



Final Project – Don't Forget to Lock the Door!

Due: All Documents Due Before 8:00am on Thursday, May 2, 2019
Presentations During Lab Period on Thursday, May 2, 2019

Introduction

In this final project you will be implementing a two-zone security system for the small two-room office shown in Figure 1 below. This is an alarm system, but by implementing it into zones we can use the alarm system to restrict access to the zones. You will implement three levels of access. There will be some people (e.g., low-level employees and vendors) who will have unrestricted access only to the outer office area (Zone 1 on the right). There will be a few people (e.g., high-level employees) who will have unrestricted access to both the outer and inner office area (Zone 1 and Zone 2). Zone 2 is where all the important or sensitive data and equipment is kept. Finally, there will be a couple of people (e.g., Owners, executive management) who will have administrative access which means access to all areas and the ability to change the passwords for zone access.

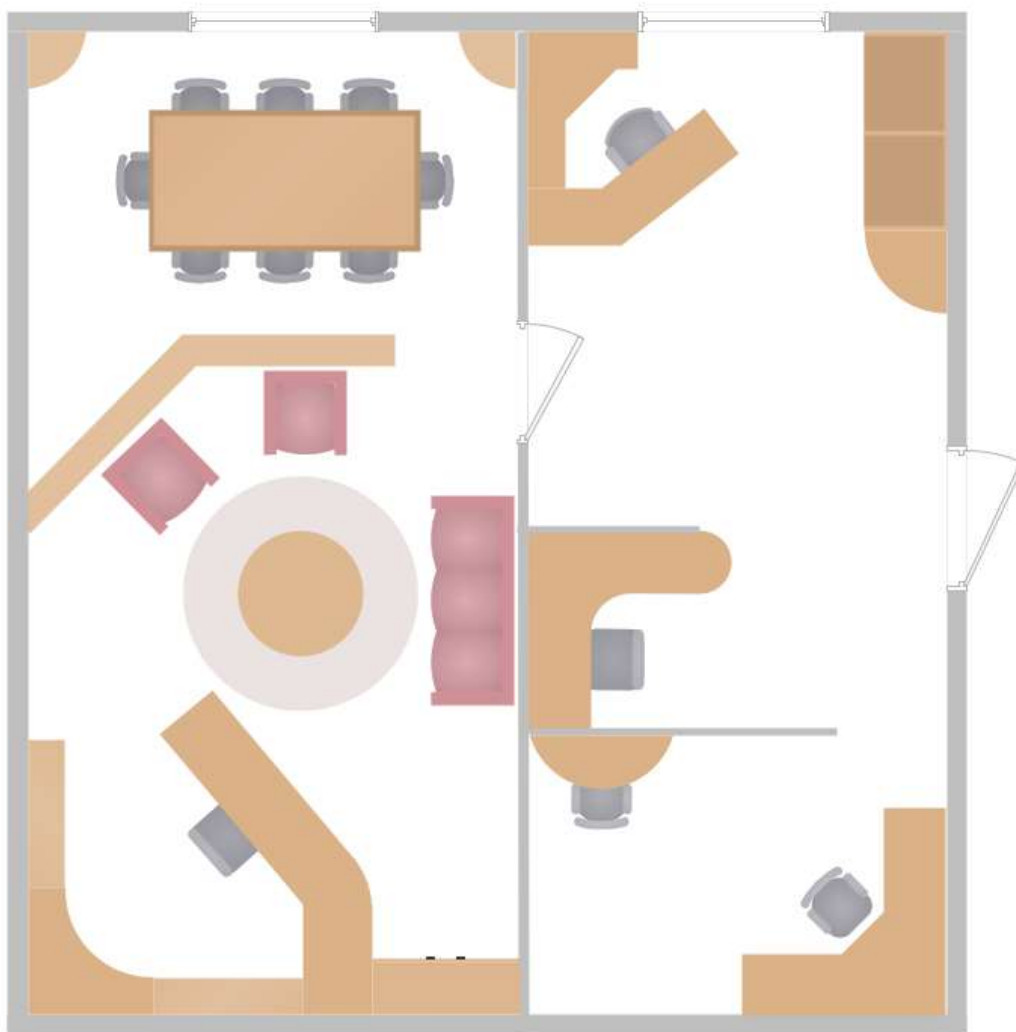


Figure 1: Two Room Office Layout



To implement this security system, your group will be provided with (or already have), a MSP430FR6989 LaunchPad development board, an external 16x2 character LCD, 3 4-channel level shifter boards, 4 magnetic reed sensors (one for each door and window), 2 passive IR motion