Microprocessors and Interfacing Design Assignment - Digital Scanner

Batch no. 34, Question no. 5
By

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1 Introduction

1.1 Problem Statement

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 black and white 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.

1.2 User Specification

The user is required to scan an image and save the image information , into the RAM in form of bits, where one bit represents one pixel. The "Start Scan" switch can be used to turn on all the LED's and to start the scan. When the scanner reads all the pixels, the "Scan Complete" LED lights up to indicate that the scan is complete. The maximum size of the image to be scanned is 10cm x 10cm. The photodiodes used in the design have a diameter of 0.9cm and an active area of 1mm in diameter, with a gap of 1cm between the centers of two adjacent photodiodes. The photodiodes are designed to detect visible light. Each pixel scanned by a photodiode-LED pair has dimensions of 0.1 cm x 0.1 cm. The stepper motor used has a step angle of 1.8 degrees, meaning there are 200 steps per revolution. To ensure the motor rotates at 300 rpm, a delay of 1ms must be maintained between each step of the stepper motor, which is done using a timer. The lead screw, which translates the rotational motion of the stepper motor, has a lead of 1mm, meaning there is 1mm forward motion per complete revolution of the stepper motor.

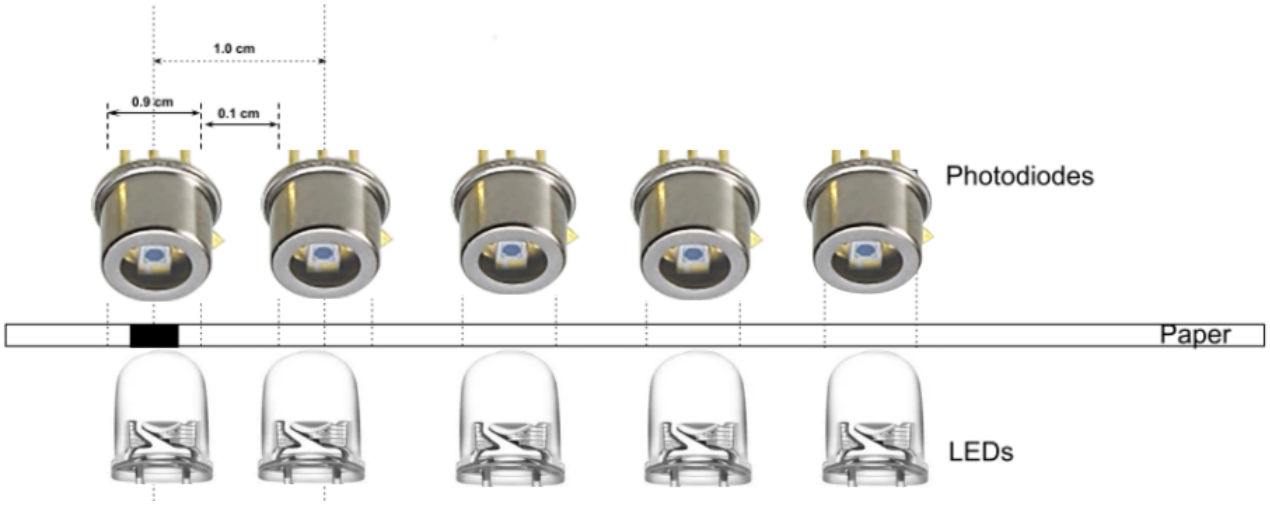
1.3 Assumptions

a) There is no power failure while the system is operating
b) The mechanical setup of the design during physical implementation is such that the stepper motor's axle can rotate at 300 rpm, indicating that the stepper motor's torque is sufficient to rotate the axle.
c) To prevent the LEDs from affecting adjacent photodiode readings, they must be surrounded by black cylinders.

1.4 Justifications

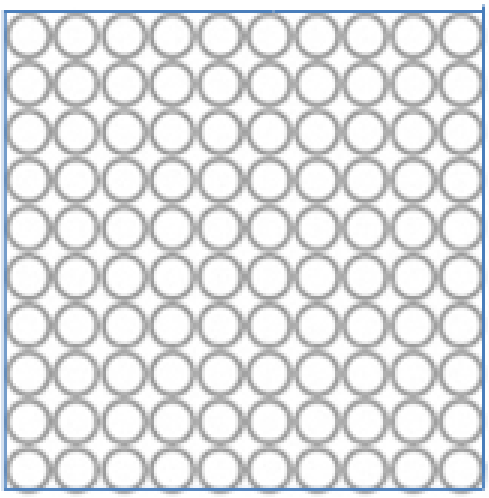
a) The radiant sensitive area or active region of the photodiode is circular with a 1mm diameter, which is sufficient to scan a 1mm X 1mm pixel since the active area receives light from different angles.
b) If the image size is smaller than 10cm x 10cm, any additional area will be recorded as white pixels in the RAM. This is because the design always saves data for a 10cm X 10cm image, regardless of the actual size, as the microprocessor cannot determine the actual image size.

