Microprocessors and Interfacing
DESIGN ASSIGNMENT

DIGITAL SCANNER

Hardik Shah (2019A7PS0076G)

Table of Contents:

Problem Statement:

Scanner

Design a microprocessor based scanner which will scan a black and white image and store it as binary data. The scanner has two stepper motors for motion along two orthogonal coordinates. The rotational motion is converted into transnational motion through a lead-screw mechanism.

Five paired LED photodiodes intended for B&W image scanning are placed 0.1 centimeter apart. The maximum size scannable is 10cm X 10cm.

The photodiode output is analog signal (between 0 to 5 Volts) which is to be digitized.
Image information is stored sequentially in the RAM.
The user presses a switch labelled Start Scan when he wants the scanning process to be started. Once scanning is completed an LED labelled Scan Complete will glow.

User Requirements and Technical Specifications:

The design requires the user to scan an image and store the image information(one bit per pixel scanned) into the RAM. Also, the user must be able to control the start of the scan using a “Start Scan” switch and the end of the scan is marked by the glowing of “Scan Complete” LED.

The technical specifications are mentioned below:

1. The image to be scanned has a maximum size of 10cm x 10cm.
2. There is a gap of 0.1cm between two photodiodes. The photodiodes (FDS010) used in the design have a packaging diameter of 0.9 cm (standard TO-5 packaging) and an active area of diameter 1 mm. So, there is a gap of 1cm between the centres of two adjacent photodiodes.
3. The photodiodes chosen are meant for detecting light in the visible range.
4. Each pixel scanned by a photodiode-LED pair has dimensions of 1.25mm x 1.25mm.
5. The lead screw which converts rotational motion of the stepper motor to translation has a lead of 1mm i.e. in one complete revolution(360^o) of the stepper motor there is a forward motion of 1mm.
6. The stepper motor(NEMA17) has a step angle of 1.8^o i.e. 200 steps per revolution.
7. A delay of 1ms must be ensured between each step of the stepper motor so that the motor rotates at 300 rpm. This is done using the timer.

Assumptions and Justifications:

Justifications:

1. The active area of photodiode .i.e the radiant sensitive area is a circular region of diameter 1mm. This area is enough to scan a 1.25mm X 1.25mm pixel, since there will be some light incident at the active area from different angles.

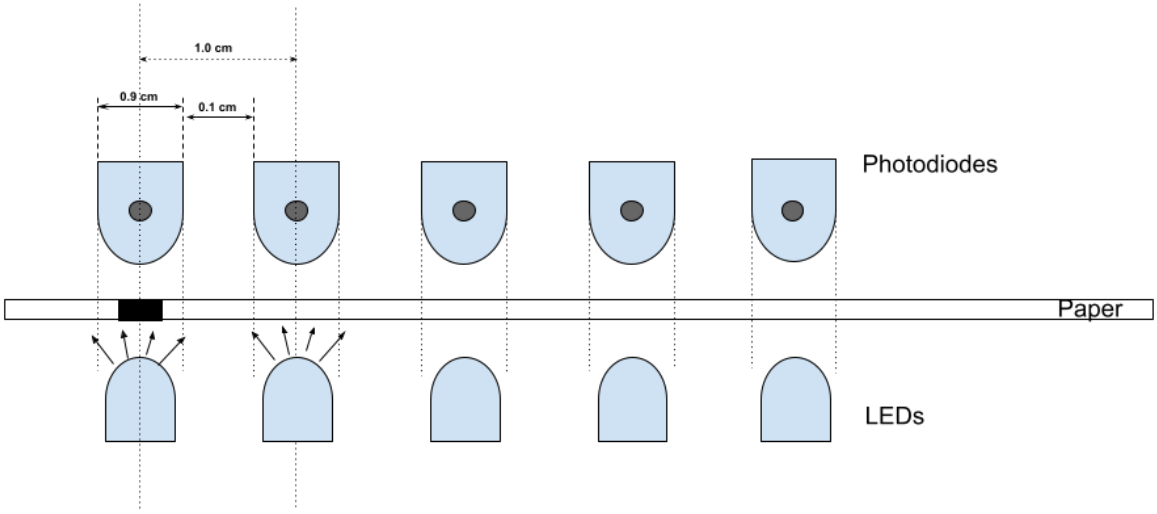
2. If the size of the image is less than 10cm x 10cm, the extra region will be stored as white pixels in the RAM i.e. the design always stores data for a 10cm X 10cm image irrespective of the actual size, since there is no way for the microprocessor to know the actual size of the image.