detectors (one for each zone), 2 piezo buzzer alarms, a 12 button keypad, a MSP430G2553 LaunchPad development board, 1 830 tie point solderless breadboard (to supplement the breadboards that you already have), misc. breadboard jumper wires, some 20 AWG stranded wire, breadboard wire terminal blocks, LEDs, and a cardboard box. You will use this hardware to implement the office two zone security system described below. In addition, you will provide a short instruction manual for using your two-zone security system.

Description

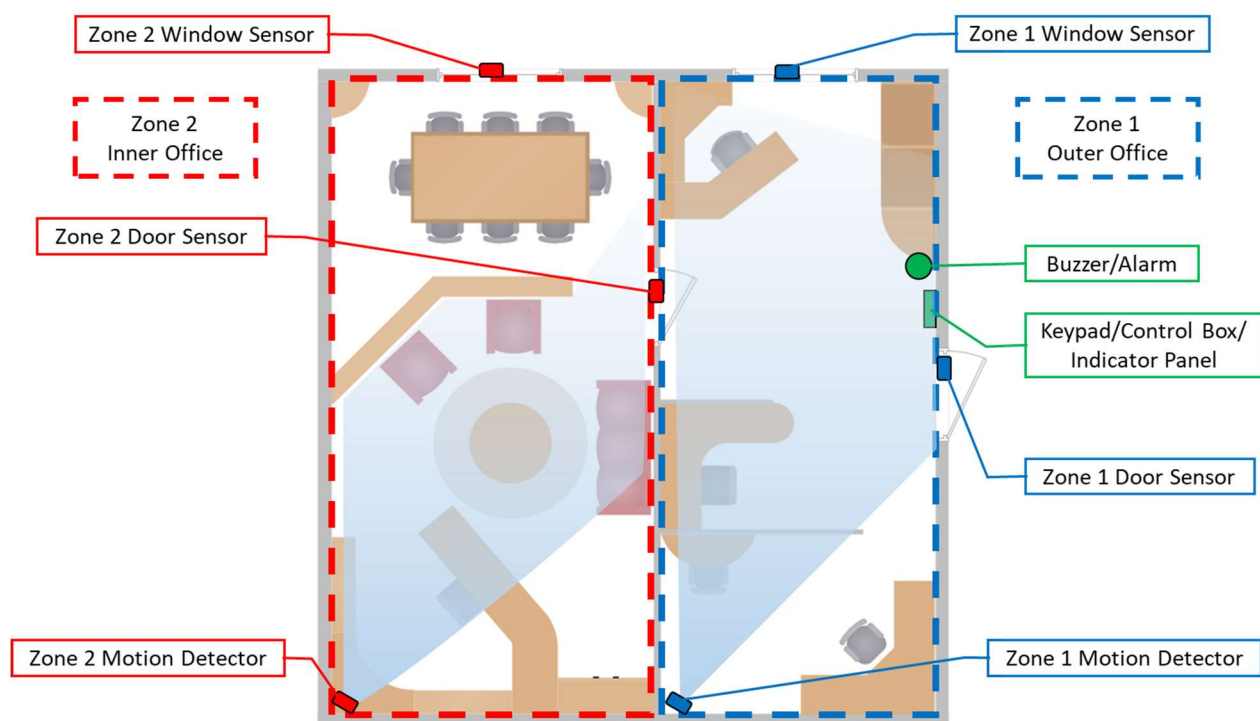


Figure 2: Two Room Office Sensor Layout

The cardboard box will be used as a crude model of the two-room office (Figure 2), where its main purpose is to provide a place to mount the door and window sensors and to place the motion detector sensors in an enclosed area (so they will not be continuously set off by other people moving in the room). You may wish to place a divider in the box, so each motion detector has a separate area. You will have to use the longer stranded wire to connect the six sensors to the rest of your circuitry (microcontrollers, LCD, and keypad, etc.) which should be outside the box (so you can access it without setting off the motion detectors). **Do not solder any wires directly to the sensors** (we want to reuse these sensors)! Use the terminal blocks or solder to a jumper wire that we can throw away.



