Birla Institute Of Technology and Sciences, Pilani

CS F241-Microprocessor Programming and Interfacing

P26-Elevator Control

Submitted to-

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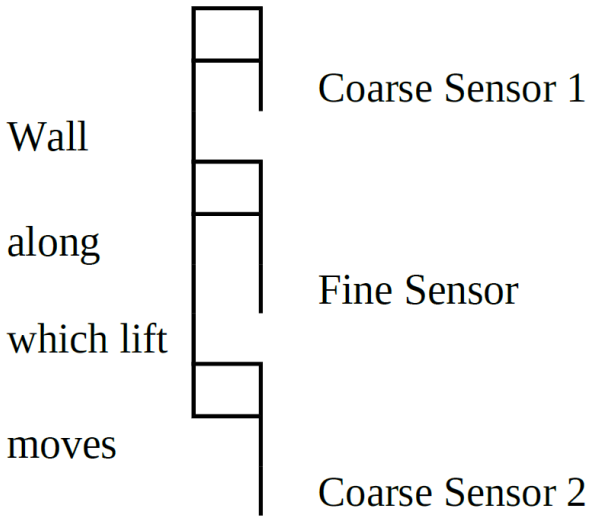
ELEVATOR CONTROL

SYSTEM REQUIREMENTS

- The elevator operates along **3 floors**.
- When not in use the elevator is always on the ground floor.
- The elevator can be called by pressing any one of **two buttons available on each floor**.
    - One button is **up** and the other is **down**.
- Whether the elevator stops at the floor or not depends on the direction in which the lift moves. For eg: if the lift is moving in upward direction and the person on say the 2nd floor presses the down button; the lift will not stop in the current journey. When the lift reaches the 3rd floor and starts moving down then the lift will stop at the 2nd floor.
- At **every floor there is a 7-segement display** that indicates the floor in which the lift is right now. The display can be any value from 0 - 3. '0' indicates the ground floor.
- Inside the lift **- buttons are available for floor selection**.
- **The floor towards which the lift is moving is also displayed** within the lift.
- **Doors to the lift open and close automatically**.
- When the lift reaches any floor where it has to stop it opens automatically, and it closes when a button called "Door Close" is pressed. **Lift does not move until the door is closed.**
- System runs from a standard power inlet.

SYSTEM SPECIFICATIONS

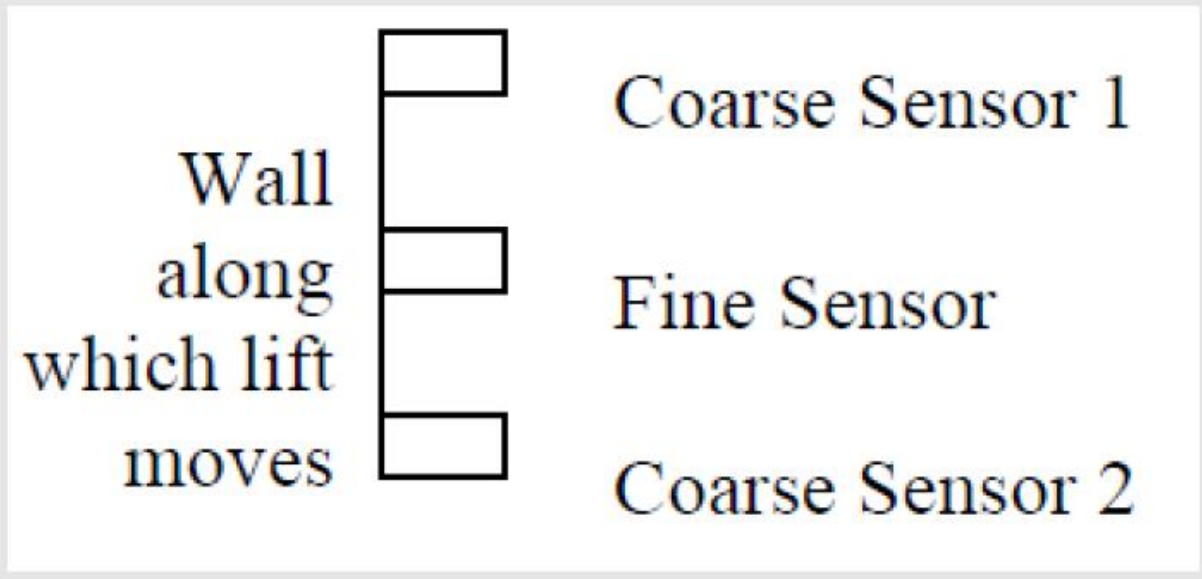
- An Electro-magnetic system is used for open and close of the door. We have just provided the on/off control.
- A heavy duty servo motor is used for lift movement. We have just provided the input to the driver circuit.
- The inputs are direction (up/down) and a PWM input which control the speed at which the lift moves. The duty cycle can vary from 20% to 60%.
- The frequency of the PWM signal is 20 Hz.
- For detecting whether the lift has reached a floor, the system has a set of three sensors –
    - Two 'coarse' sensors and a 'fine' sensor. All the sensors are contact switches (i.e.) when the lift reaches the point where the sensors are placed, the contact switch gets pushed in. Output of contact switches are low when closed and high otherwise. The sensor arrangement is represented in the fig below



- On the ground floor – only Coarse Sensor1 and Fine Sensor will be available. On the 3rd floor only Coarse Sensor 2 and the Fine Sensor will be available.
- When the lift starts at the ground floor it starts at a low speed gradually accelerating to the maximum speed. It should operate at maximum speed when it reaches 'Coarse Sensor 1". As the lift moves up if it has to stop at floor '1', when Coarse Sensor 2 is detected at that floor the lift starts moving at a low speed until it can stop when it reaches Fine sensor. When it starts again it moves at low speeds and reaches the maximum possible speed when it reaches the fine sensor. The same is done in the reverse direction with the appropriate sensors.
- Speed at which the lift moves is proportional to the duty cycle. For acceleration, duty cycle has to be gradually increased from 20 % to 60 %. And for deceleration, the duty cycle reduced from 60 % to 20 %. The increase is in steps of 20 %
- A 7447 chip (BCD to seven segment converter) is used for driving the 7-segment displays.
- 7447 takes a 4-bit BCD value and converts into the corresponding 7-segement equivalent.

ASSUMPTIONS

1. The Program starts at 0100H when the processor is reset.
2. Coarse and fine sensors that are available on each floor produce a binary output. Each sensor (coarse and fine) is assumed to be a push button, pushed by the elevator as it moves.
    - Coarse and fine sensors have to be manually pressed during the simulation. (However, in reality they would be automatically pressed by the contact from the elevator, as it moves.)



3. Floor buttons – both in and outside the life – have been assumed to be push buttons, as well. The floor buttons are pressed by the user.
    - While a button is not being pressed, it generates a logic 0 since it has been pulled down. This has been done to prevent the input from floating.
4. Unless the door is closed manually, the lift will not move.
5. Only one button is pressed at a given instant. However, any button on the floor may be pressed while the elevator is in motion.
6. By default the elevator is on the ground floor, and awaits user input.
7. Uni-directional motors have been used in this design project. Thus, to simulate both the upward and downward motion, two motors have been used – one for taking the lift up and one for taking it down.
8. PWM (Pulse Width Modulation) input is given through a pulse generator.
9. An Electro-magnetic system is used for opening and closing of the door. We have assumed that the doors open automatically, and have just provided a push button for closing the elevator door (just an on/off mechanism). We have also assumed that some mechanism exists that takes the door close button input and closes the door.
10. We have assumed that some mechanism involving a heavy duty servo motor already exists, and we have just provided an input to its driver circuit.
11. In the physical implementation, there will be separate sets of sensors for each floor. However, we have simplified the design to have just one set of sensors (one fine and two coarse). Since any two sets of sensors will never be triggered together, this is a reasonable simplification. These sensors can be used to accelerate or decelerate the lift, and the number of times the sensors are triggered can be used to infer the floor on which the lift is.

Hardware Description

- ✓ Two 8255 chips have been used – one having start address as 00H and the other as 10H.
  - ➢ The first 8255 chip has been used to interface the two motors – via a series of resistors. Two LEDS which indicate the status of the coarse sensors have also been connected to this chip. Its Port A and Port C are used for controlling the motors, and Port B has indicator LEDs for the contact sensors.
  - ➢ The second 8255 chip has been used to interface the 7-segment displays as well as the various (input) buttons and the coarse and fine sensors. Its Port A is used for controlling the seven segment displays, and Port C is used to access the sensor data. Port B is unused.

- ✓ 4KB of RAM has been used in this project – two 6116 chips. The RAM has been divided into two banks (odd and even) of 2KB each. The starting address of the RAM is 01000H.

- ✓ 4KB of ROM has been used in this project – two 2716 chips. The ROM has also been divided into two banks (odd and even) of 2KB each. The starting address of the ROM used is 02000H.

- ✓ 4 seven segment displays, one on each floor, indicate the floor the elevator is currently at.

  - ➢ One seven segment display inside the lift indicates the target floor (the floor to which the elevator is headed).
  - ➢ All these displays are interfaced using BCD to Seven Segment Display converters (7447).

- ✓ There are two sets of motors, one for the movement of the lift in upward direction, and one for the movement in the downward direction.

- ✓ There are ‘Up’ and ‘Down’ buttons outside the lift on each floor, except the third floor (which has no ‘Down’ button) and the ground floor (which has no ‘Up’ button’).

- ✓ In addition, there are four buttons (one for each floor) inside the lift to select the destination floor. Thus, there are 14 buttons in all.