Assumptions:

1. During the physical implementation of the design, the mechanical setup is such that the force on the axle of the stepper motors allows them to rotate at 300 rpm i.e. the torque of the stepper motor is enough to rotate the axle.
2. The LEDs must be surrounded by black cylinders so that it does not affect the readings of the adjacent photodiode.

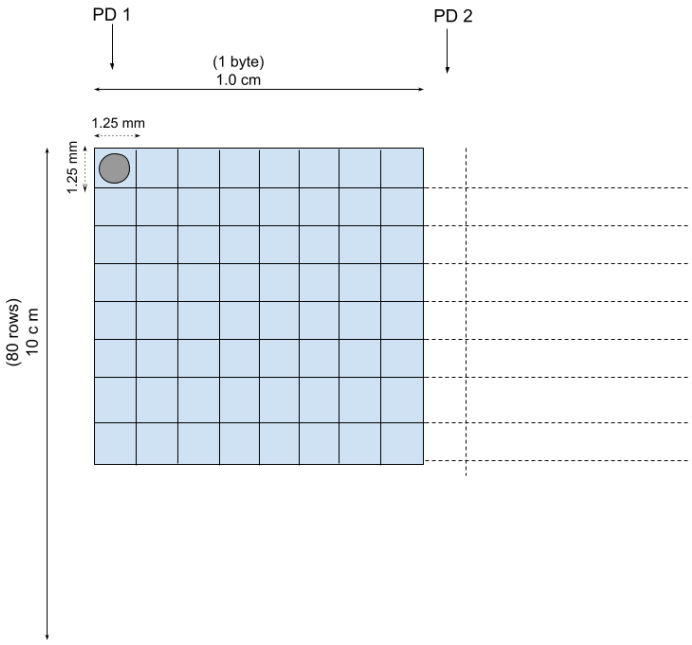
Interpretation and Approach:

The photodiode-LED pair will be used for detecting whether a pixel is black or white. Photodiodes are placed at the top of the paper and LEDs at the bottom.

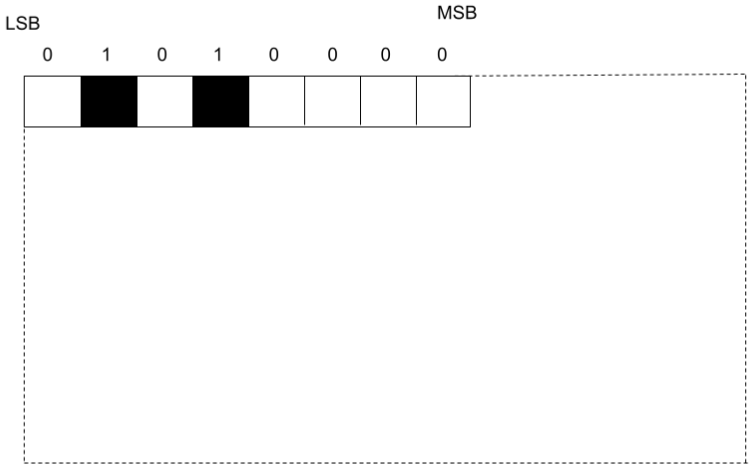


The grey circle denotes the radiant sensitive area of the photodiode. If the pixel being scanned by a photodiode-LED pair is black(1st photodiode), light from the LED won't fall on the active area of the photodiode and the output voltage of the photodiode will be very low. If the pixel being scanned is white(2nd photodiode) light will fall on the active area and the output voltage will be high.

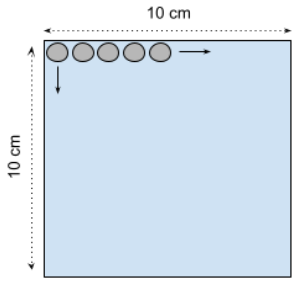
The gap between two photodiodes is 1 cm, hence each photodiode is responsible for scanning 1 cm. For ease of storage and also accurate classification of image data into black and white, the pixel size is chosen to be 1.25 mm x 1.25 mm. Each 1cm to be scanned by a photodiode is divided into 8 parts each of length 1.25 mm.