You also will build and wire an indicator board similar to Figure 3 that will visually show the operation of your office security system. This indicator board can lean on the outside of the box but must be near (above) the External LED and keypad and can be used to hide the bulk of the wiring and microcontrollers. You may use a plastic acrylic panel (downside: you have to drill all the holes), or a piece of sturdy cardboard (you can punch out or poke holes, just make them neat). Whichever you choose, it must be painted or have a paper image similar to Figure 1 with the indicator LEDs placed and labeled as in Figure 3 (you could just print out Figure 3...). You may use just the supplied red LEDs for all your indicator lights, or you could use other colors and additional LEDs. However, the status of the sensors and the security system must be easily and clearly obvious to a user with just your indicator panel.

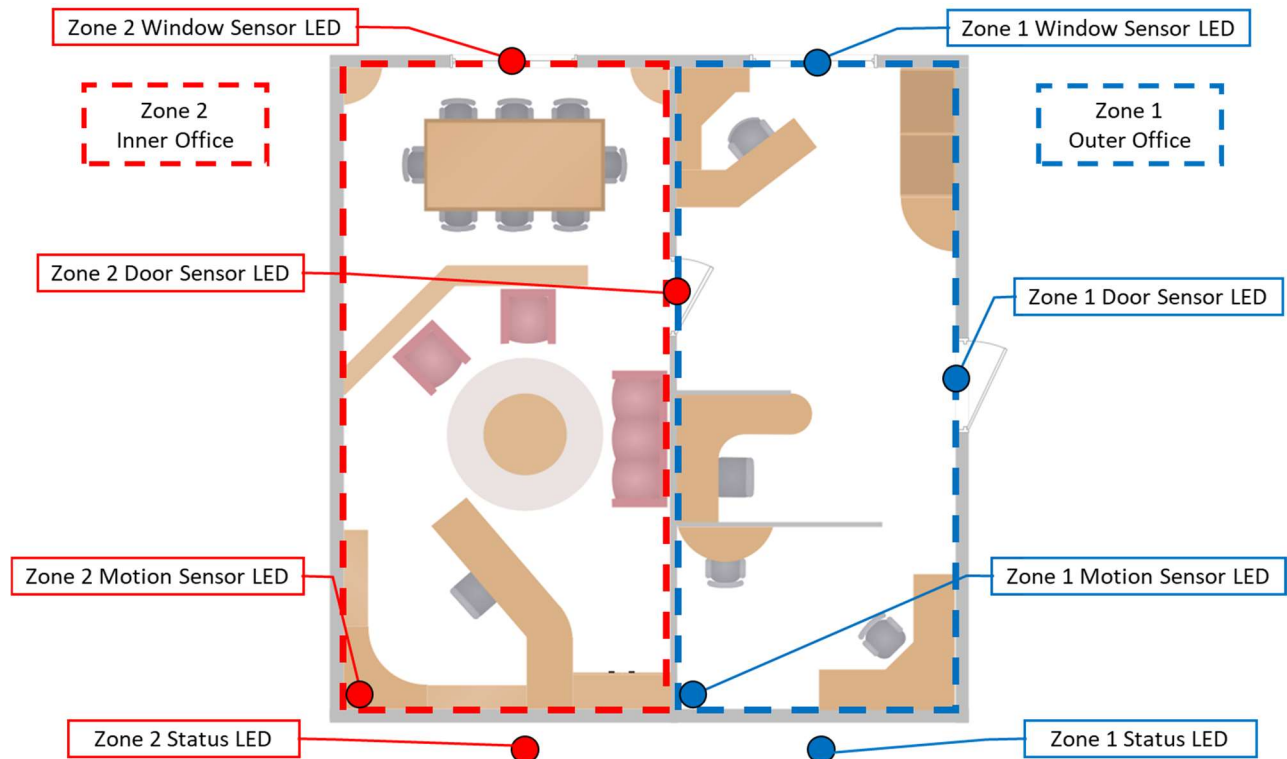


Figure 3: Minimum Indicator Panel Layout.