- ✓ Two ‘coarse’ and one ‘fine’ sensor are used to track the movement of the elevator

Components Used

Sr. no.	HARDWARE	CHIP NO.	NUMBER
1.	**Microprocessor**: The programming unit which executes the program and controls the other units of the system.	INTEL 8086	1
2.	**Octal Latch**: To de-multiplex the AD lines and interface the components in the system.	74LS373	3
3.	**Read Only Memory:** Data storage.	2716(2K x8)	2
4.	**Random Access Memory:** Memory Operations.	6116(2K x8)	2
5.	**Programmable Peripheral Interface:** The interfacing device which connects the latched Micro Processor to the I/O devices	INTEL 8255	2
6.	**BCD to Seven-segment Decoder:** To convert BCD to seven segment pattern and interface the seven segment display.	7447	2
7.	**Seven Segment Display (Common anode):** To display relevant floor information.	FND507	5
8.	**Logic Gates:** For Chip selection and address decoding logic.	TTL ICs	Multiple
9.	**Push Buttons:** To get input from user and for sensors.		14
10.	**LED:** To show the status of doors and sensors		3

MEMORY MAPPING

	A19	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
RAM	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
ROM	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1

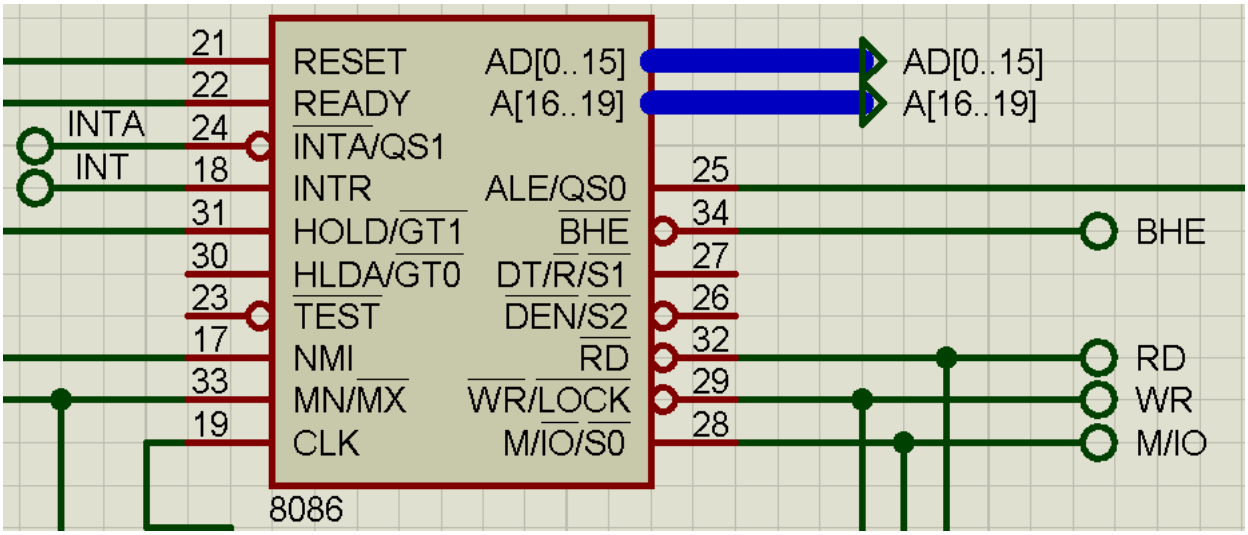
RAM_{even} 01000H, 01002H, 01004H, ……. 01FFEH

RAM_{odd} 01001H, 01003H, 01005H, ……. 01FFFH

ROM_{even} 02000H, 02002H, 02004H, ……. 02FFEH

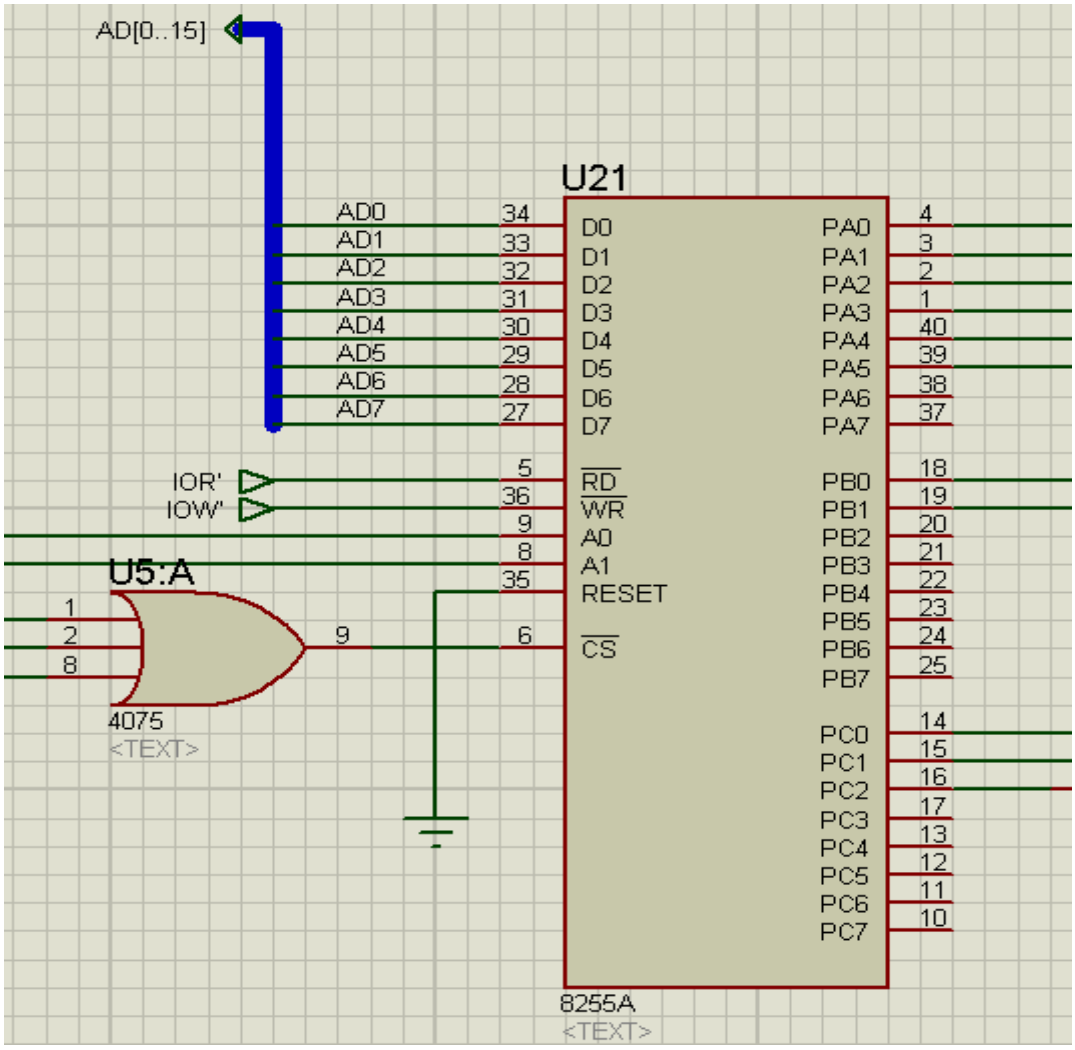
ROM_{odd} 02001H, 02003H, 02005H, ……. 02FFFH

8086 – INTEL MICROPROCESSOR



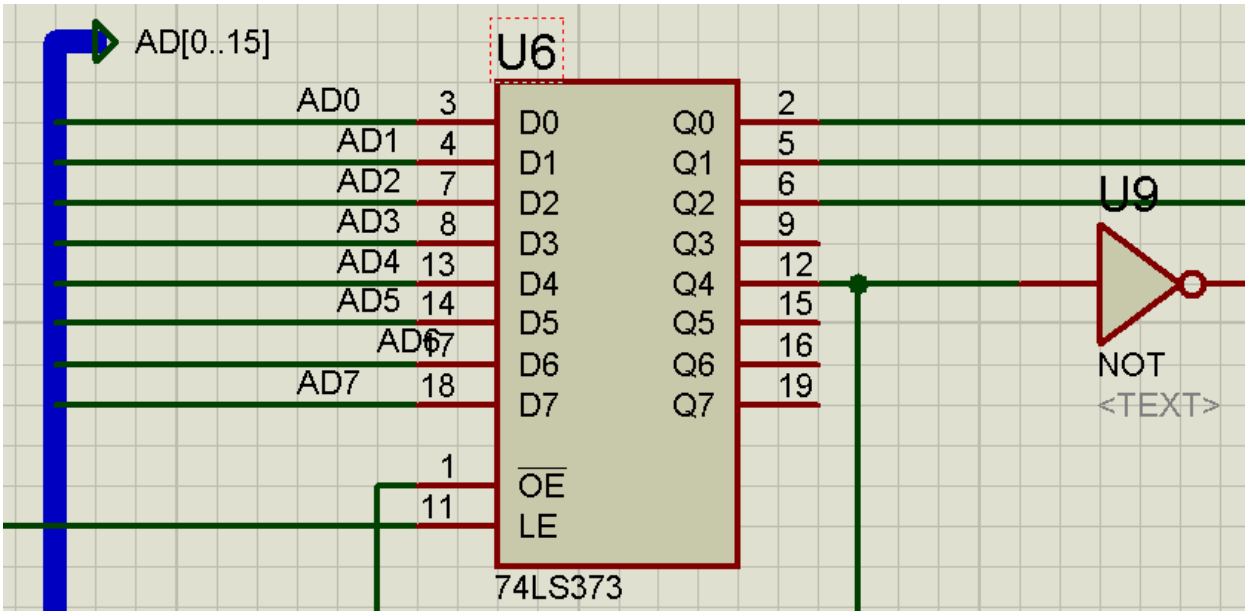
Intel 8086 microprocessor is a first member of x86 family of processors. The 8086 has complete 16-bit architecture - 16-bit internal registers, 16-bit data bus, and 20-bit address bus (1 MB of physical memory). Because the processor has 16-bit index registers and memory pointers, it can effectively address only 64 KB of memory.

8255- INTEL Programmable Peripheral Interface chip



The **Programmable Peripheral Interface (PPI) Intel 8255A** is a general purpose programmable I/O device which was designed to give the CPU access to programmable parallel I/O. It provides 24 I/O pins which may be individually programmed in 2 groups of 12 and used in 3 major modes of operation.

