Lab 3 – Prototype Phase 1

ECE 298 – F2021

Lab Section: IN-PERSON Group: 10

Part 1 – Pin Mapping

MCU Pin	Pin Mode	Functional Description
PA2	USART2_TX	Reserved
PA3	USART2_RX	Reserved
PA5	GPIO_Output	Reserved
PA14	SYS_JTCK-SWCLK	Reserved (Green Led)
PC13	GPIO_EXTI13	Reserved
PB7	TIM4CH2	Reserved (Blue PushButton)
PA6	ADC1 input	ADC input for ultrasonic sensor (Front door)
PA7	ADC1 input	ADC input for ultrasonic sensor (Back door)
PC6	USART6_TX	LCD Screen Output
PC7	USART6_RX	LCD Screen input
PA8	GPIO Output	Keypad Input – Column 1 (1,4,7,*)
PC9	GPIO Output	Keypad Input – Column 2 (2,5,8,0)
PA15	GPIO Input	Keypad Input – Column 3 (3,6,9,#)
PB15	GPIO Input	Keypad Output – Row A (1,2,3)
PB14	GPIO Input	Keypad Output – Row B (4,5,6)
PB13	GPIO Input	Keypad Output – Row C (7,8,9)
PB12	GPIO Input	Keypad Output – Row D (*,0,#)
PC0	GPIO Input	Window Switch 1
PC1	GPIO Input	Window Switch 2
PC2	GPIO Input	Window Switch 3
PC3	GPIO Input	Window Switch 4
PB9	GPIO Input	Door Switch 1
PB8	GPIO Output	Door Switch 2
PC12	GPIO Output	SYSTEM_ALARM LED
PB6	GPIO Output	Alarm Relay (Sound)
PB5	GPIO Output	Lighting Relay 1 (Front Door)
PB4	GPIO Output	Lighting Relay 2 (Back door)
PC11	GPIO Output	Window 1 Status LED (Red)
PC10	GPIO Output	Window 1 Status LED (Green)
PC4	GPIO Output	Window 2 Status LED (Red)
PC5	GPIO Output	Window 2 Status LED (Green)
PB0	GPIO Output	Window 3 Status LED (Red)
PB1	GPIO Output	Window 3 Status LED (Green)
PB2	GPIO Output	Window 4 Status LED (Red)
PB10	GPIO Output	Window 4 Status LED (Green)
PA12	GPIO Output	Door 1 Status LED (Red)
PA111	GPIO Output	Door 1 Status LED (Green)
PA10	GPIO Output	Door 2 Status LED (Red)
PA9	GPIO Output	Door 2 Status LED (Green)

Part 2 – MCU Resources

MCU Resource	Functional Description
USART6	Sends characters and commands to the LCD screen module on the TX channel, so that information can be displayed on the screen. Receives input from COMM terminal on RX channel using interrupts.
ADC1	Reads analogue voltage output from both ultrasonic sensors (on ADC1_IN6 and ADC1_IN7), to be converted into distance of an object from the sensor.
GPIO	When set to input mode, provides interface for reading digital signals including: – Open/close states of doors and windows given by the switches – Which keypad buttons are being pressed When set to output mode, provides digital signals to control: – System alarm LED – Relays for lighting and audible alarm systems – Status LEDs for all doors and windows
TIM2	Acts as a timer so that events such as detecting button states from the keypad can be performed with a set periodicity, without halting the whole system for that period.
TIM10	This timer causes an interrupt once every second. This is used to keep track of the system time.

Part 3 – Test Cases

Test 1: UART Port (Setup mode)

Brief Test Summary

User can set system parameters through the virtual terminal with a series of commands. All commands need to end with a ';' symbol. All the commands must be run in setup mode only. In run mode, the only command that we can run is 'setup;'. Invalid commands will be silently ignored.

Task	Command	Description
Start run mode	run;	Starts the run mode
Start setup mode	setup;	Starts the setup mode
Arm/disarm windows	w[1234] [ad];	Enter a single number after w to indicate which window you want to select. Enter either 'a' or 'd' to arm/disarm the sensor respectively.
Arm/disarm front door	fd [ad];	Enter either 'a' or 'd' to arm/disarm the front door sensor
Arm/disarm back door	bd [ad];	Enter either 'a' or 'd' to arm/disarm the back door sensor
Arm/disarm front door light	fl [ad];	Enter either 'a' or 'd' to arm/disarm the front door external light

Arm/disarm back door light	bl [ad];	Enter either 'a' or 'd' to arm/disarm the back door external light
Set front door distance	fdd [1-4];	Enter the distance within which the front door external lighting should turn on. It must be between 1-4
Set back door distance	bdd [1-4];	Enter the distance within which the back door external lighting should turn on. It must be between 1-4
Set Activation Delay	ad [num];	Enter a number to set the activation delay. The external alarm relay will turn on after this delay. Also, while system is disarmed, the system will get armed after this delay value. Allowed values are 30, 45, 60, 120
Set the current time	time hh:mm:dd;	Set the current time of the system
Set the passcode	key [num];	Sets the passcode of the security system. This must be a four-digit code.
Refresh the LCD screen	print;	This forces the LCD screen to refresh and re-print the contents of the screen

Instructions

Run the simulation and open the virtual terminal. Type new commands after the LCD screen has finished printing. Otherwise, the LCD screen sometime displays the wrong character. If this happens you can run the command `'print;'` which will refresh the screen.

```
w2 d;
w4 d;
bd d;
fdd 3;
ad 60;
bl d;
key 4567;
print;
time 4:05:10;
```

After running the commands, the LCD screen should update to display the latest status, and the RGB LEDs will also display the latest status (Red: Alarm, Yellow: Armed, Green: Disarmed)

You can run the command "run;" to start run mode and "setup;" to go into setup mode.