You will be given the specs for the sensors and will need to ensure that you use the appropriate voltages for power to and data from your sensors. You will need to pick appropriate resistors for your indicator panel LEDs. All of the above is to be controlled with the MSP430FR6989 microcontroller on the LaunchPad development board.

But wait. What is the MSP430G2553 microcontroller for? Well, every good security system has an off-site monitor and alarm that is continuously monitored 24/7 by a security company who will notify the owners and/or the police as per their contract. The MSP430G2553 microcontroller will be used to emulate the off-site monitor. The MSP430FR6989 microcontroller will communicate the security system status to the MSP430G2553 microcontroller via UART, and the MSP430G2553 microcontroller will then control (at a minimum) two LEDs and a piezo buzzer alarm to indicate the status of the two zones of the system. In addition, the MSP430G2553 provided uses a 20pin DIP package and will be used standalone without its LaunchPad development board. Yes, you will have to program the microcontroller while in the LaunchPad development board, and then remove it from the development board and use it in your system with the microcontroller chip plugged directly into a breadboard. We will discuss this more in class along with details on the MSPG2553 microcontroller and UART communications.



Details of the Security System Operation

Keyboard Entry

Because all controller interactions will take place through the keypad, you will always have to monitor the keypad for a command input. There will be four commands that will control the four modes of the system, where each command code is essentially a password. Therefore, we will want to use a six-digit number at a minimum (optionally, you could use more) for the command codes. We also want the user to actively indicate the end of the code so we will use the # symbol for this. We also want the user to be sure that each key press is read, so as each number is input, the microcontroller will send a short “beep” to the piezo buzzer. Each input digit will also be displayed on the LCD as the user enters each digit (or optionally you could hide the number but show some symbol like an asterisk on the LCD so no one can see the command code on the LCD over the user’s shoulder). In addition, we want a back key for mistakes so that the user can delete one at a time any digits previously entered. You will use the * key for this and send a 2 short “beeps” to the piezo buzzer on each digit deletion and clear the digit on the LCD. Finally, when the # key is pressed indicating that the full command code is entered, 3 short “beeps” will be sent to the piezo buzzer and an appropriate message will display on the LCD (see Modes below).

Your keypad entry routine must use button debounce and be able to handle when two buttons are pressed at once (fat fingering).

Finally, you must also implement a time out in case the user gets distracted (or mugged) in the middle of entering a command code. If no key presses are detected for more than 6 seconds, you will delete any digits entered, send 3 short “beeps” to the piezo buzzer, and then wait for the next input attempt.

Summary: Keypad Input:

- On valid key detected: 1 short beep to buzzer, store key value in memory, and display digit (or symbol) on LCD.
- On * key: 2 short beeps to buzzer and delete the previous digit from memory and the LCD.
- On # key: end of number entry and 3 short beeps to buzzer.
- After 6 seconds with no keypress: 3 short beeps to buzzer, delete all digits entered, and clear the LCD to wait for the next entry attempt.
- Use button debouncing and appropriately handle fat fingering.

Security System Operating Modes

To implement an alarm system with 2 zones and the desired access restrictions, we will define 4 operating modes that each have a unique code (password). These operating modes are:

- **Mode 1:** Both Zones Armed Mode,
- **Mode 2:** Only Zone 2 Armed Mode,
- **Mode 3:** Both Zones Disarmed Mode, and
- **Mode 4:** Administration Mode.

In Both Zones Armed Mode (**Mode 1**), the alarm will be armed for both zones and all sensors will be active. This will be the default for when no one is in the office (because the IR motion detectors will activate if someone is in the office). In the Only Zone 2 Armed Mode (**Mode 2**), the alarm is turned off for the outer office (Zone 1) but the inner office alarm is still armed and all Zone 2 sensors are still active. In the Both Zones Disarmed Mode (**Mode 3**), the alarm is turned off in both zones, all sensors are inactive, and people can move freely through both the inner and outer office areas (we assume that since there are authorized Zone 2 people there, they can monitor the sensitive data and equipment in the inner office areas). Finally,



there is the Administration Mode (**Mode 4**) for a couple of select people where the alarm is also turned off in both zones, all sensors are inactive, and these people can change the system mode codes and turn off an alarm that was activated.

We will assume that your security system will have a robust battery backup so that we do not have to worry about start up from a power outage.

