data communications between the TCM and the HHU. The RF9901 (FSK transmitter) and the RF9902 (FSK receiver) are designed to work together as a two-chip set to provide all the functions necessary to implement a binary FSK transceiver in the 915 MHz frequency range.

The final cost of the project is approximately $200.



2 Digit, 7-Segment Leds (Common Anode)

Status	INPUT A2	A3	A0	PIN ON Low	LED
OFF	0	0	0	15	Change BCD to
ON	0	0	1	14	Green 10
OFF	0	1	1	12	Change BCD to
ON	0	1	0	13	Green 1
OFF	1	1	0	9	Change BCD to
ON	1	1	1	7	Red 10
OFF	1	0	1	10	Change BCD to
ON	1	0	0	11	Red 1
PIC16C63 PIN#	24	23	22		

Figure 11.2. Seven-Segment LED Display Circuit.

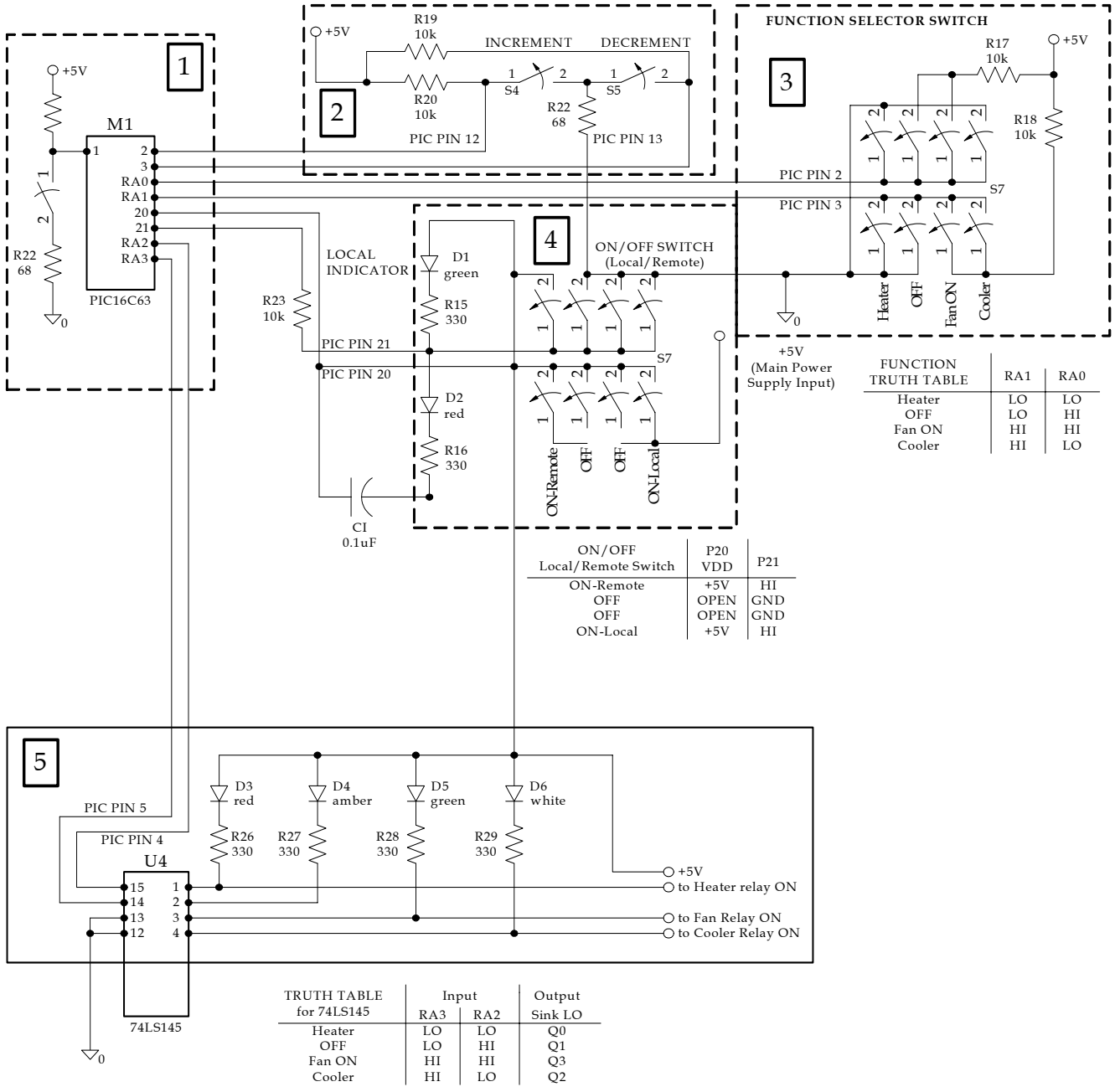


Figure 11.3. TCM Input Switches, LEDs, and Output to Relay/Demo Box.