Schematics and Simulations

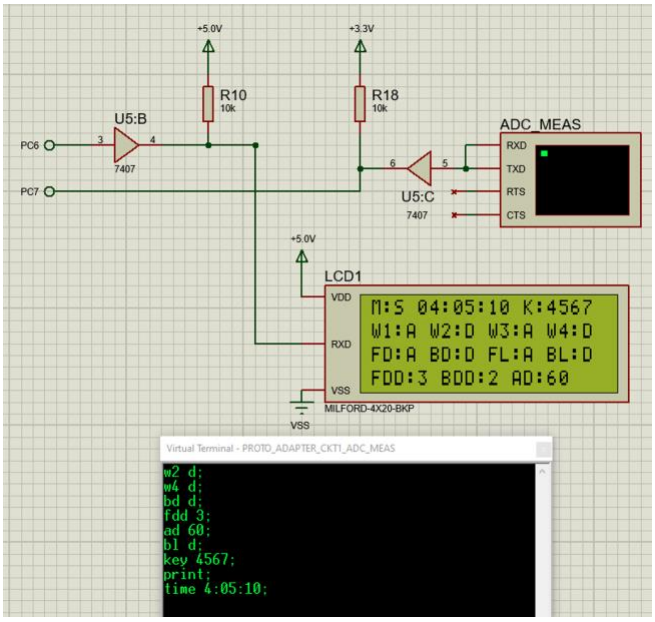

Figure 1: LED screen readout after entering commands

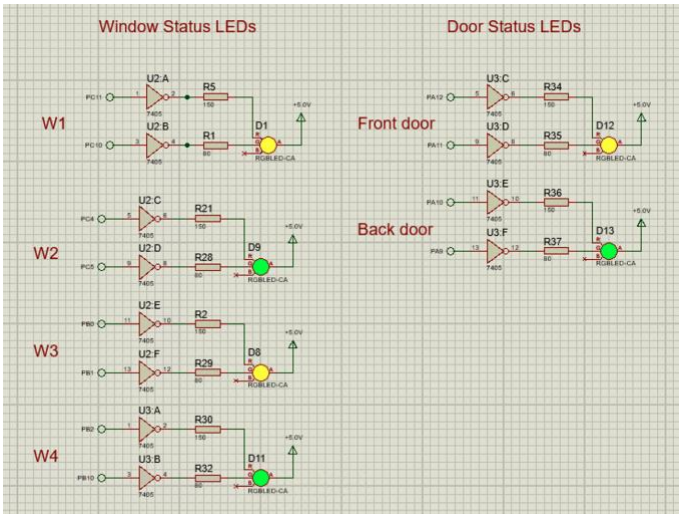

Figure 2: Status LEDs showing windows/doors armed and disarmed by the commands in figure 1

Test 2: Keypad

Brief Test Summary

Typing in the correct password (default password: 1234) will arm/disarm the system, and numbers typed on the keypad will also be shown as they are typed out. The system will get armed after a delay

Instructions

Upon running the simulation and issuing the command *run;* into the virtual terminal, pressing buttons on the keypad will result in them being output to the bottom right quadrant of the LCD. Please note that due to keypad polling, a button being held down may remain unregistered for about 15ms simulation time (with additional delay for the keypress being displayed on the screen). To make testing easier, we decided to display the keys pressed to the LCD screen. If the simulation is running too slowly, then you can hold down the key till it registers.

If the combination is typed in correctly the system will toggle its state from armed to disarmed. You can see the current status in the LCD screen. If typed in again, it will change from disarmed to armed, after the 2-second activation delay (this delay can be changed in setup mode). Incorrect combinations will do nothing if entered, and the combination system is invulnerable to De Brujin Sequences.

Schematics and Simulations....