Each pixel will be stored as a bit in the RAM sequentially. Hence, each photodiode-LED pair will be scanning a byte. Consider the top-left corner of the page. In the figure below, there are two black pixels among the 8 scanned by a photodiode-LED pair. The data is stored as 05h in a memory location in the RAM.



The scanning starts from the top-left corner of the image. The photodiode-LED pairs scan the image row-wise, and once the entire row is scanned, they move to the next row.



Components used:

Name of the component	Number of the component used	Purpose
INTEL 8086	1	The main processor of the design. All signals to devices are controlled by the 8086.
8284	1	It generates clock signals for 8086 and peripheral devices(here 8254 which generates the clock for ADC0808)
Photodiode (FDS010)	5	It is used to detect the light from the LED.It is connected with an operational amplifier. It gives an output voltage from 0 to 5V. If it receives light it outputs a higher value of voltage close to 5V and if it does not receive light it outputs a lower value of voltage close to 0V.
Operational amplifier (LM 324)	2	LM 324 consists of quad operational amplifiers. They are used in order to ensure that the output voltage from the photodiode is between 0 to 5V, and the voltage drop across the photodiode does not affect the Vout.
LED	6	The light from the LED is detected by the photodiode if the pixel being scanned is white. If not, then light from the LED does not pass through the paper. 5 LEDs are used for this purpose. One LED is labelled the "Scan Complete" LED and it glows when the scanning is complete.
Switch	1	The switch is for the user to press when the scanning needs to start.
Unipolar Stepper Motor (NEMA 17)	2	The two stepper motors are used for the movement of the photodiodes across the paper to be scanned. One is used for horizontal movement and another is used for vertical movement.
Lead Screw	2	Two lead screws are used as the axes for the linear movement of the stepper motors across the page. The pitch/lead of the lead screw is 1mm, i.e. in one complete rotation, the screw travels a linear distance of 1mm.
ULN2003A	2	This is a stepper motor driver which amplifies the current from 8255 enough to drive the motors. It consists of 7 darlington pairs. One chip is for driving the horizontal motor and the other is for driving the vertical stepper motor.
ADC0808	1	It is used for conversion of analog value to digital value. It has 5 analog inputs with voltage varying from 0 to 5V connected to it. The 5 photodiodes are connected to it.

8255	2	The 8255 is used to interface the various input output devices in the design to the microprocessor. It connects the ADC and "Start Scan" switch to 8086 as inputs and the stepper motors and "Scan Complete" LED as output.
8254	1	It is used to generate the 1 MHz clock for the ADC0808 and also the timing signal of 1ms for the stepper motor.
2716 ROM	4	One ROM consisting of 2 nos. 2716(even and odd bank) is at the starting address 00000H for the IVT(Interrupt Vector Table) and the other also consisting of 2 nos.2716(even and odd bank) is at the end starting from address FF000H so that the reset address of 8086 i.e. FFFF0H is in the ROM.
6116 RAM	2	The 4K RAM(2K even and 2K odd) i.e. 4096 bytes is used for storing the digitized image information(amounts to 800 bytes) and also for temporary storage of data and stack operations.
LS138 3:8 Decoder	2	Used for I/O and memory mapping of the I/O devices and ROM and RAM respectively to 8086
LS373	3	Used for the system bus of 8086(address bus)
LS244 and LS245	1,2	Used for the system bus of 8086(control signals and data bus)

Address Map:

Memory Map:

**Address lines A14-A12 are used to decide the memory*

A19	A18	A17	A16		A15	A14	A13	A12		A11	A10	A9	A8		A7	A6	A5	A4		A3	A2	A1	A0	Address	Memory
0	0	0	0		0	0	0	0		0	0	0	0		0	0	0	0		0	0	0	0	00000H	ROM1
0	0	0	0		0	0	0	0		1	1	1	1		1	1	1	1		1	1	1	1	00FFFH	
0	0	0	0		0	0	0	1		0	0	0	0		0	0	0	0		0	0	0	0	01000H	RAM1
0	0	0	0		0	0	0	1		1	1	1	1		1	1	1	1		1	1	1	1	01FFFH	
1	1	1	1		1	1	1	1		0	0	0	0		0	0	0	0		0	0	0	0	FF000H	ROM2
1	1	1	1		1	1	1	1		1	1	1	1		1	1	1	1		1	1	1	1	FFFFFH	