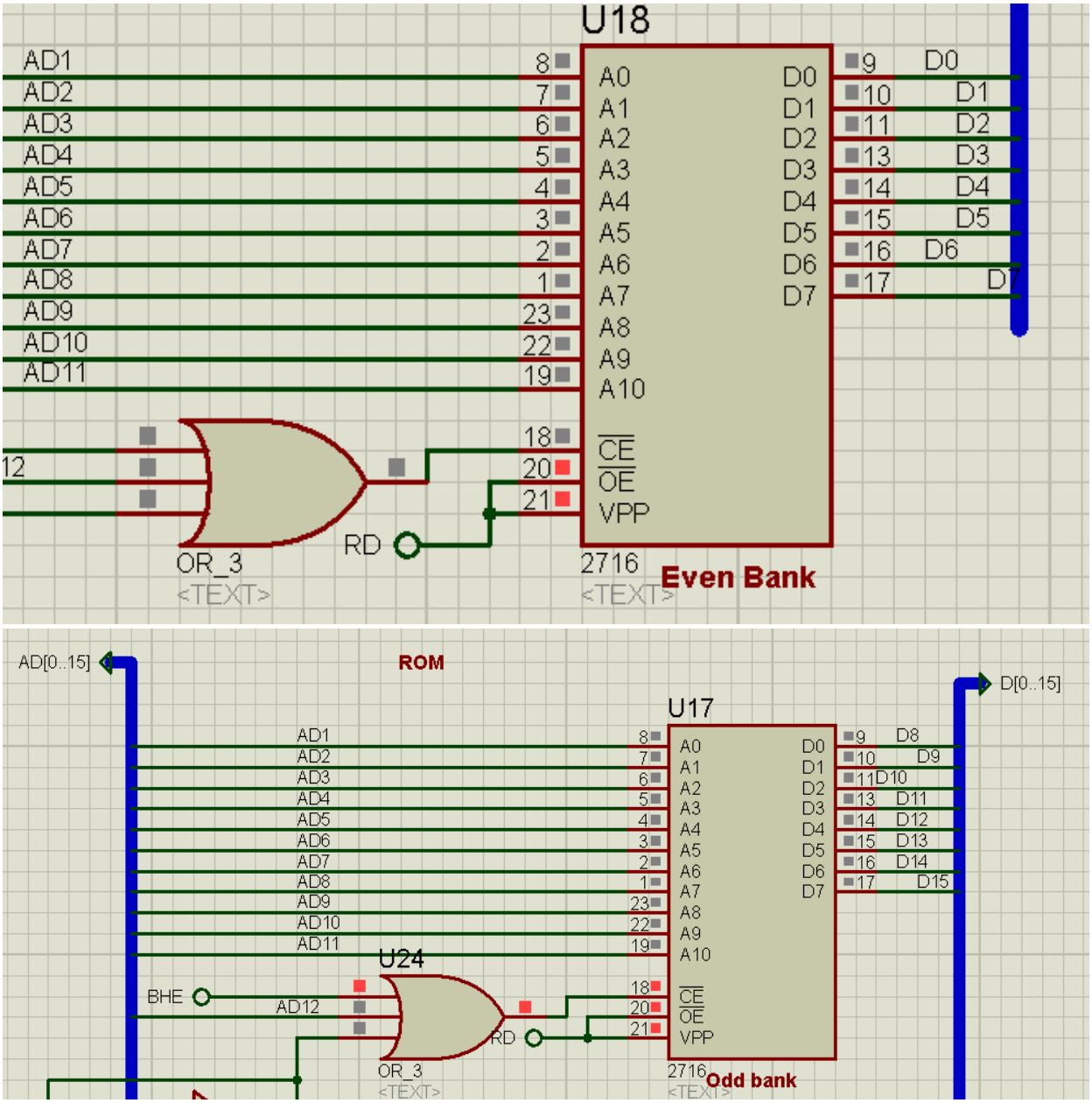
74LS373- OCTAL D-TYPE LATCH



The **74LS343 IC** consists of 8 latches with 3-state outputs for bus organized system applications. The flip-flops appear transparent to the data (data changes asynchronously) when Latch Enable (LE) is HIGH. When LE is LOW, the data that meets the setup times is latched. Data appears on the bus when the Output Enable (OE) is LOW. When OE is HIGH the bus output is in the high impedance state.

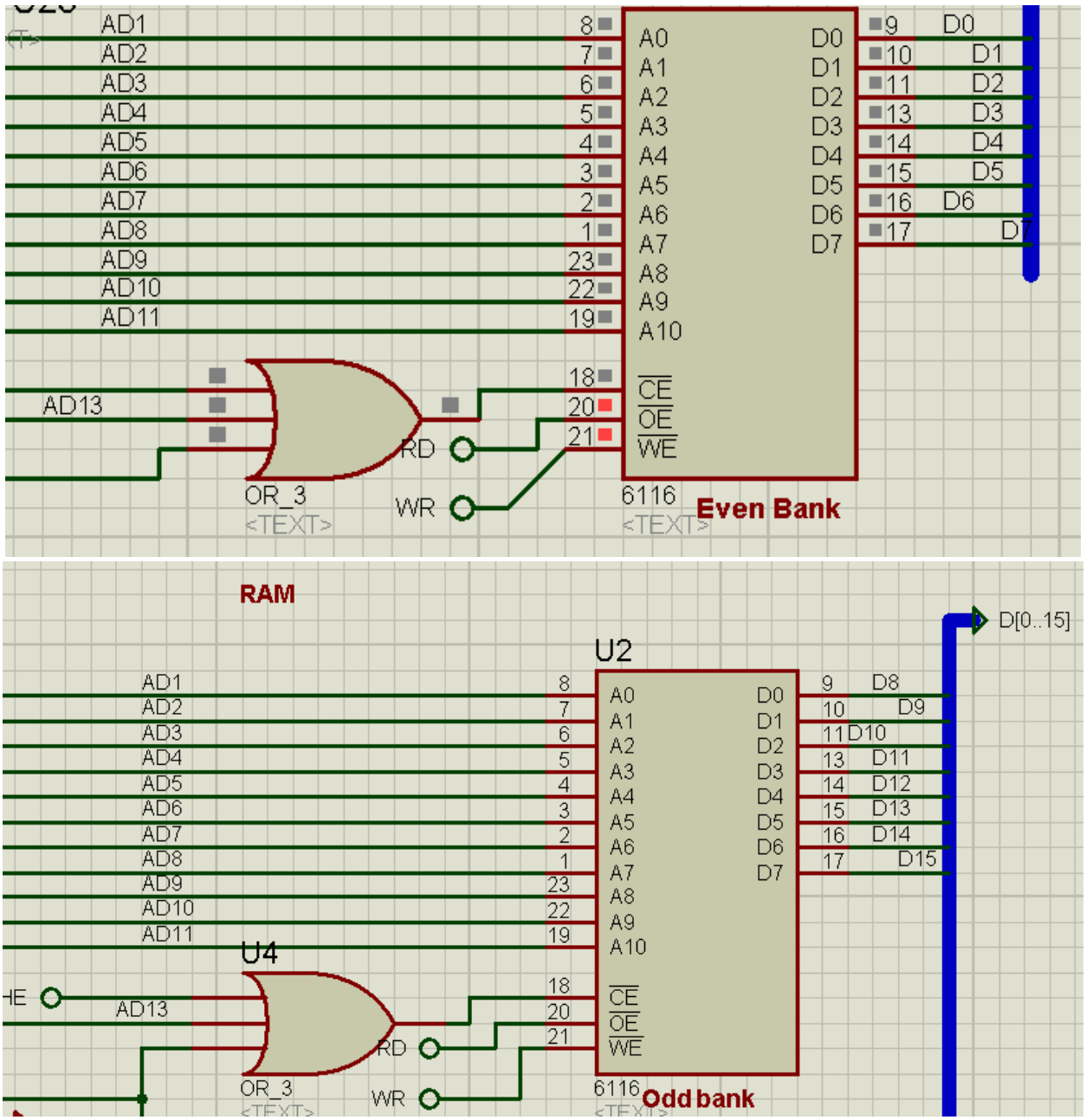
Two 74LS343 have been used in this design to de-multiplex the Address lines and interface the components in the system.

2716-(ROM-READ ONLY MEMORY)



The **2716** is a 16,384-bit EPROM organised as 2K x 8. A **read-only memory** is a type of non-volatile memory and is usually hard-wired. EPROM can be erased and re-programmed, but usually this can only be done at relatively slow speeds, may require special equipment to achieve, and is typically only possible a certain number of times. Two such chips have been used in this project – one serves as the odd bank of memory and the other serves as the even bank of memory.

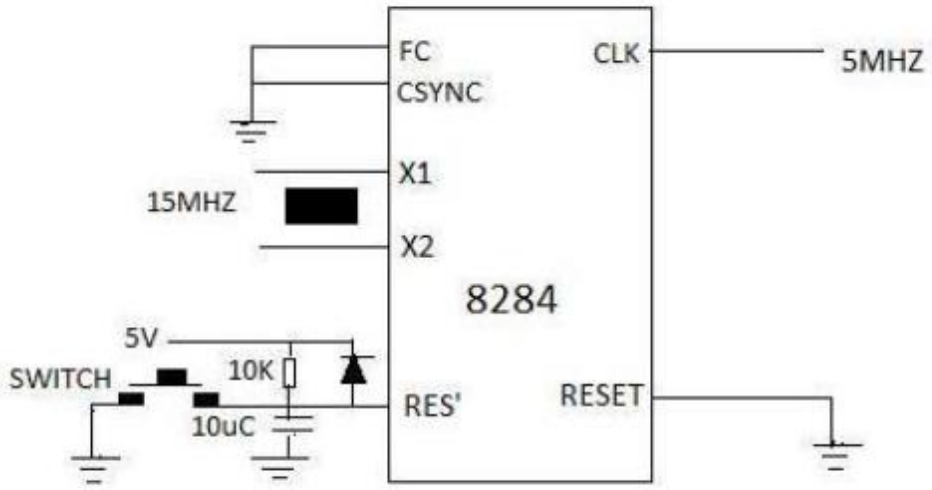
6116-(RAM-RANDOM ACCESS MEMORY)



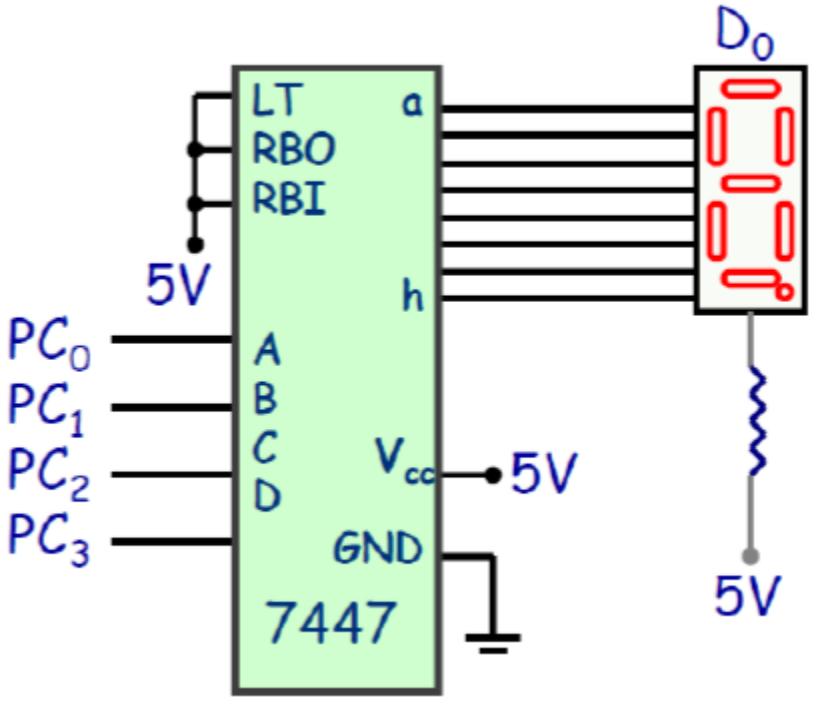
The 6116 is a 16,384-bit high speed static RAM organised as 2K x 8. A **random-access memory device** allows data items to be read or written in almost the same amount of time irrespective of the physical location of data inside the memory. RAM also allows for faster access of data.