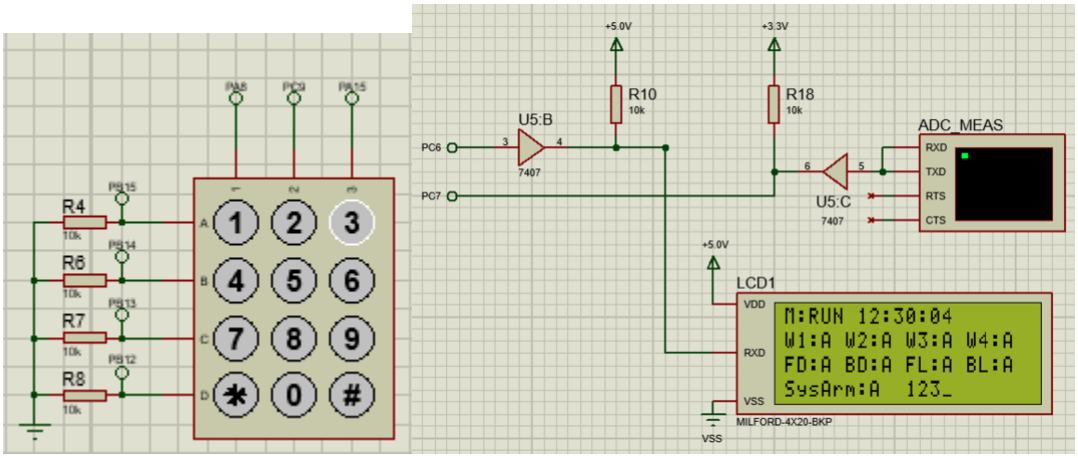

Figure 3: LED Display after pressing the sequence 1,2,3

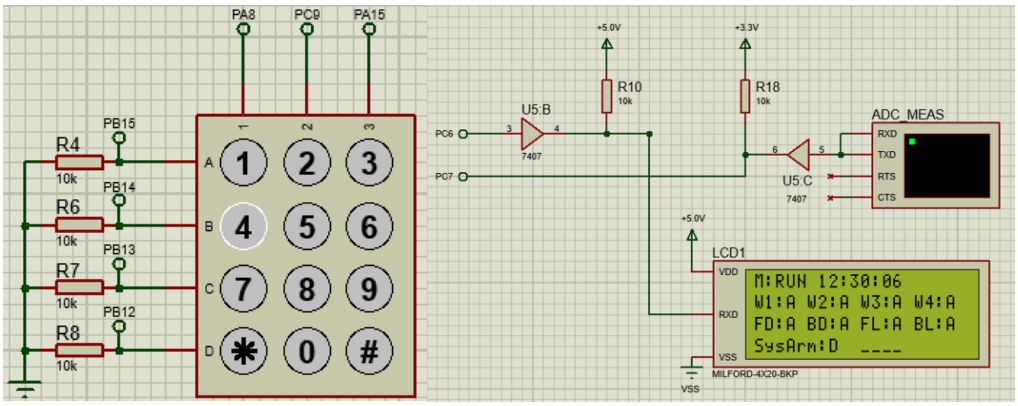

Figure 4: Pressing 4 after pressing 1,2,3 from an armed state disarms the system.

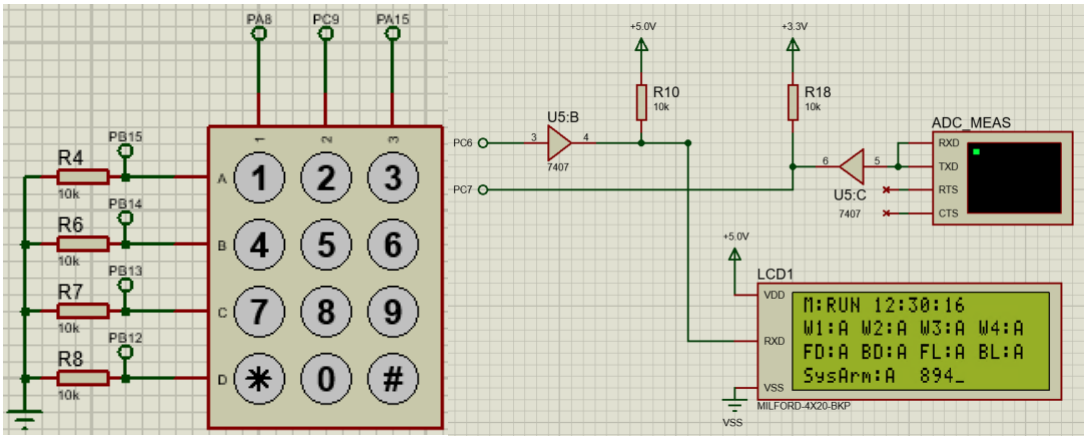

Figure 5: Invalid combinations are registered but will not arm/disarm the system.

Test 3: Alarm and Notification System

Test Summary

This system includes the window and door switches, the status LEDs, the system alarm LED, and the alarm relay. Note that the default alarm delay is two seconds. Even though the project requirements only support 30, 45, 60 and 120 seconds, you can use two seconds as the simulation runs very slowly. The RBD LEDs indicate the state of the sensor (Red: Alarm, Yellow: Armed, Green: Disarmed).

Instructions

Run the simulation and run command "ad 30;" to set the alarm delay to 30 seconds. This step can be skipped if the simulation runs too slowly (will default to 2 seconds if skipped). Run the command "run;" to switch to run mode. By default, the system will be armed, and all windows and doors will be armed. In this state, all status LEDs for the windows/doors should be yellow, and the LCD should read all statuses as “A”.

Open a door or window to cause it’s respective LED to change to red and change its status on the LCD to “X”. This indicates an alarm state, and will cause the system alarm LED to blink red. Once a window or door is in this state, closing its switch will not affect its state.

Once the system is triggered, if you punch in the passcode before 30 seconds, then the alarm relay will not turn on. For this test, wait 30 seconds of simulation time for the external alarm to be activated. Punch in the passcode now (1,2,3,4) to turn off the alarm and disarm the system.

While the system is disarmed, opening the door or windows will not trigger the system. The LEDs and LCD screen will display the armed/disarmed status.

Now, open the virtual terminal and enter

```
setup;
w1 d;
run;
```

This will disarm the Window 1 sensor. It’s status LED will be green and its status on the LCD will be “D” to reflect this. Now, push the button corresponding to window 1 sensor. You will notice that the LED stays green and the system does not get triggered.