I/O Map:

**Address lines A5-A3 are used to decide the peripheral device*

A7	A6	A5	A4		A3	A2	A1	A0	Address	Device
0	0	0	0		0	0	0	0	00H	8255(1)
0	0	0	0		0	1	1	0	06H	
0	0	0	0		1	0	0	0	08H	8255(2)
0	0	0	0		1	1	1	0	0EH	
0	0	0	1		0	0	0	0	10H	8254
0	0	0	1		0	1	1	0	16H	
0	0	0	1		1	0	0	0	18H	8259
0	0	0	1		1	0	1	0	1AH	

8255(1) Ports:

PORT in 8255(1)	Address to the access port	Purpose of the port
PORTA	00h	Data lines of the ADC0808 (D0-D7)
PORTB	02h	-
PORTC	04h	ADC Control signals (ALE, SOC, OE and AD0-AD2)
Control Register	06h	Initialize 8255(1) ports

8255(2) Ports:

PORT in 8255(2)	Address to the access port	Purpose of the port
PORTA	08h	Control signals for the horizontal stepper motor
PORTB	0Ah	Control signals for the vertical stepper motor
PORTC	0Ch	Output(lower portC) - GATE1 to 8254 Output(upper portC) to *Scan Complete* LED
Control Register	0Eh	Initialize 8255(2) ports

8254:

The 8254 is used for two purposes:

1. Generating the clock for ADC0808(Max clock frequency of 1.048 MHz) at 1 MHz. This is done by operating the Counter0 in Mode 3 and loading the count value as 5.
2. Generating an accurate timing of 1ms between two step sequences of the stepper motor so as to rotate the stepper motor at 300 rpm. To do so, we will use Counter1 in mode2 and control the GATE signal of 8254 using 8255. The OUT signal is connected to 8259 and the moment it goes high, an interrupt will be raised by the processor.
   The count value loaded will be 5000d.

   Calculations:
   Step angle of stepper motor = 1.8^{o}.
   Steps per revolution = 200
   Speed = 300 rpm
   Time taken for 1 revolution = 60/300 = 0.2s
   Time taken for 1 step = 0.2/200 = 1ms

8259:

The 8259 is used for handling three interrupts.

IR0:
Interrupt from the *Start Scan* switch. Once pressed the scanning will start, else 8086 waits for this interrupt. Hence, highest priority given to it.
(in the ISR of this interrupt we mask IR0 so that if the user presses the switch in between the scan, the scanning is not interrupted)

IR1:
Interrupt from the OUT1 signal of 8254. Since we want to read data from the photodiodes only after movement of the stepper motor, this is given a higher priority.

IR2:
Interrupt from EOC signal of ADC0808. The ISR of this interrupt enables OE and reads data from D0-D7 of the ADC0808.