2 Working



To scan the image present on the paper, the photodiodes can be places above and a LED can be placed below corresponding to each photodiode. If the pixel being scanned by a photodiode. Light from the LED won't fall on the active area of the photodiode if the pixel is black as light wont pass through the paper, and the output voltage of the photodiode will be very low. Light will fall on the active area If the pixel being scanned is white as light will pass through the paper, and the output voltage will be high. The pixel is of size 0.1cmX0.1cm, so each 1cm to be scanned by a photodiode is divided into 10 parts each of length 1 mm. Each pixel will be stored as a bit in the RAM sequentially. Hence, each photodiode-LED pair will be scanning a byte.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.

The scanning starts from the top left corner of the image. The image is scanned row-wise from the top to bottom. In ram, we can store 8 bits of data in one location,so we have to move the photodides and LEDs such that we are taking 8 bits at a time. Data is initially collected from the first five photo diodes after which we can shift the photodides and LEDs horizontally by 0.3 cm.The upper 3 bits are read after the shift and they are appended to the previous five bits so store 8 Bits in RAM. The photodides and LEDs are then horizontally shifted by 0.5 cm and the cycle continues until 96bits(12 bytes) are read. After reading 12 bytes, the photodides and LEDs has to move horizontally by 0.4cm , and the upper 4 bits are read.These 4 bits are paaded with zeros and are stored as a byte. After this step, the photodides and LEDs have to be shifted horizontally backwards by 9.5cm (to reach the starting position and) and shifted vertically downward by 0.1cm. This process continues till the setup(photodiode and LED) reaches the last row and completes reading all the data.At this point, the 6th LED has to be setup and the motors have to go back to their original position.



The LSB bit is the bit representing the pixel scanned by the leftmost diode.We obtain information of 13 bytes per row, hence the total number of bytes read are 1300(1.3KB).

3 Components Used

1. **8086 (1 Unit) :**
   The main processor of the design. All signals to devices are controlled by the 8086.

2. **8284 (1 Unit) :**
   It generates clock signals for 8086

3. **Photodiode - FDS010 (5 Unit) :**
   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.

4. **LED (6 Unit) :**
   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.

5. **Switch (1 Unit) :**
   The switch is for the user to press when the scanning needs to start.

6. **Unipolar Stepper Motor-NEMA 17 (2 Units) :**
   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.

7. **Lead Screw (2 Units) :**
   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.

8. **ULN2003A (2 Units) :**
   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.

9. **8255 (2 Units) :**
   Used to interface LM139 which connects the photodiodes, the motor drivers that connect the stepper motors, the 'start scan' switch and 'scan complete' LED.

10. **8254 (1 Unit) :**
    Used to generate a precise time of 1 millisecond (ms) between two step sequences on the stepper motor, which will cause it to spin at 300 revolutions per minute (rpm). To do this, Counter1 in mode 2 will be used, and 8255 will be used to regulate the GATE signal of 8254. The processor will issue an interrupt if the OUT signal, which is attached to 8259, reaches high.

Calculations :
Step angle of stepper motor = 1.8°
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
The loaded count value will be 5000d.

11. **8259 (1 Unit) :**
Used for handling 2 interrupts.

    (a) **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)

    (b) **IR1 :**
    Connected to the OUT1 signal of 8254 which is used to control the movement of the stepper motor. Data is read from the photodiodes once the movement of the stepper motor is complete and thus IR1 is assigned a higher priority than IR2

12. **LM 139 (2 Unit) :**
Used as a comparator. If voltage is lesser than 2.3V, then it gives out 0 as the voltage, if it is greater than 2.3V, then it gives 5 as the output voltage.

13. **2716 ROM (4 Units) :**
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.

14. **6116 RAM (2 Units) :**
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.

15. **LS138 3:8 Decoder (2 Units) :**
Used for I/O and memory mapping of the I/O devices and ROM and RAM respectively to 8086.

16. **LS373 (3 Units) :**
    Used for the system bus of 8086(address bus)

17. **LS244 & LS245 (1 Unit & 2 Units) :**
    Used for the system bus of 8086 (control signals and data bus)

4 Address Mapping

4.1 Memory Mapping

- 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	

4.2 I/O Mapping

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

A7	A6	A5	A4	A3	A2	A1	AO	Address	Memory
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	8259
0	0	0	1	0	1	1	0	12H	
0	0	0	1	1	0	0	0	14H	8254
0	0	0	1	1	1	1	0	1AH	