If further testing is conducted, the following rules will be observed:

1. The LED for a sensor that has been specifically disarmed is green.
2. When the system is disarmed, the opening windows/doors will not trigger the system. The status LEDs for all armed doors and windows will be yellow, regardless of switch inputs.
3. For an armed system, all armed doors/windows whose switches have not been opened since the system was armed will be yellow.
4. For an armed system, all armed doors/windows whose switches have been opened since the system was armed will be red.
5. The system alarm LED will blink red if the system is armed, and any door/window has been opened since the system was armed.
6. The external alarm will be activated if the passcode was not entered within the activation delay time.

Schematics and Simulations....

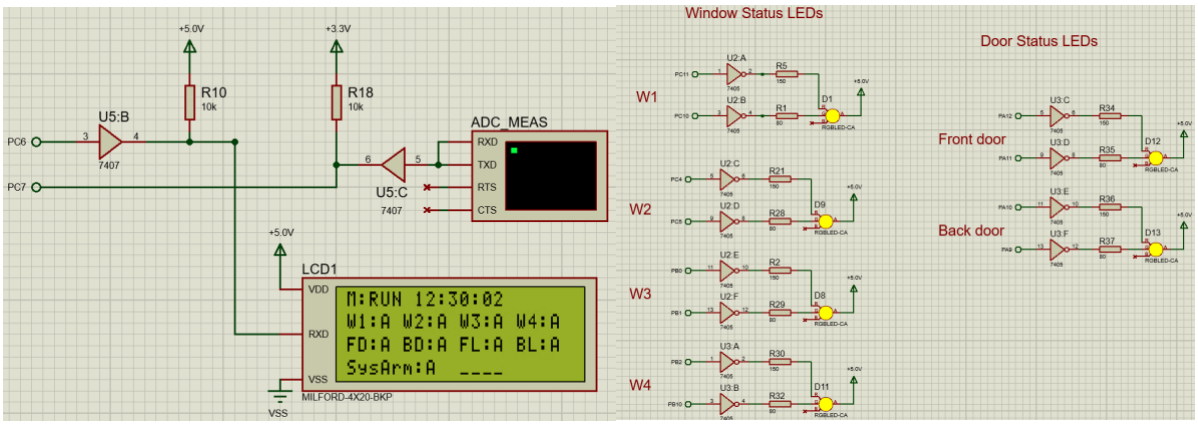

Figure 6: System running and armed with all switches pressed (all windows/doors are closed)