Two such chips have been used in this project – one serves as the odd bank of memory and the other serves as the even bank of memory.

8284 CLOCK GENERATOR



7-SEGMENT DISPLAY



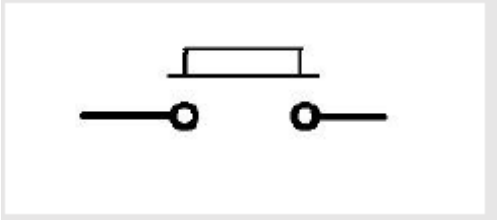
The 7447 IC take in a BCD value (4 bits) as input and outputs the corresponding seven-segment display value. Two 7447 ICs have been used.

4 – Seven segment displays have been used (one on each floor) to display the floor where the elevator has reached.

1 – Seven segment display has been set up inside the elevator which displays the destination floor where the elevator is headed

Two such chips have been used in this project – one for interfacing the motor and sensor LEDs, and the other for interfacing the various 7 segment displays and the push buttons.

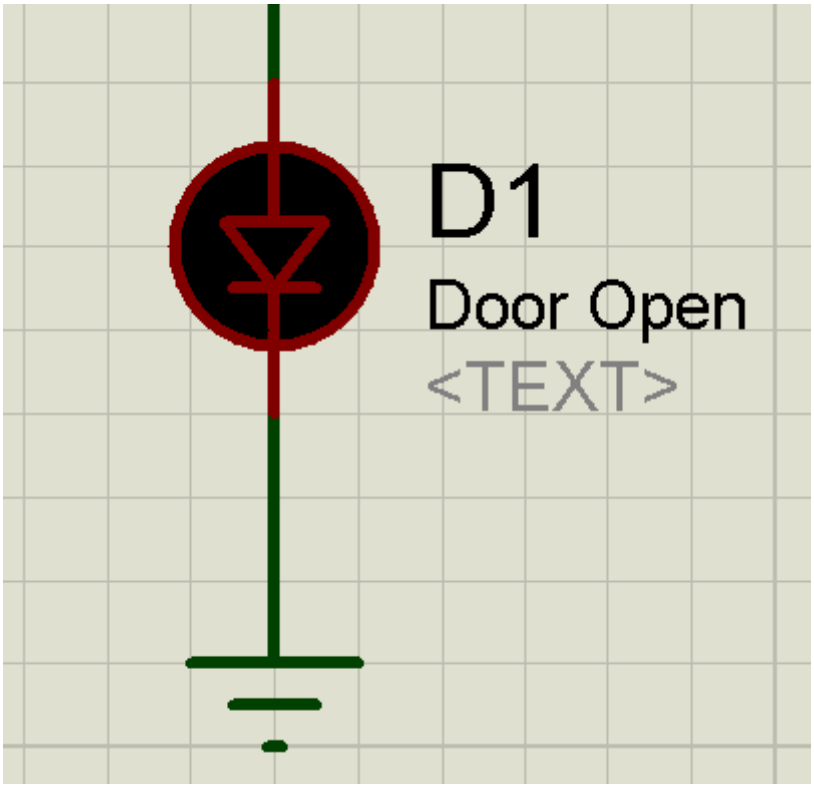
PUSH BUTTON



Each coarse and fine sensor, floor button outside and inside the elevator have been assumed to be a push button pushed by the elevator as it moves.

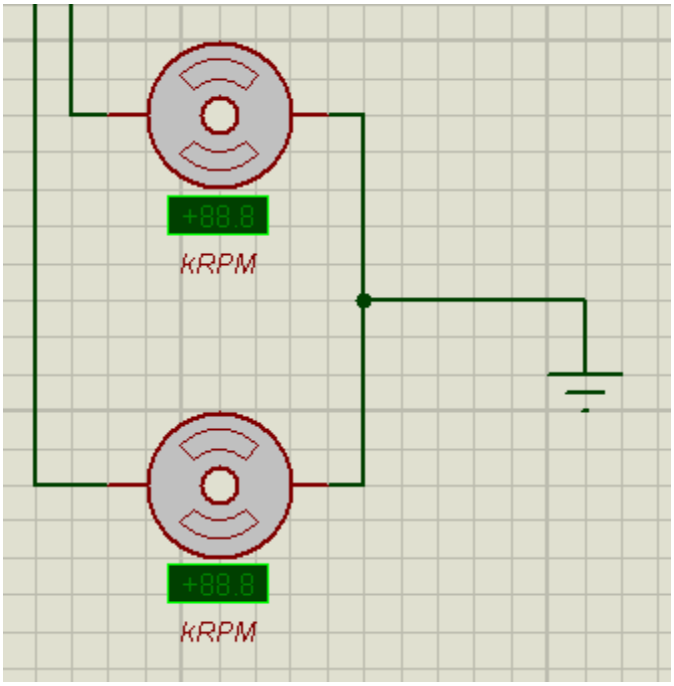
If not pressed, it generates a logic 0. This is being done to prevent the input from floating.

LED-LIGHT EMITTING DIODE



A **light-emitting diode (LED)** is a two-lead semiconductor light source. It is a p–n junction diode that emits light when activated.

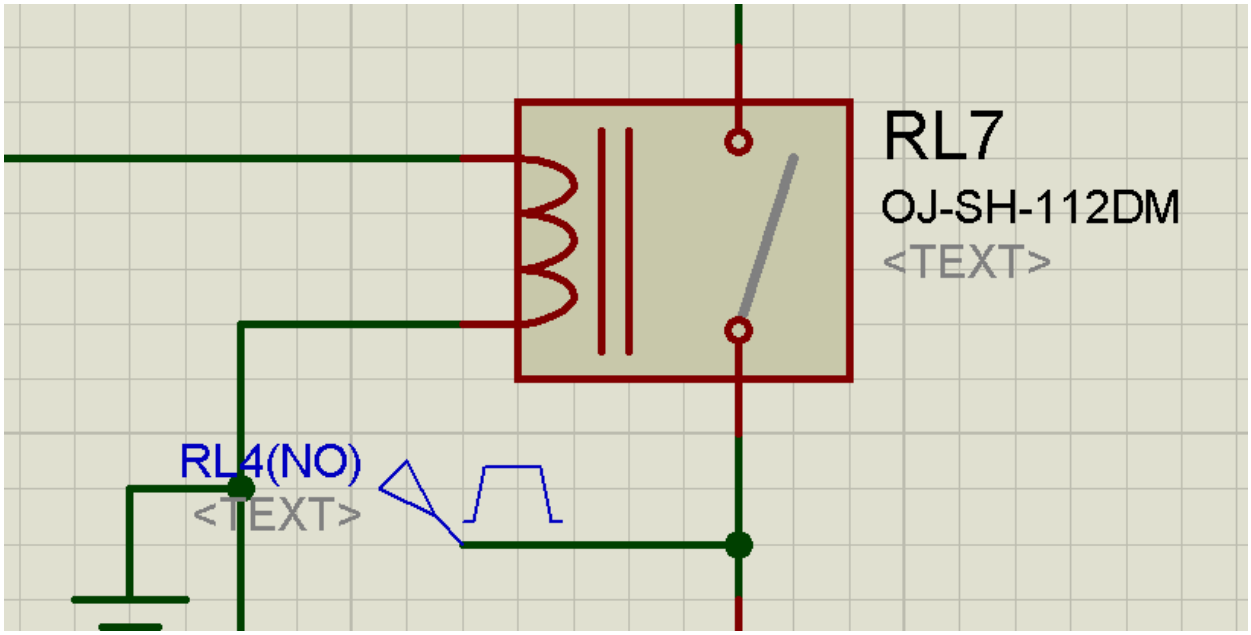
HEAVY DUTY SERVO MOTOR



A **servomotor** is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. They are small in size but pack a big punch and are very energy-efficient.

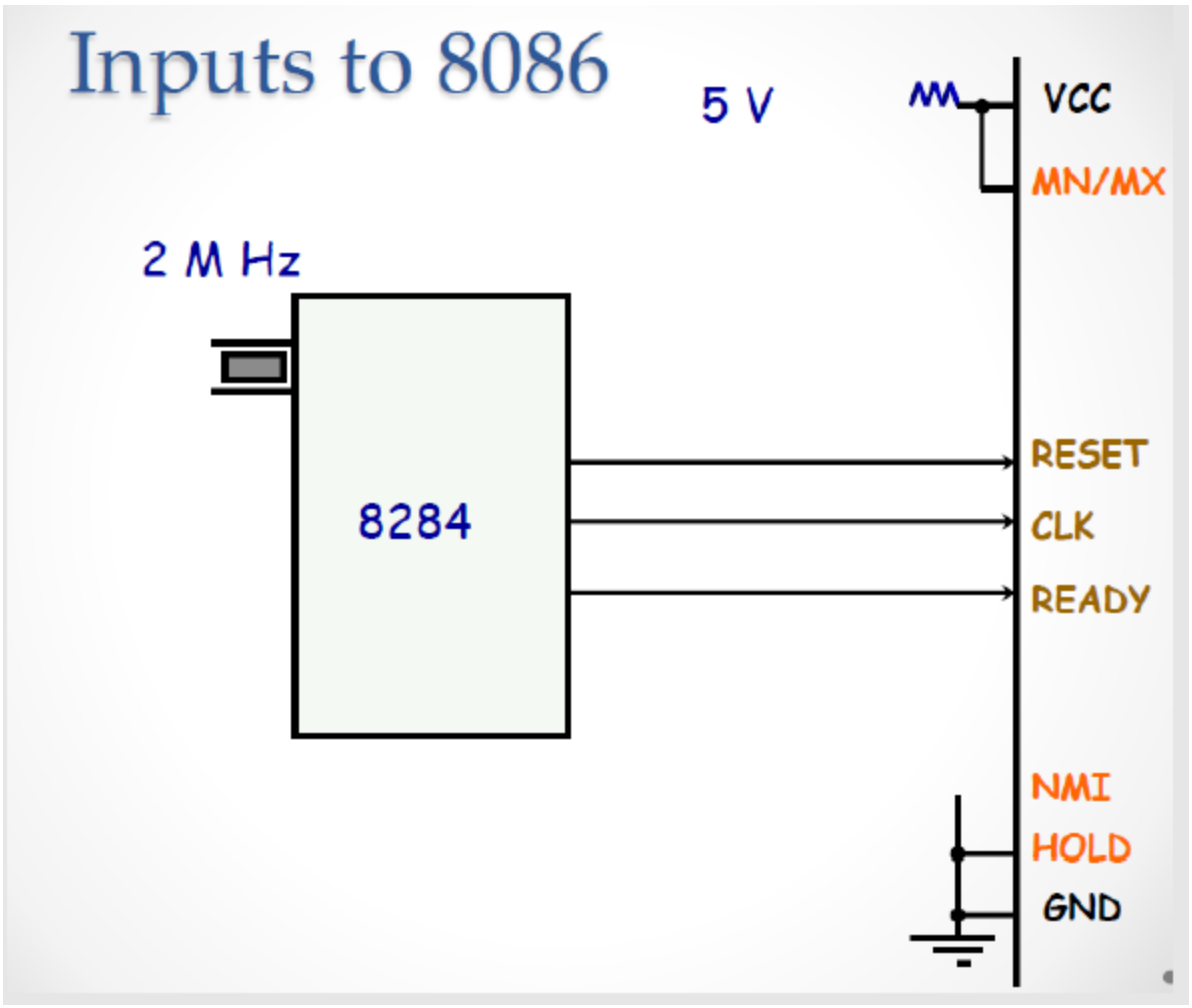
Two heavy duty servo motors have been used in this project – one for moving the elevator in the upward direction, and the other for moving it in the downward direction.