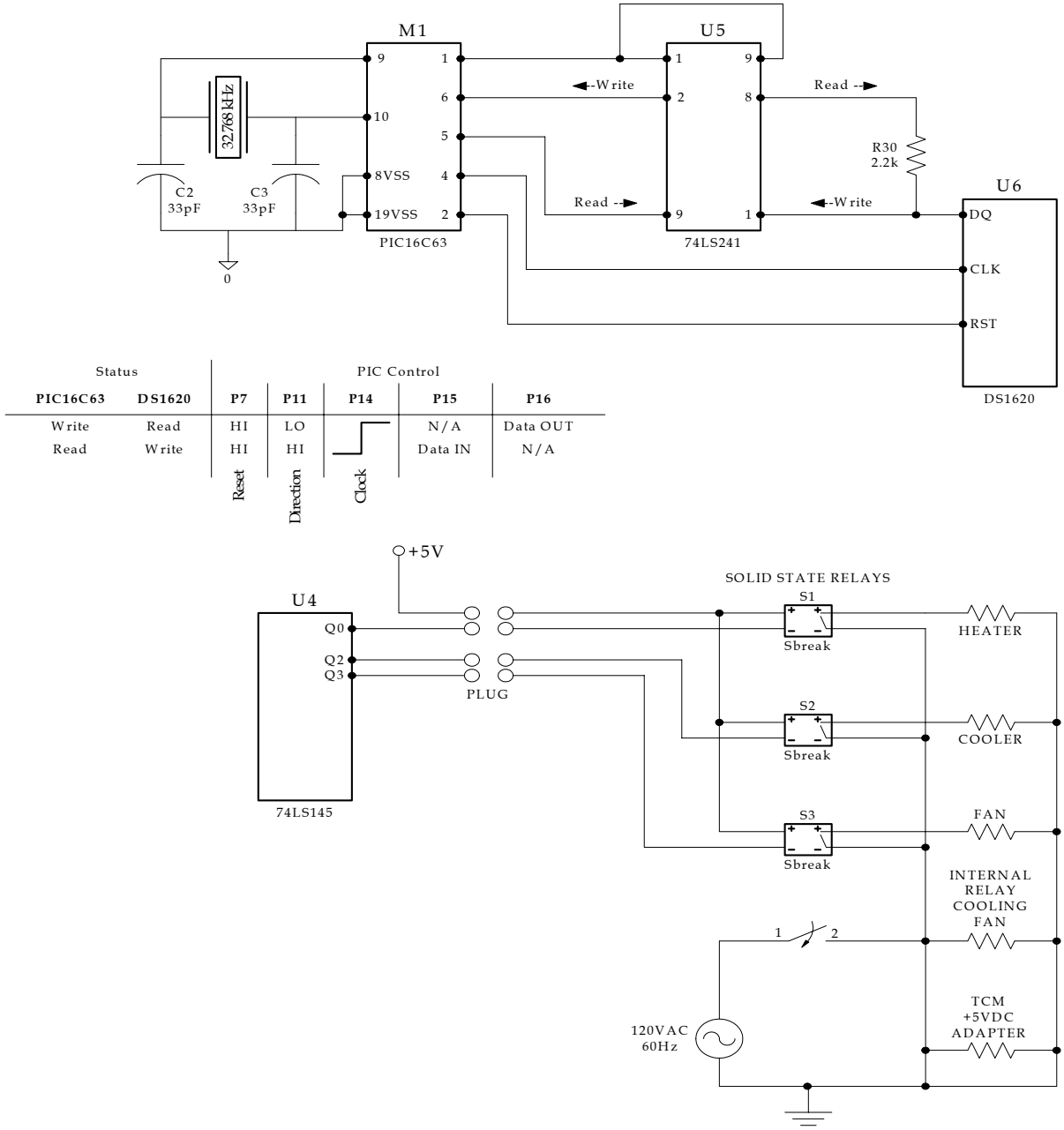


Figure 11.4. PIC Clock/Temperature Support and Relay/Demo Box Circuit.