But wait, how will people enter the office without setting off the alarm if the control keypad is placed INSIDE the office? Magic! No. Just like most office and home security systems that have the control box inside (if you place it outside then the burglars will have access to it!), we will have a short delay for an alarm triggered by someone entering the outer door to allow them time to enter a disable code.

On the indicator panel you will have a status light for each sensor in addition to a zone status light for each zone. The microcontroller will turn the zone status lights on and off or blink them as necessary to indicate different statuses. We also have an alarm buzzer that we will use both as the alarm and to give some audible status information (as we did with the keypad input above).

The sensor indicator lights will indicate the status of the sensor. When a door or window is open the appropriate sensor light(s) will be on to show which door(s) or window(s) are open. When a motion detector detects motion, that motion sensor's light will be on. Otherwise, the sensor lights will be off. This is independent of the alarm or Mode of the system.

When the alarm is armed (set) for both zones then the both status lights will be solid on. When the alarm is armed only for zone 2 then only the zone 2 status light will be solid on.

When the alarm sounds (is activated) in any operational mode, the piezo buzzer will emit 2 second long buzzes with a quarter second pause between buzzes and repeat continuously until turned off. The status light(s) from the zones that were armed when the alarm went off will flash in time with the buzzing (2 seconds on, 0.25 seconds off, and repeat). The alarm will continue to go off until the Administrative Mode code is entered at the keypad.

While in any operational mode, if the code 911# is entered, the alarm will sound (and the lights flash) and continue to sound until the Administrative Mode code is entered. This is the panic code to be used only in emergencies.

The External LCD will always display an appropriate and clear message or instruction in all modes.

The two LEDs and the piezo buzzer alarm at the remote site (controlled by the MSP430G2353 microcontroller) will mimic the zone status LEDs and piezo buzzer on your indicator panel. They do not have to be in sync.

A full description of the functionality and operation of each mode follows.

1. Mode 1: Both Zones Armed Mode (default code: 111111#)

In this operating mode, if any of the sensors in Zone 2 (inner office) or the window sensor in Zone 1 are activated, the alarm will sound. Wait. What about the door and motion detector in zone 1? Since the keypad is inside the office (in the real office, not your crude box model), we must allow the door to be unlocked and opened so that someone can get to the keypad. So, when the door is opened, there is a delay of twenty seconds to allow the person to enter a correct command code to prevent the alarm from sounding. The Zone 1 motion detector signal must also be disregarded during these 20 seconds. However, if this motion detector goes off and the Zone 1 door has not been opened within 20 seconds, the alarm should sound. At the beginning of the 20 second delay, the buzzer will begin emitting short beeps once per second and the Zone 1 Status light will flash in time with the buzzer. 10 seconds after the door



(or window) sensor was activated the short beeps and Zone 1 status light will increase frequency to 2 beeps and flashes per second. Finally, at 15 seconds from the Zone 1 door sensor activating, the frequency of the beeps and flashes will increase to 4 per second. Then at 20 seconds the alarm will sound. Clearly, this beeping and flashing will stop once the correct code is entered and the alarm is deactivated for Zone 1. However, to hear the keypad correctly, once a keypad button is pressed, the countdown beeping will stop (but the flashing will continue). The correct code to enter will be the code for any of the other three operating modes.

Wait, What? Yes, the code for one of the other three operating modes, not **Mode 1**, the current operating mode. The logic is this: If the person entering has only Zone 1 access, they will put in the code for **Mode 2** and the system switches to **Mode 2** as desired. This disarms the alarm for the outer office area that they are allowed in, but leaves the alarm activated in Zone 2. If the person entering has Zone 2 access, they must also have Zone 1 access, so they would enter the code for **Mode 3** and the system switches to **Mode 3** as desired (if they are alone they can lock the outer door if they are worried someone might come into the outer office while they are working in the inner office area). The Zone 2 people could also enter the code for **Mode 2** if they only needed to access the outer office. Finally, the people with administrative access could enter the code for **Mode 2** if they only needed access to the outer office, the code for **Mode 3** if they needed access to the whole office, or the code for **Mode 4** if they wanted to change any of the passwords or if they are turning off a sounding alarm (in **Mode 4** the alarms will also be disabled for both zones).