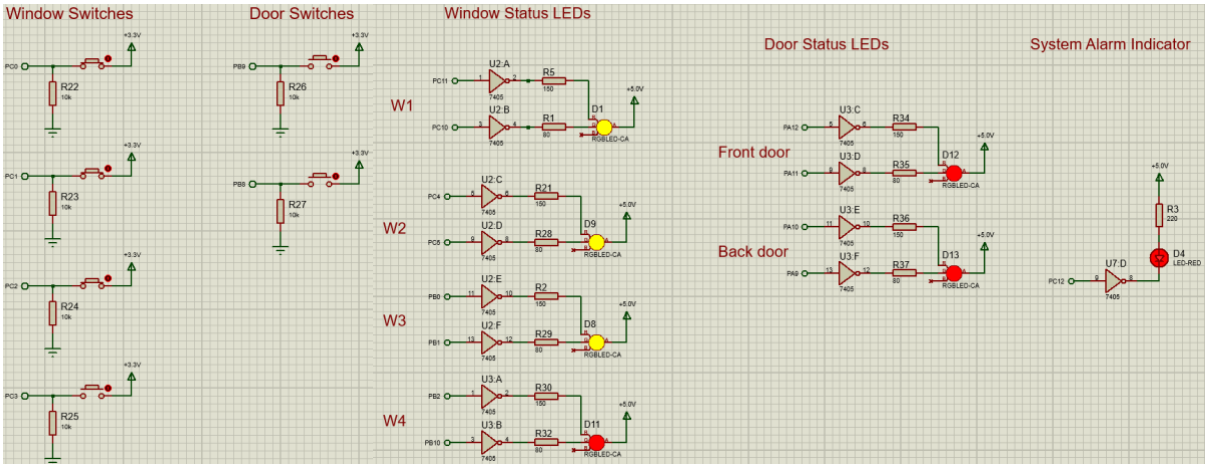

Figure 7: System running and armed with Window 4 and both doors in alarm state

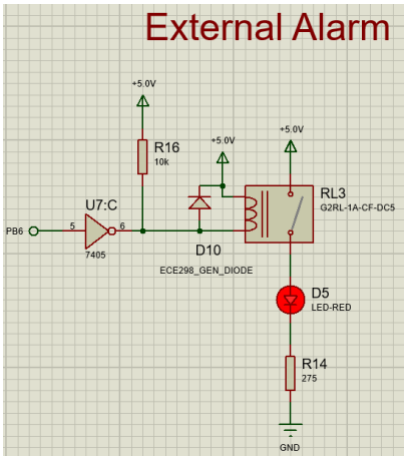

Figure 8: External alarm activates after programmed delay

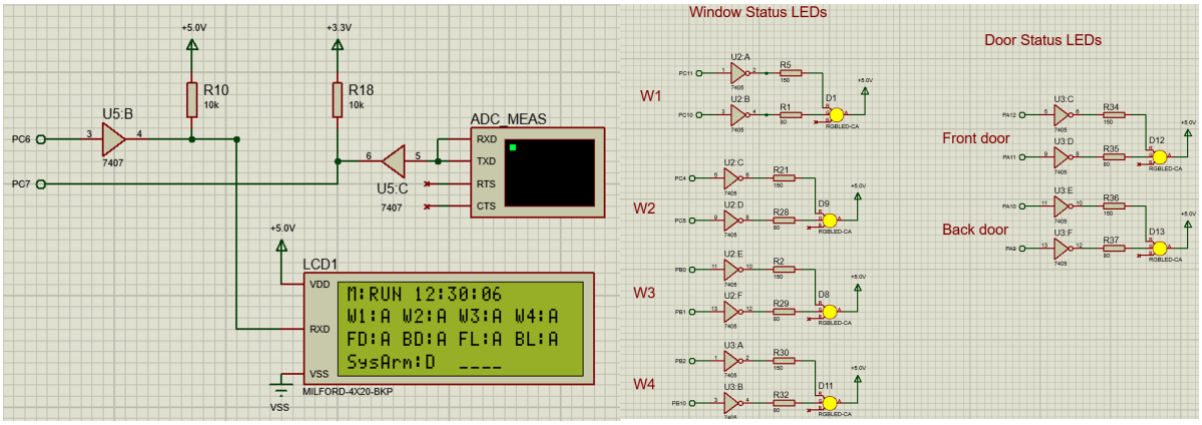

Figure 9: Disarming the system reverts all armed windows/doors to yellow

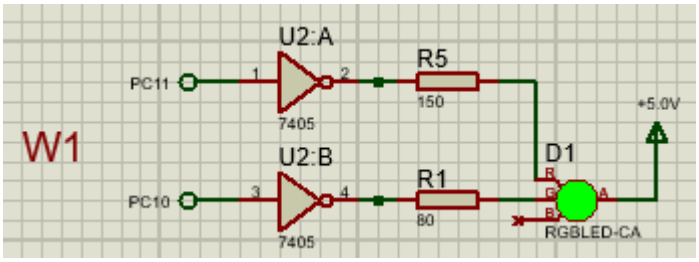

Figure 10: Disarming a window/door sets its LED to green, regardless of whether system is armed or disarmed.

Test 4: Distance Sensor System

Brief Test Summary

If the light is enabled and an object is within the distance threshold of one of the distance sensors, the relay for the external lighting is turned on. While the distance can be set to 1,2,3, or 4 meters, its default value is 2 meters. The front light and the back lights are armed by default and can be disabled in setup mode.

Instructions

Upon running the simulation, issuing the command *run;* into the virtual terminal, setting a virtual object to be less than 2m away from either door sensor will cause the corresponding external door lighting to be switched on. The external door lighting will be switched off when the object is set to be more than the trigger distance (which again, is by default 2m).

After this, run the following commands to switch into setup mode and to disable the front and back light.

```
setup;
fl d;
bl d;
run;
```

Now change the distance to be smaller than the threshold (2 meters by default). You will observe that the relay remains off as it was disarmed

