Home Security System with Remote Home Automation Control

Justin Klumpp  
Senior Project Hardware Description  
Western Washington University  
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Professor Todd Morton
**Introduction:**

This document describes the Home Security with Remote Automation Control System and its hardware implementation. This control system allows a person to monitor and control their home at a remote location.

Once properly initialized this home control system has the ability to call the end user and notify them of any break-in to their security system. This system also, allows the end user to call into their home and remotely control household appliances such as a sprinkler valve or lights by using an automated voice menu. With cell phones becoming so popular, this home security uses this fact and turns a cell phone into the ultimate remote control for the home.

**Hardware:**

There are three main modules in this control system: base control module, wireless alarm module and wireless appliance control module. The base control module will be the main controller that takes care of all the hand shaking with the phone line, user interface and the communication link between all remote modules. The base control unit has the ability to control 16 wireless alarm modules, and 4 wireless appliance control modules. This allows the end user to have the ability to expand their system for complete control and security feedback from all around their home.

**Base Control Module:**

This module is the heart of the entire system with 9 different top level components. The Motorola MC9S12DP256B microcontroller [U3] is used to synchronize and control all the components of the base control module. To
communicate with the DTMF [U4] and voice IC [U1], SPI will be used to send and receive data. For asynchronous wireless communication, SCI was chosen to transfer data at a baud rate of 300bps. For the MCU reset circuitry, a Maxim MAX6314 [U9] reset IC will reset the microcontroller if the supply input voltage is less than 4V.

**DTMF Transceiver:**

In order to make a phone call and to understand the user’s keypad input on the remote side, a DTMF transceiver [U4] is used in the base control module. To generate a DTMF tone when making a phone call, the microcontroller will output a nibble of data. This data will come from pins PM3 to PM0 on the MCU, which is connected in parallel to pins D3 to D0 on the DTMF chip. For example, to generate the tone “5” in DTMF, the microcontroller [U3] will output 0 to D3, 1 to D2, 0 to D1 and 1 to D0. Once the DTMF chip has verified the data on pins D3-D0 a DTMF tone will be output through the TONE pin. To decode DTMF signals coming over the phone line, the signal will be imported differentially into the IN+/- pins this differential signal will cancel out the common mode noise. When a valid tone is detected, the DTMF chip will present the tone in a binary nibble on pins D3 to D0.

**ISD 4002 Voice Chip:**

This chip serves two purposes in the operation of this home automation system. One part is to play back prerecorded messages when the base microcontroller has determined that a wireless alarm module has gone off. The voice messages will tell which alarm sensor has gone off, or if an alarm sensor has gone offline. The second purpose for this chip is to hold the voice streams that will be used for the voice automated menu to control household appliances.
This IC requires a 3 volt power supply, so the output of low dropout voltage regulator [U10] will be used to step 5 volts down to 3 volts. The voice IC has the capability to record up to 240 seconds of voice messages that are each stored at a designated memory address on the chip itself. The ISD chip uses a 16 bit internal shift register for all operational control. This register is broken down into two parts; 5 bits are used for control and 11 bits are used for data addressing. This chip uses SPI to communicate with the microcontroller. The MOSI, SCLK, and SS_L pins are connected respectively to PORTP: PP0, PP1, and PP3 on microcontroller [U3]. Data is clocked in when the SS_L pin is asserted low, and clocked out on the rising edge. When a valid play instruction is set, the voice message will be played on the AUD OUT pin and broadcast over the phone line through the DAA [U5].

**DAA:**

The Data Access Arrangement (DAA) IC is connected to the phone line using an RJ-11 connector. From the input of the RJ-11 jack, the tip and ring input to this IC is connected to the green (tip) and red (ring) data wires of the RJ-11 cable. These two wires will be isolated by a 350V Sidactor [SP1] and two 3000V [C10, C11] snooping capacitors to prevent any transient voltage from damaging the IC.

Since this system is developed for use in the U.S. market, it will be configured using a resistive termination to make it compatible with the U.S. telephone lines. The OH pin [pin 8], is an active low input pin, which is connected to the microcontroller [U3] to control the DAA’s on/off hook state. When OH is set to a logical low, the DAA is in the off hook state which allows for a phone call to be made or to communicate over already established phone connection. To terminate a phone call, the OH pin should be
set to a logic high which puts the DAA in the on-hook state. The other pin that is connected to the microcontroller is the RING pin [pin 9], it is used to signal the microcontroller if a call is detected. The active low ring detect output will go low for 1 second then high for 2 seconds continuously when a call is detected from the phone line.

The TX pin on the DAA is used to broadcast both voice and dual tone multi-frequency (DTMF) signals over the phone line. The TX pin connection has an internal operational amplifier; both the voice and DTMF chips are connected to the inverting side of this operational amplifier using 50 ohm resistors. The RX- and RX+ pins are differential outputs which connect to the DTMF IC [U4] for signal decoding.

**Real Time Clock:**

To keep time accurately even with a power outage, a battery backed real time clock (BBRTC) is used [U6]. This component uses SPI communication with the microcontroller. The accuracy of the RTC is dependent upon the accuracy of the crystal and its capacitance; in this particular setup, the crystal [X2] is rated for 30ppm, 6pF for a perfect capacitance match and better accuracy. Once the initial setup and time is written to the BBRTC, it will start tracking from the written setup time. If $V_{cc1}$ [pin 16] is out of service, the BBRTC will be powered by the 3V lithium battery [B1] with a max current draw of 400nA, until $V_{cc1}$ is back in service.