RELAY

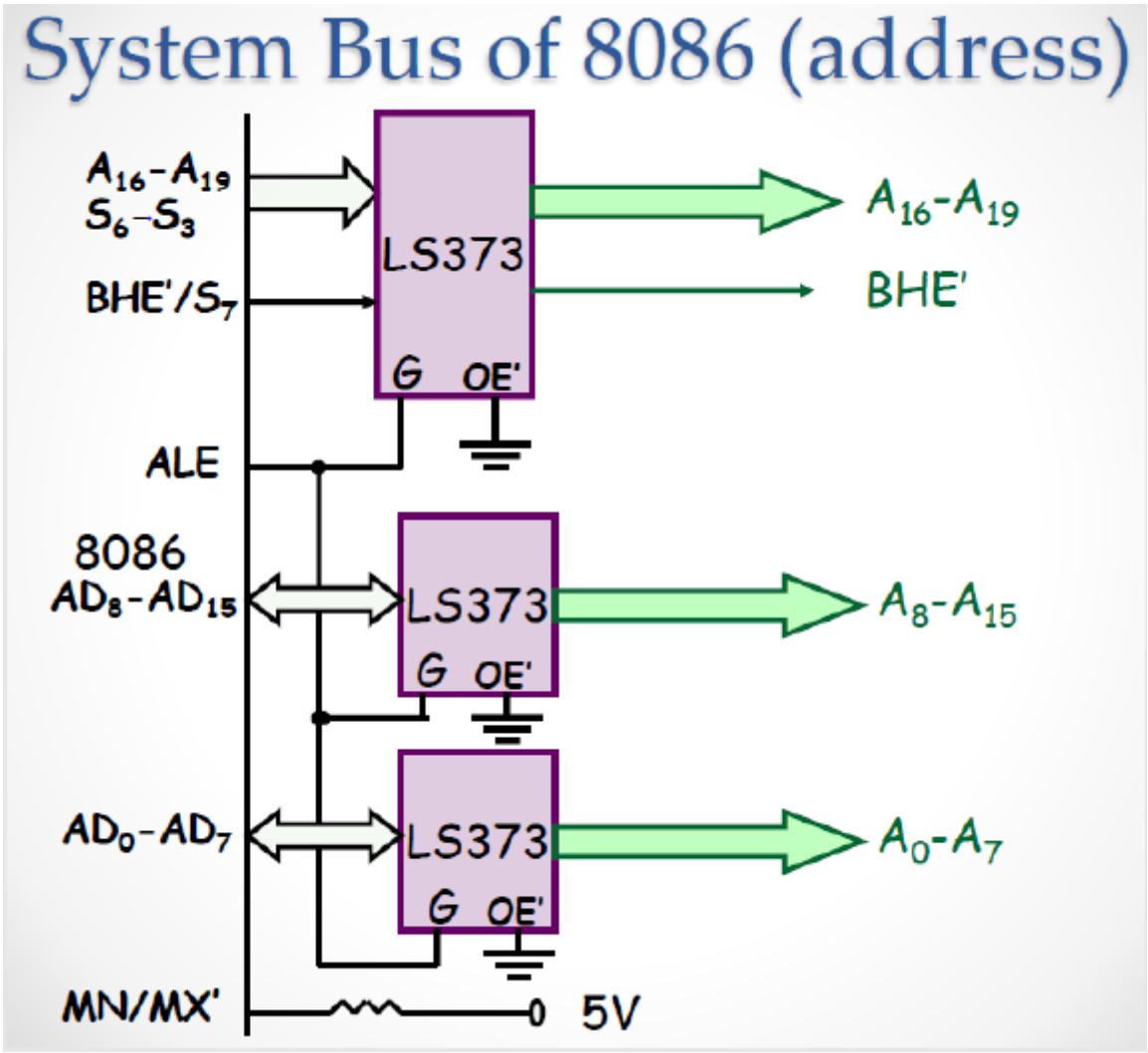


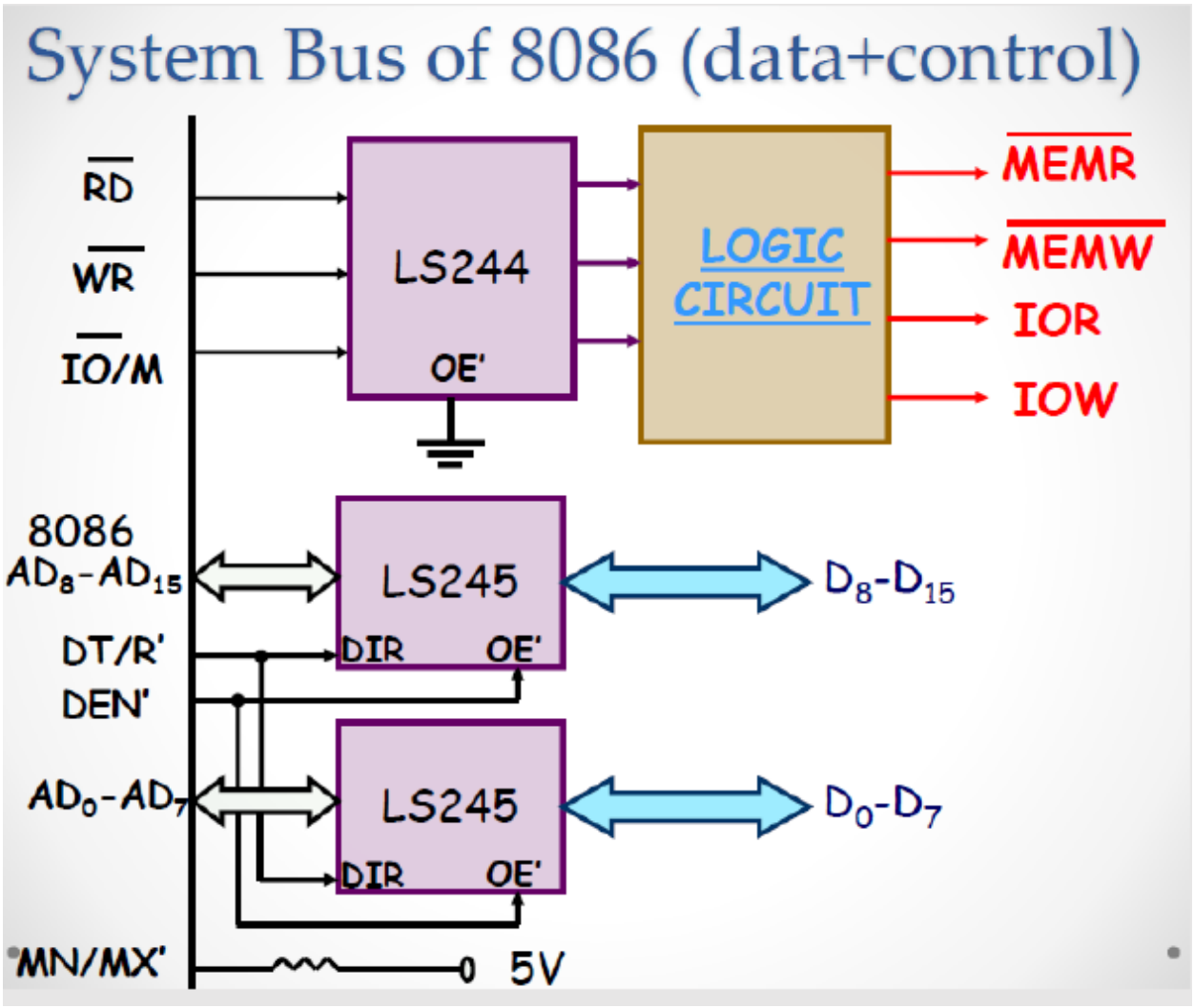
Printed circuit board (PCB) relays are compact relay devices used for power management in control system designs which require the relay to be mounted directly on the printed circuit board. In this projects the relays have been used to connect the two motors, and run them at different duty cycles.

Different PWM signals – each with the same frequency but different duty cycles - have been used to power the two motors. Relays have been interfaced to different ports of the 8255 in order to actuate and control the duty cycle values. Depending upon the output of the ports, different relays get selected, and thus the duty cycle given to the motors change as well.