Schematics and Simulations

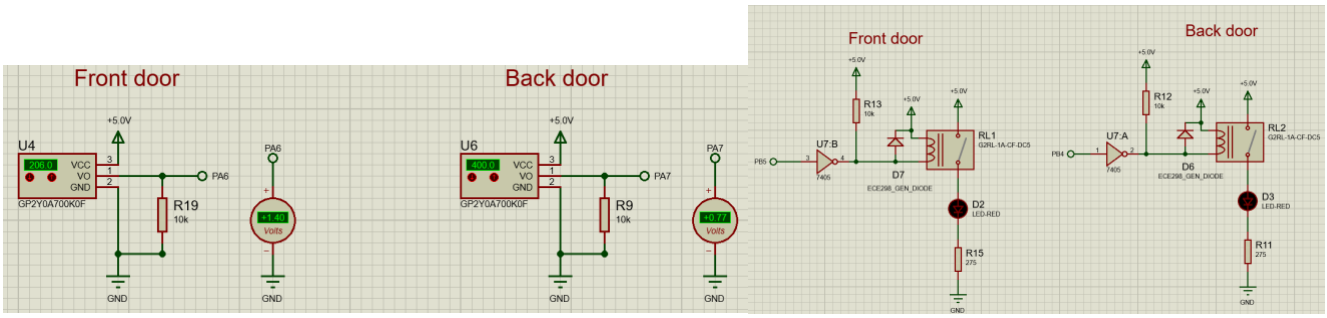

Figure 11: Nothing within range of front door or back door

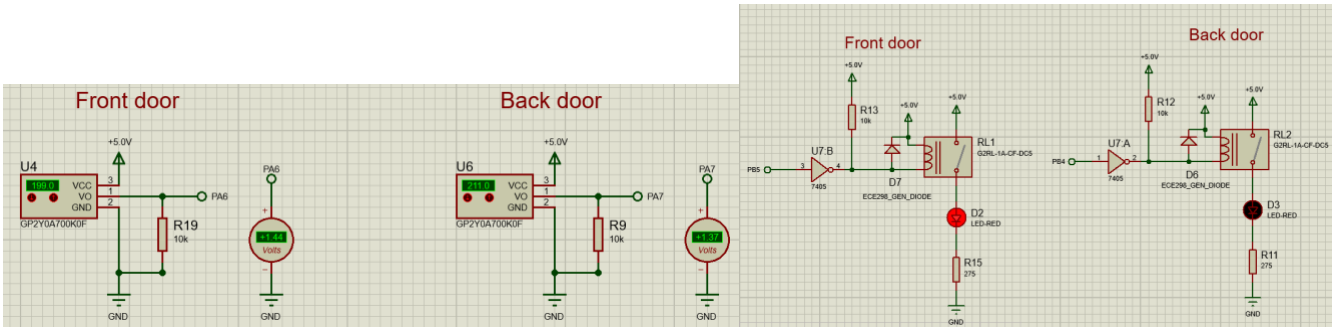

Figure 12: Object within range of front door, no object in range of back door

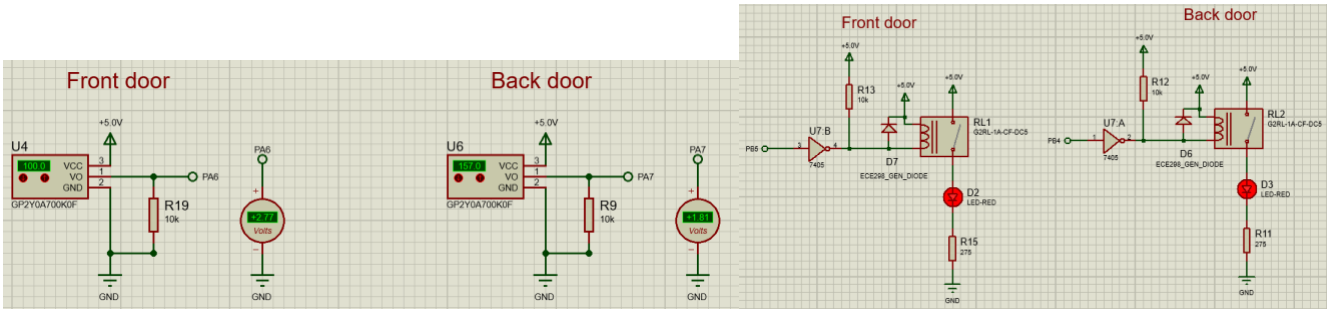

Figure 13: Objects within range of both front door and back door

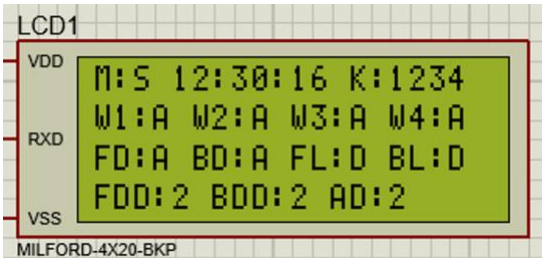

Figure 14: LCD screen shows that front and back lights have been disabled

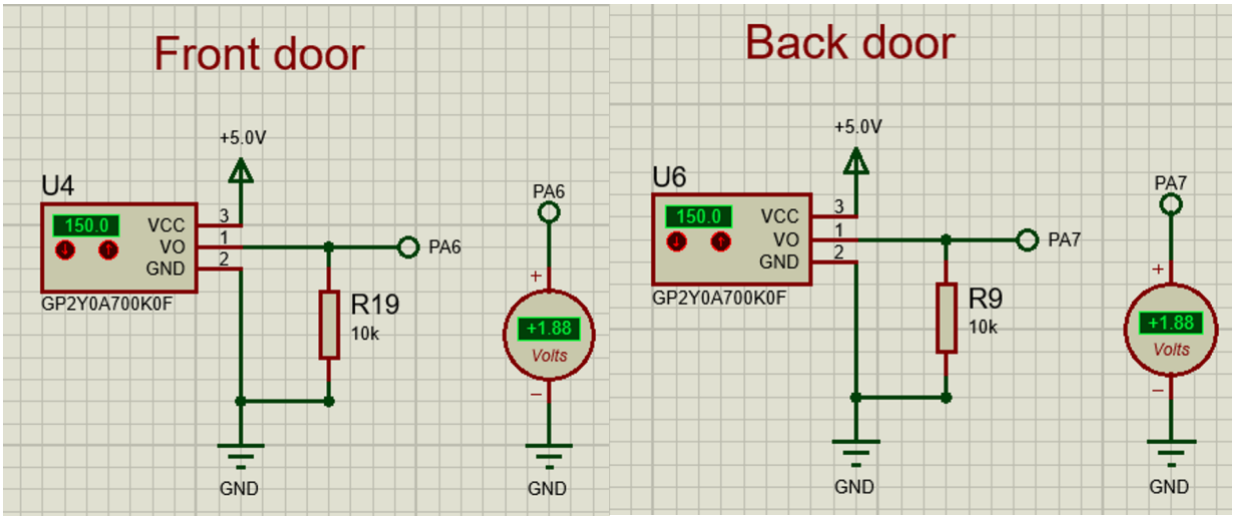

Figure 15: The distance has been set to a value smaller than the threshold (2m) when the lights are disabled