**Sprinkler Valve:**

The sprinkler valve is an off-the-shelf Rain Bird APAS-100; to make it compatible with the home control system, a relay and driver are required. The relay [K1] has a coil rated at 5V, 40mA with 112Ω of resistance. To avoid over driving the output pin of the
microcontroller, this relay will be control using a NPN transistor [Q2]. This transistor will work as an electrical switch to allow power to the relay coil during saturation. While the relay is on, its contact will allow the 24VAC from J2 to turn on the sprinkler valve. A diode is in place across the relay coil to eliminate any fly-back EMF induced by the relay coil once the power is off.

**Wireless Modules:**

For the wireless communication, a Radiotronix RCT-418-AS transmitter [U7] and RCR-418-RP receiver [U8] are used. Both of these parts communicate at 418 MHz and use on/off keying (OOK) for data transmission. These wireless ICs are designed to keep all external components to a minimum. In this system’s configuration, the antennas [ANT1, ANT2] have an impedance of 50Ω to match the ANT input/output of the wireless ICs. A 0.01µF shunt capacitor is placed between the power and ground to filter out high frequency noise from the power supply.

**Keypad and LCD**

The keypad and LCD modules will be primarily used during the initialization of the home control system. Both of these modules will be used together for setting the user parameters during setup. The keypad will also be used to reset the home control system, or to modify the initial setup values.

The LCD is a 4 line, 20 character display. This LCD display has a backlit display that requires an additional two pins for LED+ and LED-. The keypad is a 4 x 4 matrix with 16 different keys.
Wireless Alarm Module:

This module is powered by a 9 volt battery which is fed into a GL7805 [U2] 5 volt voltage regulator that is capacitor coupled on the output with a 10uF capacitor. The 5 volt output will then be used as the power supply for the wireless alarm module.

The wireless alarm module uses a General Electric motion detector as the alarm sensor. This particular motion sensor has an output of 8 volts DC, when the sensor is on and an output of 0 volts DC when it is off. The output of the motion detector is fed into a current limiting 8kΩ resistor, and the diodes [D1, D2] ensure zero and 5 volt output to the PSoC CY8C29466 microcontroller [U1]. This microcontroller is setup to wake up every second, send out a byte of data, and then go back to sleep. The byte of data is encoded with information telling about the status of the motion sensor (on/off), and the alarm sensor ID, which is a number ranging from 1-16. The microcontroller’s active high reset [pin 19] is tied low, and low voltage detection is done in the software.

A Radiotronix RCT-418-AS, 418 MHz wireless transmitter [U4] is hooked to P0[0] on the PSoC microcontroller. This transmitter sends out data at a rate of 300bps through the DATA pin which is connected to a ¼” wave antenna. A shunt capacitor with a 0.01µF capacitance is placed between the power and ground to filter out high frequency noise from the supply. The wireless transmitter has an output impedance of 50Ω which is matched to the 50Ω input impedance of the antenna. The alarm sensor ID is a selected by using an 8 pin dip switch which is hooked using pull-ups with the outputs being pins 7,8,20,21 on the PSoC microcontroller. When the motion sensor is on, the Alarm Status LED will be blinking at a rate of 1 flash per second. This LED is used to visually indicate that the alarm has been tripped.
**Wireless Appliance Control Module:**

The appliance control module is connected and powered directly from the 120V, 60Hz wall socket. On the other side of the wall plug, the hot and ground terminal is stepped down through an 18 to 1 transformer [T1]. The resulting output is a $9.4V_{\text{peak}}$ AC signal which is then applied to the bridge rectifier [CR1], and output through a coupled 100uF capacitor to create 9VDC for the input of the regulator [U2]. The regulator has an output of 5V which will be used to power the rest of this wireless module.

For this module’s output jack, the neutral and ground are connected directly to the wall plug. To control power to this jack, a relay is placed between the two hot terminals. When driving this relay, a PN2222A [Q1] transistor is used as an on/off switch to avoid over driving the output pin from the PSoC controller. There is a 35kΩ resistor at the base input of the transistor to drive [Q1] into saturation and limit the output current from the P0[7] pin. When the transistor is on, the current will flow through the relay coil and connect the two hot terminals together. To protect the transistor from fly-back EMF from the relay coil, a shunt diode [D1] is connected across the relay coil. For added protection, a 10A fuse [F1] is placed between the relay and wall plug to prevent excessive current from destroying the relay module.

This module uses a PSoC CY8C29466 as the main controller. There is a wireless receiver [U3] hooked to pin P2[1] on the MCU, the antenna and receiver are impedance matched with 50Ω. The receiver will receive data from the base control module, at a rate of a 300bps. The microcontroller will be looking for a byte of information encoded with a start nibble of 1010, and then 1 bit for on/off control and 2 bits for the sensor ID. The sensor ID will be unique for each wireless appliance module;
this ID will be used to determine which module needs to be turned on or off. The ID will be selected on the wireless module itself using a 4 pin dip switch that is connected on pins P0[2] and P0[0] on the microcontroller.