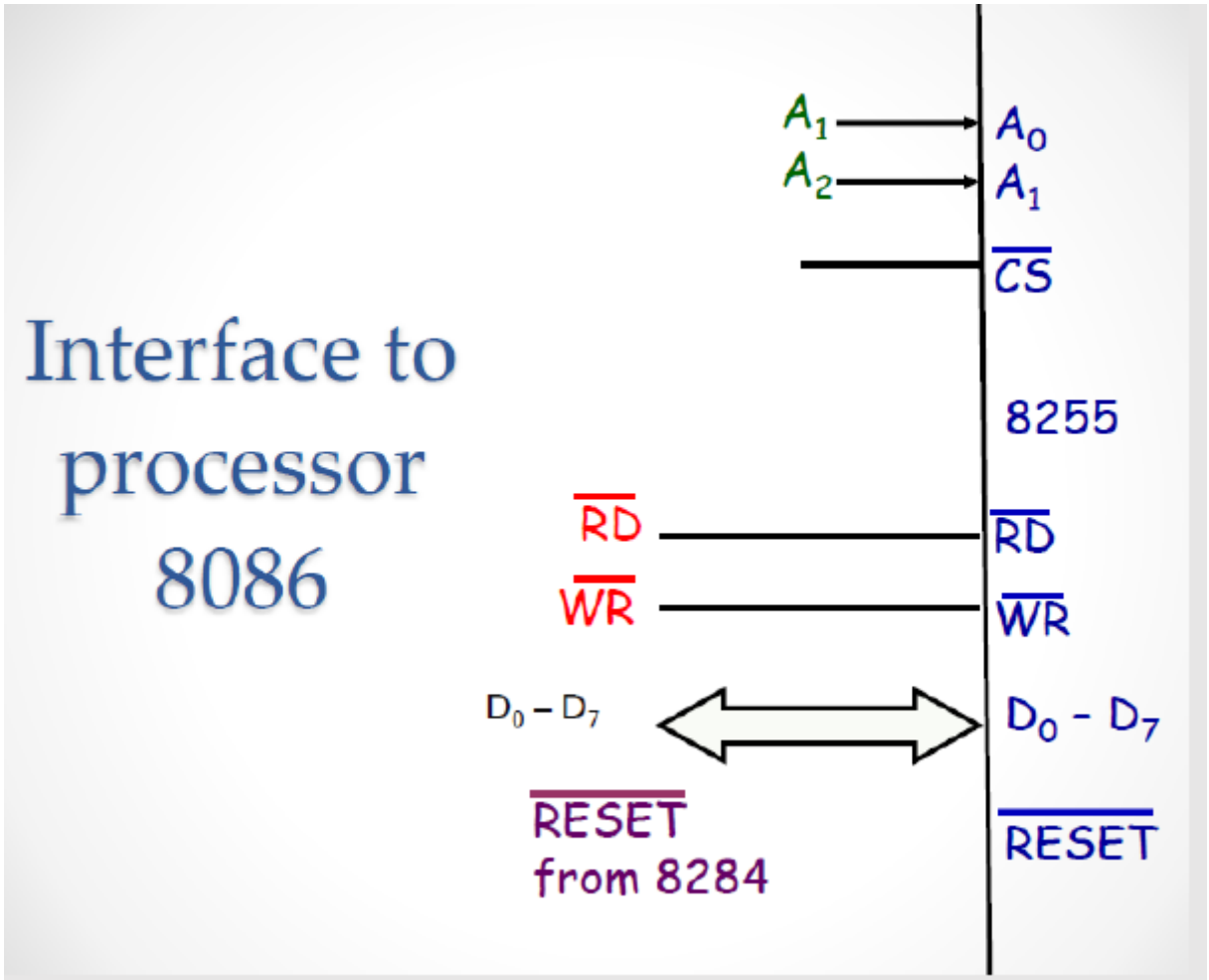

Inputs to 8086
5 V
VCC
MN/MX
2 M Hz
8284
RESET
CLK
READY
NMI
HOLD
GND

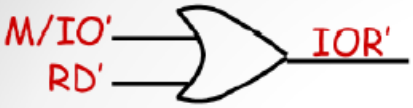
System Bus of 8086 (address)

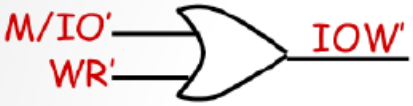



System Bus of 8086 (data+control)
RD
WR
IO/M
LS244
OE'
LOGIC CIRCUIT
MEMR
MEMW
IOR
IOW
8086
AD8-AD15
LS245
DIR
OE'
D8-D15
DT/R'
DEN'
AD0-AD7
LS245
DIR
OE'
D0-D7
MN/MX'
5V

Interface to processor 8086







M/IO'	RD'	WR'	Bus cycle
1	0	1	MEMR'
1	1	0	MEMW'
0	0	1	IOR'
0	1	0	IOW'