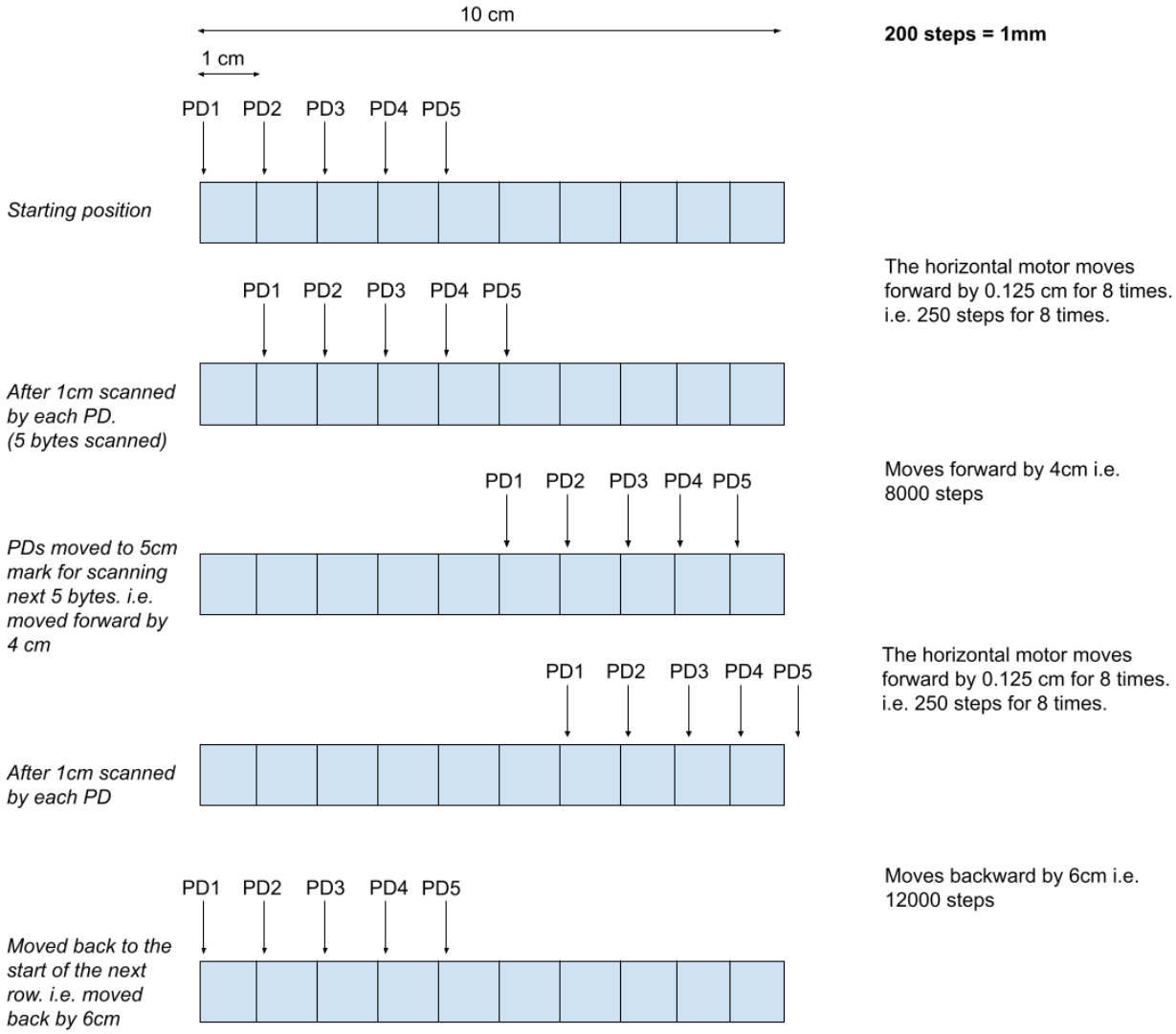
Complete Design:

The scanning process begins only when an interrupt is raised from the *Start Scan* switch. In the ISR for that we mask the IR0 of 8259, so that if the user presses the switch in between the scan 8086 is not interrupted.
The scanning starts from the top left corner of the image. The image is scanned row-wise from the top to bottom.