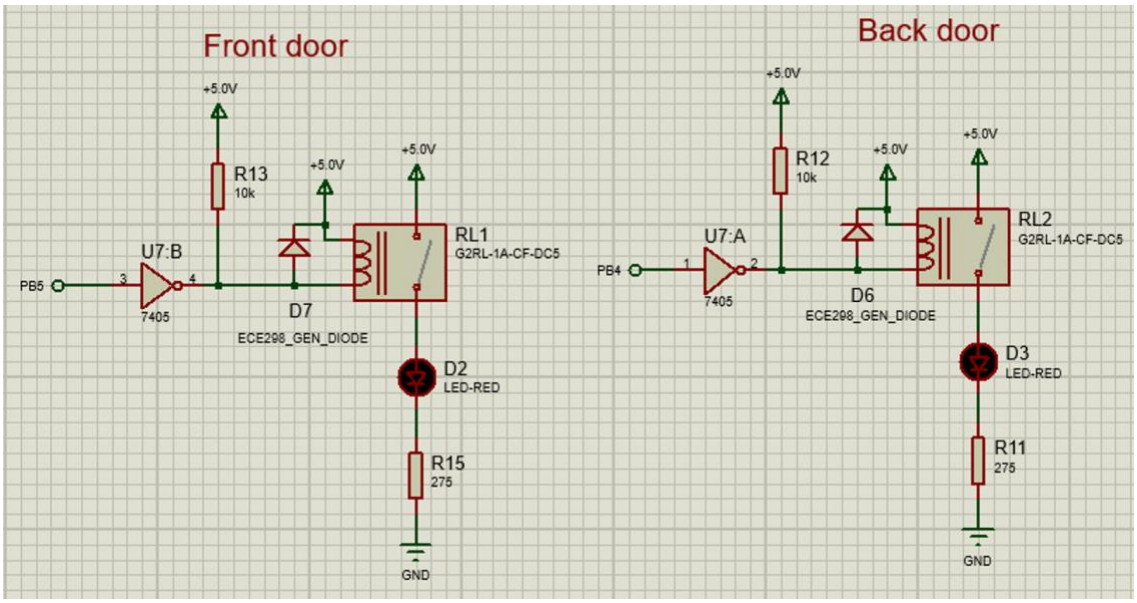

Figure 16: The relays remain off when the lights are disabled even if the distance is within the threshold

Test 5: LCD Display System

Brief Test Summary

The LCD screen, while in run mode, gives a constant readout of the mode, time, status of all windows and doors (A = armed, D = Disarmed, X = Alarm), the system state of the entire system (A,D,X), and the digits of the passcode that have been entered. While in setup mode, it also displays the mode, time, and states of windows/doors/distance sensors, as well as the Front Door Distance sensor threshold (FDD), Back Door Distance sensor threshold (BDD), Activation Delay (AD), and Keypad combination (K). For testing basic functionality, run the simulation. It will default to setup mode. For run mode, enter the command *run;* in the virtual terminal. Testing of more advanced functionality has been demonstrated in previous tests such as the UART port section (for SETUP) and User Notification system (for RUN mode).

Schematics and Simulations

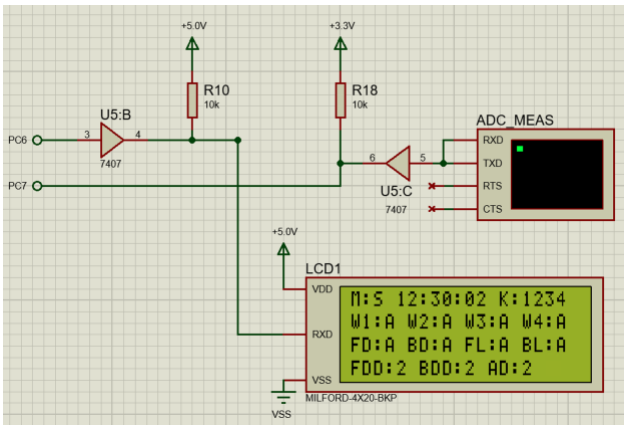

Figure 17: LCD Display in SETUP mode

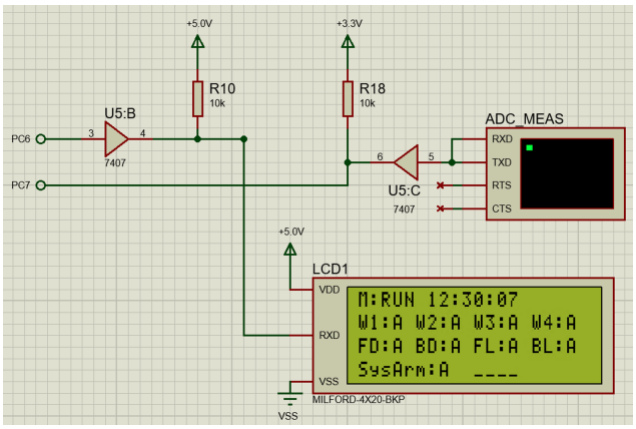

Figure 18: LCD Display in SETUP mode

MCU Pin connections

COMM Terminal:

RXD is connected directly to TXD so that we can see the characters that were typed. TXD is connected to a buffer with an open collector output. The other end of the buffer is connected to the MCU pin along with a pull up resistor connecting it to 3.3V. When TXD is 5V, the buffer produces a high impedance which gets pulled up to 3.3V, which is supported by the MCU. The MCU input pin has a high impedance and hence the current sourced/sunk will be very close to 0 as seen in Fig. 19

LCD:

The LCD is connected to 5.0V and GND. The TX pin of the USART port is connected to a buffer with an open collector output. The other end of the buffer is connected to RXD of the LCD screen with a pull up resistor connected to 5V. When PC6 is 3.3V, the buffer would produces high impedance which gets pulled up to 5.0V. When PC6 is 0V, the output of the buffer is 0V. Also, the buffer draws very little current from the MCU pin as seen in Fig. 19 (far below the 25mA requirement).