CODE

```
.model tiny

.data

elevator_position db 00h          ;00h,01h,02h,03h

travel_direction db 00h ;00(stop),01,10h

destination db 00h        ;0fh(rest),00,01,02,03

new_destination db ?


destination_buffer db 8 dup (0fh)

buffer_up db 8 dup (0fh)

buffer_down db 8 dup (0fh)

destination_size dw 0

up_size dw 0

down_size dw 0

accel_stat db 00h


creg equ 06h

pa equ 00h

pb equ 02h

pc equ 04h


creg2 equ 16h

pa2 equ 10h

pb2 equ 12h

pc2 equ 14h


door_close db 0bbh
```

```
up_cat db 0e7h,0ebh,0edh

down_cat db 0bdh,0beh,0eeh

inlift_cat db 0d7h,0dbh,0ddh,0deh

sensor_cat db 7eh,7dh,7bh



.code
.startup
;initialization
in0:            mov al,88h
                out creg,al

                mov al,80h
                out creg2,al

                mov al,00h
                out pa,al

                mov al,00h
                out pc2,al
;avoid key lockout
x0:             mov al,00h
                out pc,al
x1:             in al, pc
                and al,0f0h
```

```
                    cmp al,0f0h
                    jnz x1

                    ;call delay_20ms
                    mov dx,4544d
w1:                 nop
                    dec dx
                    jnz w1

;key press check
                    mov al,00h
                    out pc,al
x2:                 in al,pc
                    and al,0f0h
                    cmp al,0f0h
                    jz x2

                    ;call delay_20ms
                    mov dx,4544d
jf9:                nop
                    dec dx
                    jnz jf9

                    mov al,00h
                    out pc,al
                    in al,pc
                    and al,0f0h
                    cmp al,0f0h
                    jz x2
```

```
;key press identification
                    ;column 1
                    mov al,0eh
                    mov bl,al
                    out pc,al
                    in al,pc
                    and al,0f0h
                    cmp al,0f0h
                    jnz x3

                    ;column 2
                    mov al,0dh
                    mov bl,al
                    out pc,al
                    in al,pc
                    and al,0f0h
                    cmp al,0f0h
                    jnz x3

                    ;column 3
                    mov al,0bh
                    mov bl,al
                    out pc,al
                    in al,pc
                    and al,0f0h
                    cmp al,0f0h
                    jnz x3
```

```
                    ;column 4
                    mov al,07h
                    mov bl,al
                    out pc,al
                    in al,pc
                    and al,0f0h
                    cmp al,0f0h
                    jz x2

;decode key
                    ;generate hex code
x3:                 or al,bl

                    ;up key pressed
                    mov cx,03h
                    mov di,00h
x4:                 cmp al,up_cat[di]
                    jz x11
                    inc di
                    loop x4

                    ;down key pressed
                    mov cx,03h
                    mov di,00h
x5:                 cmp al,down_cat[di]
                    jz x12
                    inc di
                    loop x5
```

```
                    ;inlift key pressed
                    mov cx,04h
                    mov di,00h
x6:                 cmp al,inlift_cat[di]
                    jz x13
                    inc di
                    loop x6

                    ;sensor key pressed
                    mov cx,03h
                    mov di,00h
x7:                 cmp al,sensor_cat[di]
                    jz x14
                    inc di
                    loop x7

                    jmp x15

;operate according to the key type pressed
;up key press operations
x11:                mov dl,travel_direction
                    cmp dl,00h
                    jnz up6

                    ;if not moving
                    mov ax,di
                    cmp al,elevator_position
                    jz up4
                    mov destination,al
```

```
                mov cl,4
                rol al,cl
                mov bl,elevator_position
                or al,bl
                out pa,al
                ;set traveling direction
                mov al,destination
                cmp al,elevator_position
                jle up3
                mov travel_direction,01h        ;move elv up
                mov al,01h
                out pc2,al
                jmp up5
up3:            mov travel_direction,10h        ;move elv down
                mov al,02h
                out pc2,al
                jmp up5
up4:            mov al,04h      ;elv at pos, just open door
                out pc2,al
                jmp up5

                ;if moving
up6:            mov ax,di
                mov di,00
                cmp up_size,00h
                jz igr1
                mov cx,up_size
up1:            cmp al,buffer_up[di]
                jz up5
```

```
                    inc di
                    loop up1
igr1:               mov buffer_up[di],al
                    inc up_size

up5:                jmp x16

;down key press operations
                    ;if not moving

x12:                inc di
                    mov dl,travel_direction
                    cmp dl,00h
                    jnz dwn6

                    ;if not moving
                    mov ax,di
                    cmp al,elevator_position
                    jz dwn4
                    mov destination,al
                    mov cl,4
                    rol al,cl
                    mov bl,elevator_position
                    or al,bl
                    out pa,al
                    ;set traveling direction
                    mov al,destination
                    cmp al,elevator_position
                    jle dwn3
```

```
                    mov travel_direction,01h        ;move elv up
                    mov al,01h
                    out pc2,al
                    jmp dwn5
dwn3:               mov travel_direction,10h        ;move elv down
                    mov al,02h
                    out pc2,al
                    jmp dwn5
dwn4:               mov al,04h      ;elv at pos, just open door
                    out pc2,al
                    jmp dwn5

                    ;if moving
dwn6:               mov ax,di
                    mov di,00
                    cmp down_size,00h
                    jz igr2
                    mov cx,down_size
dwn1:               cmp al,buffer_down[di]
                    jz dwn5
                    inc di
                    loop dwn1
igr2:               mov buffer_down[di],al
                    inc down_size

dwn5:               jmp x16

;inlift key press operations
x13:                cmp travel_direction,00h
```

```
                jz inl1

                ;if moving, check if floor requested is in queue
                ;ckeck in buffer_up
                mov ax,di
                mov di,00h
                cmp up_size,00h
                jz inl7
                mov cx,up_size
inl5:           cmp al,buffer_up[di]
                jz inl2
                inc di
                loop inl5
inl7:
                ;check in buffer_down
                mov di,00h
                cmp down_size,00h
                jz inl8
                mov cx,down_size
inl6:           cmp al,buffer_down[di]
                jz inl2
                inc di
                loop inl6
inl8:
                ;check destination
                cmp al,destination
                jz inl2

                ;check in destination_buffer
```

```
                    mov ax,di
                    mov di,00
                    cmp destination_size,00h
                    jz igr3
                    mov cx,destination_size
inl4:               cmp al,destination_buffer[di]
                    jz inl2
                    inc di
                    loop inl4
igr3:               mov destination_buffer[di],al
                    inc destination_size
                    jmp inl2

inl1:               mov ax,di
                    cmp al,elevator_position
                    jz inl2
                    cmp al,elevator_position
                    jg inl3
                    mov travel_direction,10h
                    mov destination,al
                    jmp inl2
inl3:               mov travel_direction,01h
                    mov destination,al
inl2:               jmp x16

;sensor key press operations
x14:                cmp di,00h
                    jnz co1
;coarse sensor 1 pressed
```

```
                    ;check travelling direction
                    cmp travel_direction,01h
                    jnz goDown

                    ;if travelling up
                    ;light coarse 1 led
                    mov al,01h
                    out pb2,al

                    ;check acceleration status
                    cmp accel_stat,00h
                    jnz co3

                    ;if not accelerating
                    ;close 20% generator
                    mov al,00h
                    out pc2,al
                    ;start 30% generator
                    ;mov al,01h
                    ;out pa2,al

                    ;wait
                    mov dx,56800d
jf8:                nop
                    dec dx
                    jnz jf8

                    ;start 40% generator
                    mov al,04h
```

```
                    out pa2,al

                    ;wait
                    mov dx,56800d
jf7:                nop
                    dec dx
                    jnz jf7

                    ;stop 40% generator
                    mov al,00h
                    out pa2,al

                    ;start 60% generator
                    mov al,10h
                    out pa2,al
                    mov accel_stat,01h

;if travelling down
;see if needs deceleration
goDown:             mov al,elevator_position
                    dec al
                    ;check with destination
                    cmp al,destination
                    jnz co4

                    ;deceleration required
co6:                ;light coarse 1 led
                    mov al,01h
                    out pb2,al
```

```
                ;start 40% generator
                mov al,08h
                out pa2,al

                ;wait
                mov dx,56800d
jf6:            nop
                dec dx
                jnz jf6

                ;start 30% generator
                ;mov al,02h
                ;out pa2,al

                ;wait
                mov dx,56800d
jf5:            nop
                dec dx
                jnz jf5

                ;stop 40% generator
                mov al,00h
                out pa2,al

                ;stop 30% generator
                ;mov al,00h
                ;out pa2,al
                ;start 20% generator
                mov al,02h
```

```
                    out pc2,al
                    mov accel_stat,00h
                    jmp co3

;check in destination_buffer
co4:                mov di,00h
                    cmp destination_size,00h
                    jz co5
                    mov cx,destination_size
co7:                cmp al,destination_buffer[di]
                    jz co6    ;if found go for deceleration
                    inc di
                    loop co7

;check in buffer_down
co5:                mov di,00h
                    cmp down_size,00h
                    jz co3
                    mov cx,down_size
co8:                cmp al,buffer_down[di]
                    jz co6    ;if found go for deceleration
                    inc di
                    loop co8

co3:                jmp x16

co1:                cmp di,01h
                    jnz co2
;fine sensor pressed
```

```
mov al,travel_direction
cmp al,01h
jnz sen1

;if moving up
;update display
inc elevator_position
mov al,elevator_position
mov bl,destination
mov cl,4
rol bl,cl
or al,bl
out pa,al

;see if it has to stop
mov al,elevator_position
cmp al,destination
jnz alt1

;stop
mov al,04h
out pc2,al

;update destination
mov al,elevator_position
mov new_destination,al

;look in destination_buffer
mov dl,new_destination
```

```
                    mov di,00h
                    cmp destination_size,00h
                    jz igr4
                    mov cx,destination_size
p2:                 cmp dl,destination_buffer[di]
                    jg p1
                    mov dl,destination_buffer[di]
                    mov si,di
p1:                 inc di
                    loop p2
igr4:               mov new_destination,dl

                    mov al,elevator_position
                    cmp new_destination,al
                    jz sen6  ;not found in destination_buffer

                    ;found in destination_buffer
                    ;remove from destination_buffer
                    mov di,si
                    mov cx,destination_size
                    dec cx
                    cmp cx,00h
                    jz ign5
p3:                 mov al,destination_buffer[di+1]
                    mov destination_buffer[di],al
                    inc di
                    cmp di,cx
                    jnz p3
ign5:               mov destination_buffer[di],0fh
```

```
                    dec destination_size
                    mov al,new_destination
                    mov destination,al
                    jmp sen2

                    ;not found in destination_buffer
                    ;look in buffer_up
sen6:               mov dl,new_destination
                    mov di,00h
                    cmp up_size,00h
                    jz igr5
                    mov cx,up_size
p5:                 cmp dl,buffer_up[di]
                    jg p4
                    mov dl,buffer_up[di]
                    mov si,di
p4:                 inc di
                    loop p5
igr5:               mov new_destination,dl

                    mov al,elevator_position
                    cmp new_destination,al
                    jz sen7  ;not found in buffer_up

                    ;found in buffer_up
                    ;remove from buffer_up
                    mov di,si
                    mov cx,up_size
                    dec cx
```

```
                cmp cx,00h
                jz ign6
p6:             mov al,buffer_up[di+1]
                mov buffer_up[di],al
                inc di
                cmp di,cx
                jnz p6
ign6:           mov buffer_up[di],0fh
                dec up_size
                mov al,new_destination
                mov destination,al
                jmp sen2

                ;not found in buffer_up
                ;look in buffer_down
sen7:           mov dl,new_destination
                mov di,00h
                cmp down_size,00h
                jz igr6
                mov cx,down_size
p8:             cmp dl,buffer_down[di]
                jg p7
                mov dl,buffer_down[di]
                mov si,di
p7:             inc di
                loop p8
igr6:           mov new_destination,dl

                mov al,elevator_position
```

```
                    cmp new_destination,al
                    jz sen8  ;not found in buffer_down

                    ;found in buffer_down
                    ;remove from buffer_down
                    mov di,si
                    mov cx,down_size
                    dec cx
                    cmp cx,00h
                    jz ign7
p9:                 mov al,buffer_down[di+1]
                    mov buffer_down[di],al
                    inc di
                    cmp di,cx
                    jnz p9
ign7:               mov buffer_down[di],0fh
                    dec down_size
                    mov al,new_destination
                    mov destination,al
                    jmp sen2

;no place up to go
sen8:               mov travel_direction,10h        ;go down now

                    ;look in destination_buffer
                    mov dl,new_destination
                    mov di,00h
                    cmp destination_size,00h
                    jz igr7
```

```
                mov cx,destination_size
q2:             cmp dl,destination_buffer[di]
                jl q1
                mov dl,destination_buffer[di]
                mov si,di
q1:             inc di
                loop q2
igr7:           mov new_destination,dl

                mov al,elevator_position
                cmp new_destination,al
                jz ben6 ;not found in destination_buffer

                ;found in destination_buffer
                ;remove from destination_buffer
                mov di,si
                mov cx,destination_size
                dec cx
                cmp cx,00h
                jz ign8
q3:             mov al,destination_buffer[di+1]
                mov destination_buffer[di],al
                inc di
                cmp di,cx
                jnz q3
ign8:           mov destination_buffer[di],0fh
                dec destination_size
                mov al,new_destination
                mov destination,al
```

```
                    jmp sen2

                    ;not found in destination_buffer
                    ;look in buffer_up
ben6:               mov dl,new_destination
                    mov di,00h
                    cmp up_size,00h
                    jz igr8
                    mov cx,up_size
q5:                 cmp dl,buffer_up[di]
                    jl q4
                    mov dl,buffer_up[di]
                    mov si,di
q4:                 inc di
                    loop q5
igr8:               mov new_destination,dl

                    mov al,elevator_position