Then to rearm the alarm system when leaving the office, the last person to leave would enter the code for **Mode 1** and the system would switch from whichever other mode it was in to the desired both zones alarm are active **Mode 1**. However, the system would have to give the person a short 10 second delay to exit, close, and lock the outer door. If the last Zone 2 authorized person was leaving but there were still Zone 1 workers in the outer office, they would close and lock the inner door and then enter the code for **Mode 2** which would switch the system to the desired **Mode 2**.

Summary: Mode 1: Both Zones Armed Mode:

- Normal office closed operating mode: both status light on, keypad in Keypad Monitor Star Mode.
- If any of the sensors are activated except for the Zone 1 door sensor (or the Zone 1 motion detector when the outer door has been opened in the last 20 seconds), the alarm will sound and both zone status lights will flash as described above.
- If the Zone 1 door sensor is activated then the Zone 1 motion detector is disregarded for 20 seconds, and the 20 second countdown with increasing frequency beeps and flashes commences. The countdown beeps stop when a key on the keypad is pressed but the flashes continue. If a correct code for Mode 2, 3, or 4 is entered within the 20 seconds, the system switches to that operating mode. If one of these three correct codes is not entered before the end of the 20 second countdown, the alarm will sound as described above.

2. Mode 2: Zone 2 Armed Mode (default code: 222222#)

In this operating mode only the three sensors in Zone 2 are active for the alarm and people have access to the outer office Zone 1. If any of the Zone 2 sensors are activated the alarm will immediately sound. There is no delay on the Zone 2 door sensor. We don't want any of the Zone 1 people to get a hold of that sensitive data! Or a burglar could break into Zone 2 through the window (or walls or even the roof or floor!) while people are working unaware in the outer office. (Didn't you ever watch any of the many popular heist movies?)



To enter the inner office while in this mode (**Mode 2**), a person would have to enter the code for either **Mode 3** or **Mode 4** into the keypad to switch the alarm system into **Mode 3** or **Mode 4** and disable the alarm in both zones before opening the Zone 2 door.

The code for any mode may be entered into the key pad while in this mode (it will not cause any issues to re-enter the current mode). However, if the code for **Mode 1** is entered, the system will only delay 10 seconds before it arms the alarm system for both zones, so the Zone 1 window must be closed within that time or the alarm will sound. If the Zone 1 door is still open after the 10 second delay, the **Mode 1** 20 second countdown timer to alarm sequence will begin.

The Zone 2 status light will be solid on in this mode (alarm armed). If the alarm sounds then only the Zone 2 status light will flash in time with the buzzer. The Zone 1 status light will be off in this mode.

Summary: Mode 2: Zone 2 Armed Mode:

- Normal only outer office open operating mode: Zone 2 status light on, Zone 1 status light off.
- If any of the Zone 2 sensors are activated the alarm will immediately sound and only the Zone 2 status light will flash as described above.
- The code for any operating mode can be entered while in this mode. If the code for **Mode 1** is entered there is a 10 second delay before the **Mode 1** alarm sensors are activated.

3. Mode 3: Both Zones Disarmed Mode (default code: 333333#)

In this operating mode all the sensors are disabled and people have access to the whole office (both zones). The people with Zone 2 access will have to monitor the sensitive data and equipment in Zone 2.

The code for any mode may be entered into the key pad while in this mode (it will not cause any issues to re-enter the current mode). However, the Zone 2 door and window must be closed and no people inside Zone 2 if the code for **Mode 2** is entered. Otherwise the alarm will immediately sound upon the system switching to operating **Mode 2**. Also, if the code for **Mode 1** is entered, the system will only delay 10 seconds before it arms the alarm system for both zones, so Zone 2 must be empty of people and the window and door closed and also the Zone 1 window must be closed within that time or the alarm will sound. If the Zone 1 door is still open after the 10 second delay, the **Mode 1** 20 second countdown timer to alarm sequence will begin.

Both the Zone 1 and Zone 2 status lights will be off in this mode.