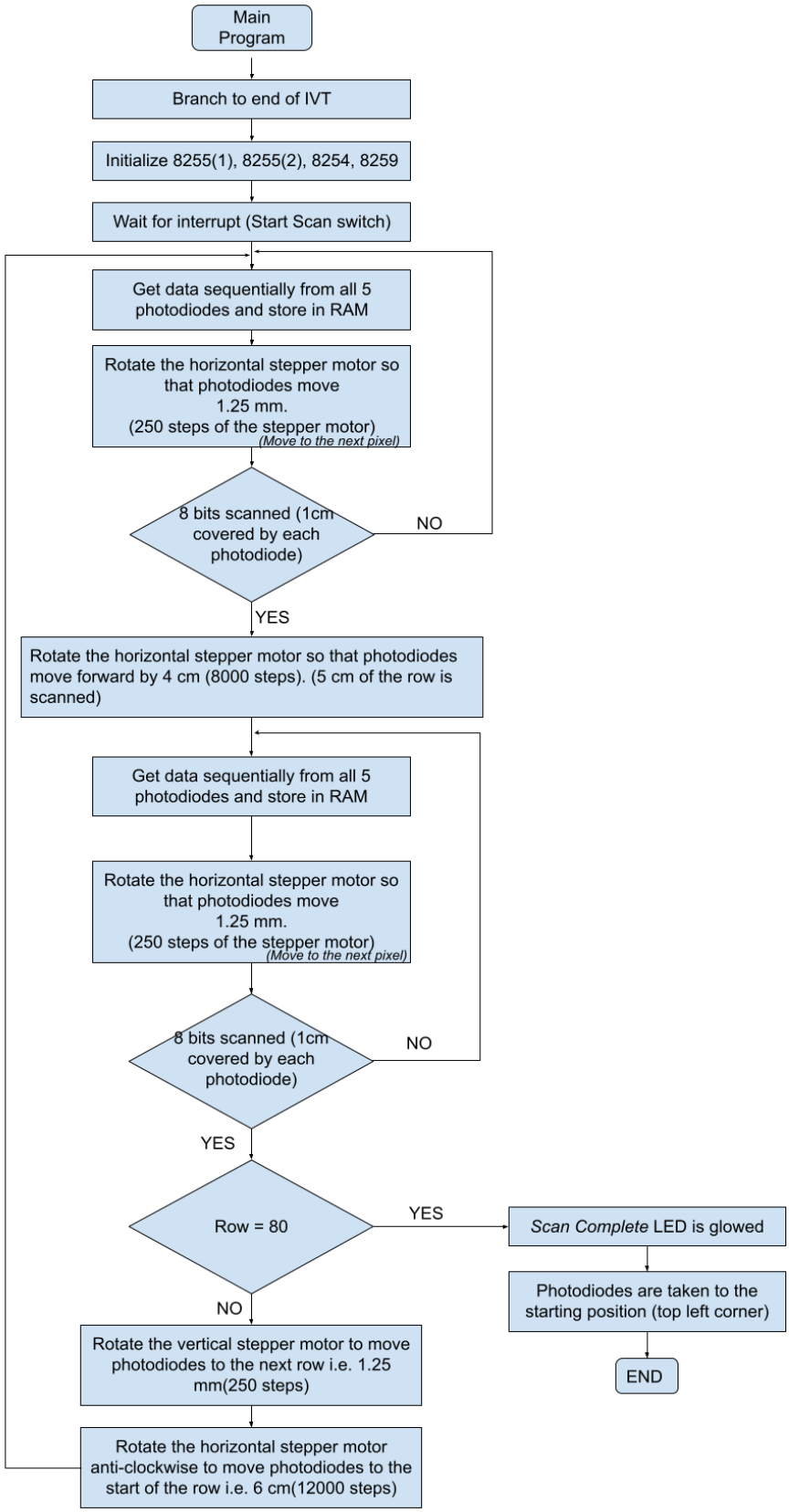
Next, we need to scan 10 bytes per row and there are a total of 10cm/0.125cm = 80 rows. We scan 5 pixels at a time, move to the next pixel.

Each photodiode scans 1cm of length and hence 5cm has been scanned. For scanning the remaining 5cm, the photodiodes are moved by 4cm(so that the first photodiode is at 5cm from start of the row.
Again, 5 pixels are scanned at a time and photodiodes are moved to the next pixel. Once, each photodiode has scanned the 8 pixels, we have scanned the entire row.

If the current row is the last one, we end the scanning and the *Scan Complete* LED is lit, and the photodiodes are taken to the starting position i.e. the top left corner of the image.
If it is not the last row, the photodiodes are moved to the next row using the vertical stepper motor and also brought back to the starting of the row so that data is stored sequentially in the RAM.

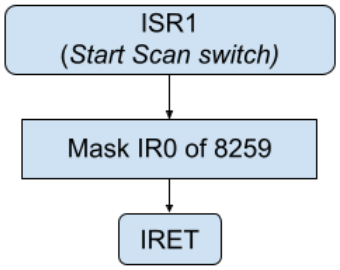


Flowchart of Main Program:



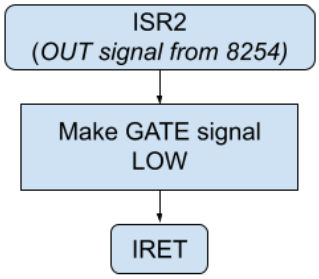
Flowchart of ISR1:

The IR0 of 8259 is masked in this ISR to ensure that if the user presses the switch in the middle of the scan, the scanning process is not interrupted.