                    cmp new_destination,al
                    jz ben7 ;not found in buffer_up

                    ;found in buffer_up
                    ;remove from buffer_up
                    mov di,si
                    mov cx,up_size
                    dec cx
                    cmp cx,00h
                    jz ign9
q6:                 mov al,buffer_up[di+1]
```

```
                mov buffer_up[di],al
                inc di
                cmp di,cx
                jnz q6
ign9:           mov buffer_up[di],0fh
                dec up_size
                mov al,new_destination
                mov destination,al
                jmp sen2

                ;not found in buffer_up
                ;look in buffer_down
ben7:           mov dl,new_destination
                mov di,00h
                cmp down_size,00h
                jz igr9
                mov cx,down_size
q8:             cmp dl,buffer_down[di]
                jl q7
                mov dl,buffer_down[di]
                mov si,di
q7:             inc di
                loop q8
igr9:           mov new_destination,dl

                mov al,elevator_position
                cmp al,new_destination
                jz ben8 ;not found in buffer_down
```

```
                    ;found in buffer_down
                    ;remove from buffer_down
                    mov di,si
                    mov cx,down_size
                    dec cx
                    cmp cx,00h
                    jz ign10
q9:                 mov al,buffer_down[di+1]
                    mov buffer_down[di],al
                    inc di
                    cmp di,cx
                    jnz q9
ign10:              mov buffer_down[di],0fh
                    dec down_size
                    mov al,new_destination
                    mov destination,al
                    jmp sen2

;nowhere to go, rest
ben8:               mov al,new_destination
                    mov destination,al
                    mov travel_direction,00h
                    jmp sen2

;look in buffs
;look in destination_buffer
alt1:               mov al,elevator_position
                    mov di,00h
                    cmp destination_size,00h
```

```
                    jz igr10
                    mov cx,destination_size
alt3:               cmp al,destination_buffer[di]
                    jz alt2
                    inc di
                    loop alt3
igr10:              jmp alt5

;found it? remove
alt2:               mov cx,destination_size
                    dec cx
                    cmp cx,00h
                    jz ign1
alt4:               mov al,destination_buffer[di+1]
                    mov destination_buffer[di],al
                    inc di
                    cmp di,cx
                    jnz alt4
ign1:               mov destination_buffer[di],0fh
                    dec destination_size
                    mov al,04h
                    out pc2,al
                    jmp sen2

;look in buffer_up
alt5:               mov al,elevator_position
                    mov di,00h
                    cmp up_size,00h
                    jz igr11
```

```
                    mov cx,up_size
alt7:               cmp al,buffer_up[di]
                    jz alt6
                    inc di
                    loop alt7
igr11:              jmp sen2

;found it? remove
alt6:               mov cx,up_size
                    dec cx
                    cmp cx,00h
                    jz ign2
alt8:               mov al,buffer_up[di+1]
                    mov buffer_up[di],al
                    inc di
                    cmp di,cx
                    jnz alt8
ign2:               mov buffer_up[di],0fh
                    dec up_size
                    mov al,04h
                    out pc2,al
                    jmp sen2



sen1:
                    ;if moving down
                    ;update display
                    dec elevator_position
```

```
                mov al,elevator_position
                mov bl,destination
                mov cl,4
                rol bl,cl
                or al,bl
                out pa,al

                ;see if it has to stop
                mov al,elevator_position
                cmp al,destination
                jnz act1

                ;stop
                mov al,04h
                out pc2,al

                ;update destination
                mov al,elevator_position
                mov new_destination,al

                ;look in destination_buffer
                mov dl,new_destination
                mov di,00h
                cmp destination_size,00h
                jz igr13
                mov cx,destination_size
m2:             cmp dl,destination_buffer[di]
                jl m1
                mov dl,destination_buffer[di]
```

```
                    mov si,di
m1:                 inc di
                    loop m2
igr13:              mov new_destination,dl

                    mov al,elevator_position
                    cmp new_destination,al
                    jz sen3  ;not found in destination_buffer

                    ;found in destination_buffer
                    ;remove from destination_buffer
                    mov di,si
                    mov cx,destination_size
                    dec cx
                    cmp cx,00h
                    jz ign11
m3:                 mov al,destination_buffer[di+1]
                    mov destination_buffer[di],al
                    inc di
                    cmp di,cx
                    jnz m3
ign11:              mov destination_buffer[di],0fh
                    dec destination_size
                    mov al,new_destination
                    mov destination,al
                    jmp sen2

                    ;not found in destination_buffer
                    ;look in buffer_up
```

```
sen3:       mov dl,new_destination
            mov di,00h
            cmp up_size,00h
            jz igr14
            mov cx,up_size
m5:         cmp dl,buffer_up[di]
            jl m4
            mov dl,buffer_up[di]
            mov si,di
m4:         inc di
            loop m5
igr14:      mov new_destination,dl

            mov al,elevator_position
            cmp new_destination,al
            jz sen4  ;not found in buffer_up

            ;found in buffer_up
            ;remove from buffer_up
            mov di,si
            mov cx,up_size
            dec cx
            cmp cx,00h
            jz ign12
m6:         mov al,buffer_up[di+1]
            mov buffer_up[di],al
            inc di
            cmp di,cx
            jnz m6
```

```
ign12:      mov buffer_up[di],0fh
            dec up_size
            mov al,new_destination
            mov destination,al
            jmp sen2

            ;not found in buffer_up
            ;look in buffer_down
sen4:       mov dl,new_destination
            mov di,00h
            cmp down_size,00h
            jz igr15
            mov cx,down_size
m8:         cmp dl,buffer_down[di]
            jl m7
            mov dl,buffer_down[di]
            mov si,di
m7:         inc di
            loop m8
igr15:      mov new_destination,dl

            mov al,elevator_position
            cmp new_destination,al
            jz sen5  ;not found in buffer_down

            ;found in buffer_down
            ;remove from buffer_down
            mov di,si
            mov cx,down_size
```

```
                    dec cx
                    cmp cx,00h
                    jz ign13
m9:                 mov al,buffer_down[di+1]
                    mov buffer_down[di],al
                    inc di
                    cmp di,cx
                    jnz m9
ign13:              mov buffer_down[di],0fh
                    dec down_size
                    mov al,new_destination
                    mov destination,al
                    jmp sen2

;no place up to go
sen5:               mov travel_direction,10h        ;go down now

                    ;look in destination_buffer
                    mov dl,new_destination
                    mov di,00h
                    cmp destination_size,00h
                    jz igr16
                    mov cx,destination_size
n2:                 cmp dl,destination_buffer[di]
                    jg n1
                    mov dl,destination_buffer[di]
                    mov si,di
n1:                 inc di
                    loop n2
```

```
igr16:      mov new_destination,dl

            mov al,elevator_position
            cmp new_destination,al
            jz ben3 ;not found in destination_buffer

            ;found in destination_buffer
            ;remove from destination_buffer
            mov di,si
            mov cx,destination_size
            dec cx
            cmp cx,00h
            jz ign14
n3:         mov al,destination_buffer[di+1]
            mov destination_buffer[di],al
            inc di
            cmp di,cx
            jnz n3
ign14:      mov destination_buffer[di],0fh
            dec destination_size
            mov al,new_destination
            mov destination,al
            jmp sen2

            ;not found in destination_buffer
            ;look in buffer_up
ben3:       mov dl,new_destination
            mov di,00h
            cmp up_size,00h
```

```
                    jz igr17
                    mov cx,up_size
n5:                 cmp dl,buffer_up[di]
                    jg n4
                    mov dl,buffer_up[di]
                    mov si,di
n4:                 inc di
                    loop n5
igr17:              mov new_destination,dl

                    mov al,elevator_position
                    cmp new_destination,al
                    jz ben4 ;not found in buffer_up

                    ;found in buffer_up
                    ;remove from buffer_up
                    mov di,si
                    mov cx,up_size
                    dec cx
                    cmp cx,00h
                    jz ign15
n6:                 mov al,buffer_up[di+1]
                    mov buffer_up[di],al
                    inc di
                    cmp di,cx
                    jnz n6
ign15:              mov buffer_up[di],0fh
                    dec up_size
                    mov al,new_destination
```

```
                    mov destination,al
                    jmp sen2

                    ;not found in buffer_up
                    ;look in buffer_down
ben4:               mov dl,new_destination
                    mov di,00h
                    cmp down_size,00h
                    jz igr18
                    mov cx,down_size
n8:                 cmp dl,buffer_down[di]
                    jg n7
                    mov dl,buffer_down[di]
                    mov si,di
n7:                 inc di
                    loop n8
igr18:              mov new_destination,dl

                    mov al,elevator_position
                    cmp new_destination,al
                    jz ben5 ;not found in buffer_down

                    ;found in buffer_down
                    ;remove from buffer_down
                    mov di,si
                    mov cx,down_size
                    dec cx
                    cmp cx,00h
                    jz ign16
```

```
n9:             mov al,buffer_down[di+1]
                mov buffer_down[di],al
                inc di
                cmp di,cx
                jnz n9
ign16:          mov buffer_down[di],0fh
                dec down_size
                mov al,new_destination
                mov destination,al
                jmp sen2

;nowhere to go, rest
ben5:           mov al,new_destination
                mov destination,al
                mov travel_direction,00h
                jmp sen2

;look in buffs
;look in destination_buffer
act1:           mov al,elevator_position
                mov di,00h
                cmp destination_size,00h
                jz igr19
                mov cx,destination_size
act3:           cmp al,destination_buffer[di]
                jz act2
                inc di
                loop act3
igr19:          jmp act5
```

```
;found it? remove
act2:           mov cx,destination_size
                dec cx
                cmp cx,00h
                jz ign3
act4:           mov al,destination_buffer[di+1]
                mov destination_buffer[di],al
                inc di
                cmp di,cx
                jnz act4
ign3:           mov destination_buffer[di],0fh
                dec destination_size
                mov al,04h
                out pc2,al
                jmp sen2

;look in buffer_down
act5:           mov al,elevator_position
                mov di,00h
                cmp down_size,00h
                jz igr21
                mov cx,down_size
act8:           cmp al,buffer_down[di]
                jz act6
                inc di
                loop act8
igr21:          jmp sen2
```

```
;found it? remove
act6:           mov cx,down_size
                dec cx
                cmp cx,00h
                jz ign4
act7:           mov al,buffer_down[di+1]
                mov buffer_down[di],al
                inc di
                cmp di,cx
                jnz act7
ign4:           mov buffer_down[di],0fh
                dec down_size
                mov al,04h
                out pc2,al


sen2:           jmp x16

;coarse sensor 2 pressed
;check for travelling direction
co2:            cmp travel_direction,10h
                jnz goUp
                ;if travelling down
                ;light coarse 2 led
                mov al,02h
                out pb2,al

                ;check acceleration status
                cmp accel_stat,00h
```

```
                jnz cos3

                ;if not accelerating
                ;stop 20% generator
                mov al,00h
                out pc2,al
                ;start 30% generator
                ;mov al,02h
                ;out pa2,al

                ;wait
                mov dx,56800d
jf1:            nop
                dec dx
                jnz jf1

                ;start 40% generator
                mov al,08h
                out pa2,al

                ;wait
                mov dx,56800d
jf2:            nop
                dec dx
                jnz jf2

                ;stop 40% generator
                mov al,00h
                out pa2,al
```

```
                    ;start 60% generator
                    mov al,20h
                    out pa2,al
                    ;update acceleration status
                    mov accel_stat,01h
                    jmp cos3

;if travelling up
goUp:               mov al,elevator_position
                    inc al
                    ;check with destination
                    cmp al,destination
                    jnz cos4

                    ;deceleration required
cos6:               ;light coarse 2 led
                    mov al,02h
                    out pb2,al
                    ;start 40% generator
                    mov al,04h
                    out pa2,al

                    ;wait
                    mov dx,56800d
jf3:                nop
                    dec dx
                    jnz jf3
```

```
                    ;start 30% generator
                    ;mov al,01h
                    ;out pa2,al

                    ;wait
                    mov dx,56800d
jf4:                nop
                    dec dx
                    jnz jf4

                    ;stop 30% generator
                    ;mov al,00h
                    ;out pa2,al

                    ;stop 40% generator
                    mov al,00h
                    out pa2,al

                    ;start 20% generator
                    mov al,01h
                    out pc2,al
                    mov accel_stat,00h
                    jmp cos3

;check in destination_buffer
cos4:               mov di,00h
                    cmp destination_size,00h
                    jz cos5
                    mov cx,destination_size
```

```
cos7:           cmp al,destination_buffer[di]
                jz cos6  ;if found go for deceleration
                inc di
                loop cos7

;check in buffer_up
cos5:           mov di,00h
                cmp up_size,00h
                jz cos3
                mov cx,up_size
cos8:           cmp al,buffer_up[di]
                jz cos6  ;if found go for deceleration
                inc di
                loop cos8

cos3:           jmp x16

;door close key press operations
x15:
                cmp travel_direction,00h
                jz dor1

                cmp travel_direction,01h
                jz dor3

                mov al,destination
                mov cl,4
                rol al,cl
                mov bl,elevator_position
```

```
                or al,bl
                out pa,al
                mov al,02h
                out pc2,al
                jmp x16

dor3:           mov al,destination
                mov cl,4
                rol al,cl
                mov bl,elevator_position
                or al,bl
                out pa,al
                mov al,01h
                out pc2,al
                jmp x16

dor1:           mov destination,00h
                mov elevator_position,00h
                mov travel_direction,00h
                jmp in0
                ;mov al,elevator_position
                ;cmp al,destination
                ;jz dor2
                ;mov al,02h
                ;out pc2,al
                ;mov al,00h
                ;mov cl,4
                ;rol al,cl
                ;mov bl,elevator_position
```

```
                    ;or al,bl
                    ;out pa,al
                    ;jmp x16
dor2:               mov al,04h
                    out pc2,al


x16:                jmp x0

.exit
End
```

DESIGN