Summary: Mode 3: Both Zones Disarmed Mode:

- Normal whole office open operating mode: Both Zone 1 and Zone 2 status lights off unless a window or door is open when the appropriate zone status light will flash (0.5 second on, 2 seconds off), keypad in Keypad Monitor Star Mode.
- The code for any operating mode can be entered while in this mode. If the code for **Mode 2** is entered and any Zone 2 sensors are activated, the alarm will immediately sound. If the code for **Mode 1** is entered there is a 10 second delay before the **Mode 1** alarm sensors are activated.

4. Mode 4: Administrative Mode (default code: 444444#)

The administrative operating mode is the same as operating **Mode 3** with three exceptions.

1. Entering this operating mode (and only this operating mode) will immediately turn off the alarm if it is sounding.
2. There are 4 additional keypad codes recognized in this operating mode that allow you to change the code for any of the four operating modes. You wouldn't want to keep those default codes would you?



3. If there are no keypad buttons pressed for 10 seconds while in Administrative Mode, the operating mode will automatically switch to **Mode 3**. You don't want to forget and leave the system logged into Administration Mode!

The four addition keypad codes that are only recognized in Administrative Mode are as follows:

1# After entering this code, the keypad will be enabled such that entering in xxxxxx# will change the code for **Mode 1** to xxxxxx# where an x represents a number from 0 to 9.

2# After entering this code, the keypad will be enabled such that entering in xxxxxx# will change the code for **Mode 2** to xxxxxx# where an x represents a number from 0 to 9.

3# After entering this code, the keypad will be enabled such that entering in xxxxxx# will change the code for **Mode 3** to xxxxxx# where an x represents a number from 0 to 9.

4# After entering this code, the keypad will be enabled such that entering in xxxxxx# will change the code for **Mode 4** to xxxxxx# where an x represents a number from 0 to 9.

Note that you may choose longer or even a variable length codes. If no keys are pressed within 10 seconds, then timeout to **Mode 3** without changing any of the codes.

Great. Enjoy your now secure office and hope your workers are productive and make you a lot of money!

Demonstration (40%)

On the day of your Demo and Presentation lab, you should come prepared to quickly setup and then demonstrate and explain the operation of your project to your instructor or TA. You will receive marks for your functionality and BONUS POINTS for any optional or extra features you have implemented.

The following are the Minimum Requirements for Full Credit on your Implementation/Demo.

You are required to:

1. Implement the two-zone security system with the 4 modes and keypad input as described above.
2. Build a crude cardboard box office model to mount your sensors.
3. Build an indicator panel with:
 - a) The layout of the office on the panel;
 - b) A status LED and label for each door sensor (2);
 - c) A status LED and label for each window sensor (2);
 - d) A status LED and label for each motion detector sensor (2); and
 - e) A status LED for each Zone (2).
4. Use a piezo buzzer as an indicator as described above during keypad entry, 20 second countdown timer to alarm sequence, and for the alarm;
5. Use the 16x2 LCD to always display appropriate and clear messages or instructions in all modes;
6. Emulate an off-site monitor and alarm using the MSP430G2553 microcontroller:
 - a) Implement as a standalone microcontroller (not in the LaunchPad board);
 - b) Communicates with the MSP430FR6989 microcontroller vis UART to get the status of the zones of the security system;
 - c) Controls 2 LEDs to mimic the Zone status LEDs on your indicator panel (does not have to be in sync);
 - d) Controls a piezo buzzer that mimics the main security piezo buzzer only during an alarm.
7. Show your clear and complete instruction manual for your two-zone security system to your instructor.

**Presentation (25% based on peer and instructor reviews)**

After all demonstrations are concluded, teams will take turns formally presenting their projects to the class. Presentations must be ready before the lab period. Plan on an 8-10 minute presentation outlining your project, covering the useful features you've included, any algorithms you used, what problems you ran into, how you overcame this, useful features you discovered about the microcontroller, your accompanying hardware, and future additional features or functionality that you would like to add. Be prepared to answer a few questions after your presentation. Remember that you must present as if your audience consists of non-technical (or at least less technically capable than you) managers that are there to decide whether to continue funding for your project.

You will be expected to use PowerPoint or some other visuals to aid in your presentation and all members of the group should participate equally in the presentation. Please remember to take time to prepare and practice your presentation. Often in practice, doing good work is vastly overshadowed by a bad presentation. Be proud of your work and show it off! Please present flowcharts state diagrams and other graphics as appropriate and make sure they can easily be read. A sample presentation review sheet is available.