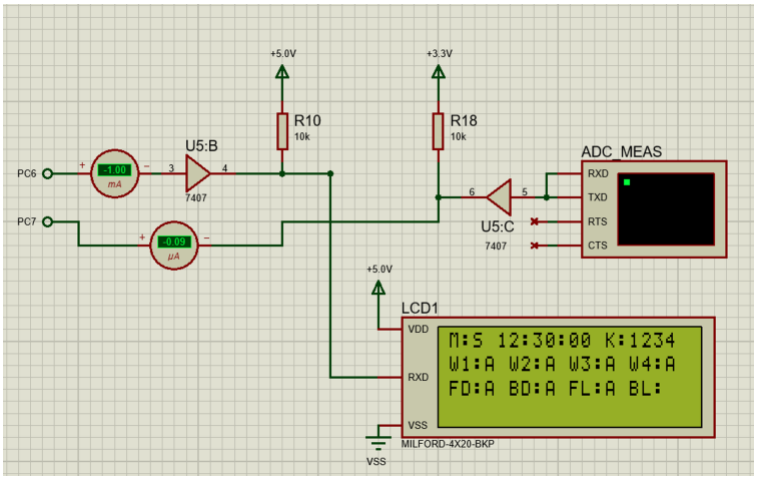

Figure 19: Figure shows the current drawn from pins PC6 and PC7 of the MCU

Alarm LED:

Pin PC12 is connected to an inverter with an open collector output. When the PC12 is 3.3V, invertor outputs 0V and the LED turns on. The invertor draws very little current (refer Fig. 20) which is below 25 mA.

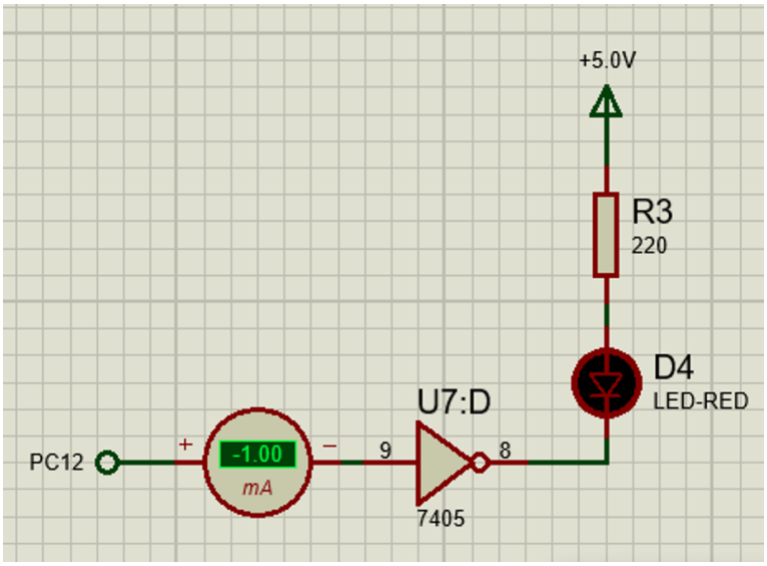

Figure 20: Current drawn by the system alarm indicator

Keypad:

Each row is connected to a 10 kΩ resistor which is connected to ground. When the key is pressed, the current flowing out of pins PA8, PC9 and PA15 would be 3.3V/10 kΩ = 0.33 mA. This satisfies the current requirements. Pins PB12-PB14 have a high impedance and the current sunk into the pin will be very low. Voltage requirements are also satisfied as the voltage will never exceed 3.3V.

Relays:

The GPIO output pin which controls the relay is connected to an inverter with an open collector output. The output of the invertor is connected to one end of the relay with a pull up resistor connected to 5V. The other side of the relay is connected to 5V. When the GPIO pin is set to 0V, there will be a voltage difference of 5V across the relay coil. This is sufficient to turn on the relay. Also, the invertor draws very little current (0.17 mA) which satisfies the current requirements of the MCU pin.

Digital sensor (push button):

The MCU pin are connected to one side of a push button switch. The voltage will never exceed 3.3V as the switch is connected to a power source of 3.3V. Due to high input impedance, the current sunk from the pin will be very low (Smaller than 1 mA).

Sensor Status RGB LEDs:

Each MCU pin is connected to an inverter with an open collector output. When the MCU pin is set to 1, the invertor produces an output of 0V, which causes a voltage difference of 5V across the LED and the resistor. This causes the LED to light up. The current drawn from the buffer is very low (close to 1 mA) which satisfies the current requirements.

Analog Distance Sensor:

As specified in the data sheet, the distance sensor output will not exceed 3.3 V. We do not need to scale the output voltage. The MCU pin has a high impedance and draws very little current (less than 1 µA). This satisfies the current requirements.