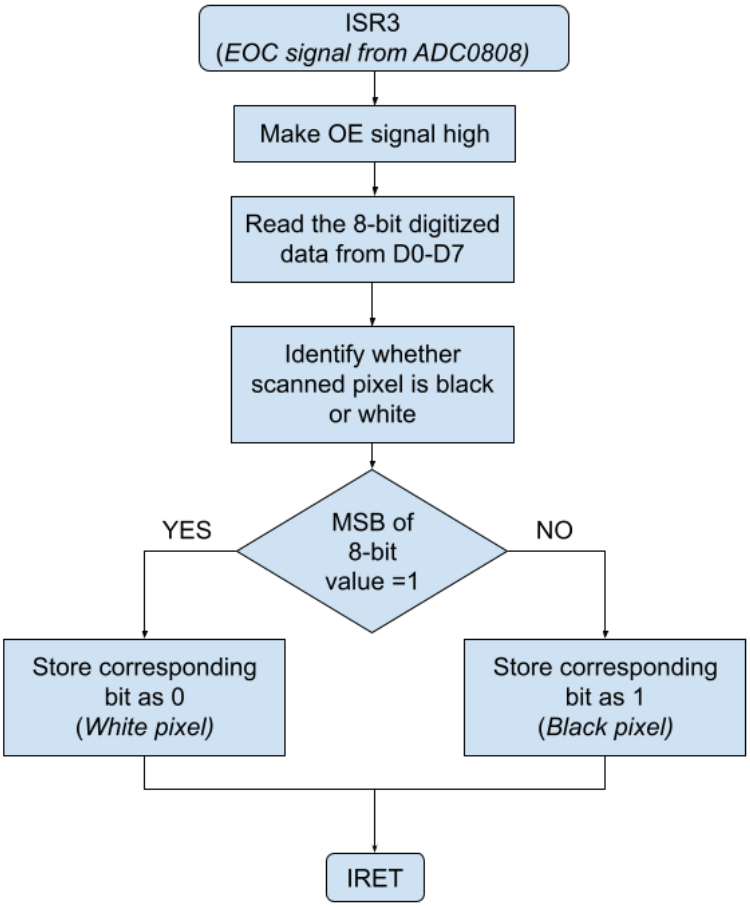


Flowchart of ISR2:

The GATE1 signal is made low in order to stop counting of the Counter1 in 8254.



Flowchart of ISR3:



Variations in Proteus Implementation with Justification:

1. Using 1 ms software delay as 8259 does not work in proteus – EOC from the ADC0808 is used as NMI and the Timer Int replaced by software delay as 1ms. The *Start Scan* switch is connected to 8255 and is detected using polling.
2. ROM only at 00000 – as proteus allows to change reset address.
3. Using 8253 – because 8254 is not available in Proteus.
4. Clock is at 2 MHz as the clock generated for 8086 requires a long rise and fall time of clock. So the ADC clock will be only 500KHz , which works because 1 MHz is the max clock that can be provided.
5. 2732 is used as 2716 – not available in Proteus.
6. Using a gate-based circuit for memory – does the same as LS 138 here
7. Photodiode is replaced by Torch LDRs in proteus.
8. 8259 is not present – justification is as per point 1.

Firmware:

Implemented using emu8086 attached.

List of Attachments:

1. Complete hardware design - Hardware Design and Pinouts-Batch 54.pdf
2. Source Code(exactly according to on-paper design) - scanner_code.asm
3. Proteus file - scanner.dsn
4. EMU8086 ASM File(considering proteus limitations) - scanner_emu.asm
5. Binary file after assembly - scanner_emu.bin
6. Attached manuals:
    a. ADC0808 (analog to digital converter)
    b. FDS010 (Si Photodiode)
    c. NEMA17 stepper motor
    d. ULN2003A (7 darlington pairs)
    e. LM 324 (Quad Operational Amplifiers)
    f. AlInGaP LED