Please use a computer drawing program to create flowcharts, state diagrams, circuit diagrams and other graphic aids for professional looking results. For flowcharts, state diagrams, and other tree, graph, or bubble diagrams, I highly recommend draw.io (www.draw.io) which is a free to use browser-based application. For drawing circuits, I highly recommend CircuitLab (www.circuitlab.com). This browser-based application can output high-quality circuits and allows you to carry out SPICE simulations in-browser. Valpo has a license for CircuitLab and you only need to register using your Valpo email.

A common temptation in technical reports and presentations is to think: I spent 80% of my time on feature X, so I should spend 80% of my report/presentation on feature X. NO! Most people will not care about how you debugged a division algorithm for six hours. Present the solution you found, and how this operated within the context of the larger project.

Documentation (30%)

For this project you must submit your fully documented code along with a matching report level flowchart(s) or state transition diagram(s). A clear and complete instruction manual must be included for your security system. You also must submit your presentation and your completed work hour log sheets. If you used any external (to the LaunchPad) circuits, you must submit circuit diagram(s). These are described in more detail below.

These documents must be submitted to Blackboard prior to the beginning of the lab period. Your code means code that you created or modified including reused code from previous projects. Do not submit any standard CCS code or included libraries. Also do not submit any unmodified third party code or libraries although you must reference the sources of your third party code in the header comments of your code section that calls it.

Please submit the actual .c and .h files (find them in your CCS folder) and not a printout that contains the line numbers. Yes, on Blackboard the spacing and your carefully aligned code may not display properly, but when placed back into CCS it will look as you wrote it. Flowcharts/state transition diagrams and circuit diagrams must be submitted as PDF documents. Your presentation must be submitted as a .ppt or .pptx file if you used PowerPoint, and as a PDF file if you used other presentation software (unless it is a standalone executable). Your instruction manual must be submitted as a .doc, .docx, or a .pdf file.



Since this is Valpo, at the end of each submitted document you must include the Honor Code, your names, and your signatures. The Honor Code and your names should be typed and for your signature you may use a script font instead of importing your signature or using a verified electronic signature.

Code

Your fully documented code must include a header comment section for each standalone code section. This header comment section must include a description of what the code does, the author's name(s), the creation date, the version and last modification date, and the purpose of the code (e.g., ECE-422, Project 1). By standalone code section, I mean any of your code functions in separate files or included previously written code functions in your main.c file. These reused code functions must contain their own header comment sections with the required authorship, date, version, and purpose information. If you use code functions supplied by your instructor or a third party it must be noted in the comment header section and if you modify such code that also must be noted along with revision dates.

Your code must be easily readable with good whitespace and separated into logically arranged sections with section header comments. The code must be commented such that a non-technical manager can read the comments and understand what the code is doing without having to actually understand the code. A short example of properly commented code from ECE-322 is provided.

Flowcharts/State Transition Diagrams

As your projects get more complex, it may be more useful to show your program logic in state transition diagrams rather than flowcharts. This will be your choice on how to best display the logical operation of your code to your management team (i.e., instructor). The matching report level flowchart or state transition diagram should be a direct logical match to your submitted working code and must be at a level such that a non-technical manager can follow the logic and algorithms that you used to implement your solution. At the top of your flowchart/state transition diagram document there should be authorship information similar to that in your code. A simple example flowchart from an ECE-322 assignment is provided.

Circuit Diagrams

All external circuits (external to the LaunchPad) must have an easy to read and properly labeled circuit diagram which shows all connections to the LaunchPad (again with authorship information at the top of the document).

Instruction Manual

You must provide a complete instruction manual that clearly describes to the end user how to use all the features of your two-zone security system. Your user manual should be clear and complete. This should be submitted as a Word (.doc, .docx) or a text-based PDF document.

Presentation Review of other Presentations (5%)

You are expected to evaluate your peer's presentations fairly and provide constructive feedback including a comment or two. Please provide suggestions for improvement rather than leave critical comments. Everyone, including your instructors and other professional presenters can improve their presentation skills. Presentation skills are an important skill for effective and successful engineers, so please take this review process seriously. This portion of your grade will reflect how seriously and effectively you review the presenters. A sample review sheet is available.