5 Mapping Ports

5.1 8255(1) Ports

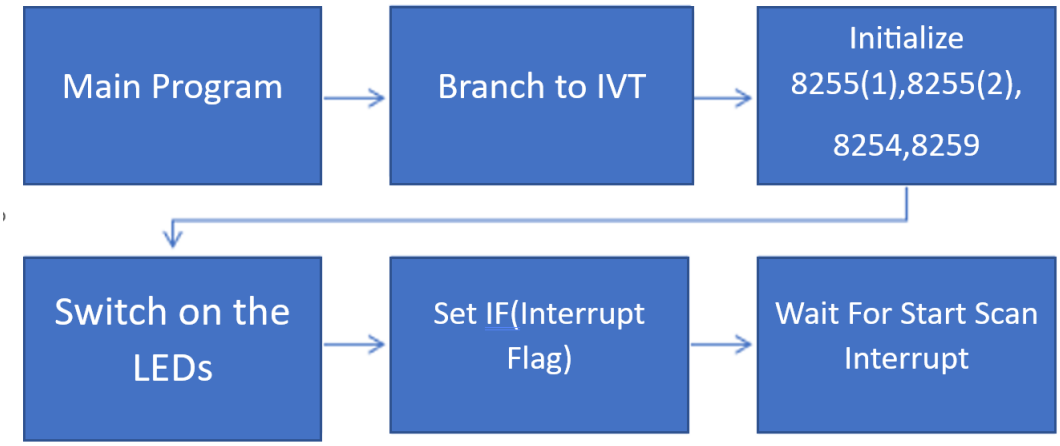
PORT in 8255 (1)	Address to the access port	Purpose of the port
PORTA	00h	Control signals for the horizontal stepper motor
PORTB	02h	Control signals for the Vertical stepper motor
PORTC	04h	Output(Upper port C) - GATE1 to 8254 Output(Lower port C) to Scan Complete LED
Control Register	06h	Initialize 8255 (1) ports

5.2 8255(2) Ports

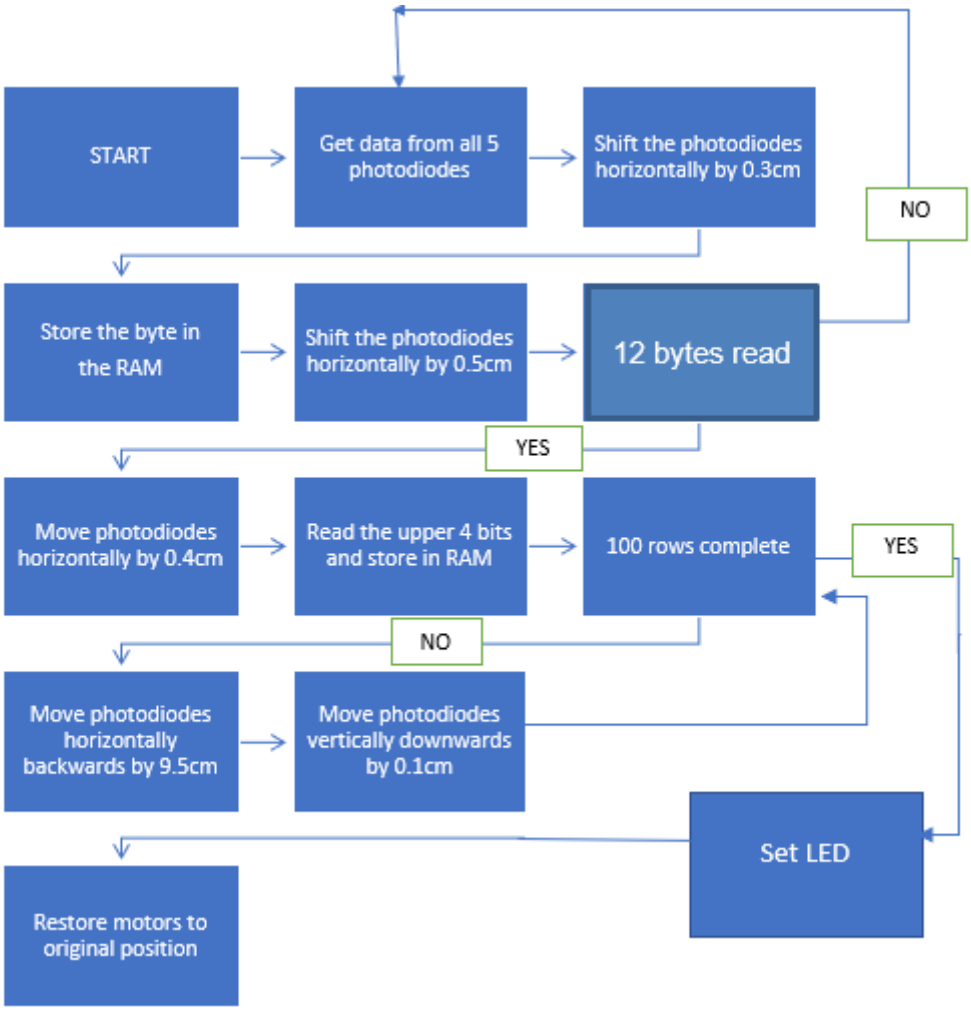
PORT in 8255 (2)	Address to the access port	Purpose of the port
PORTA	08h	Connected to LM139
PORTB	0Ah	-
PORTC	0Ch	-
Control Register	0Eh	Initialize 8255 (2) ports

6 Software Flowchart

6.1 Main Program

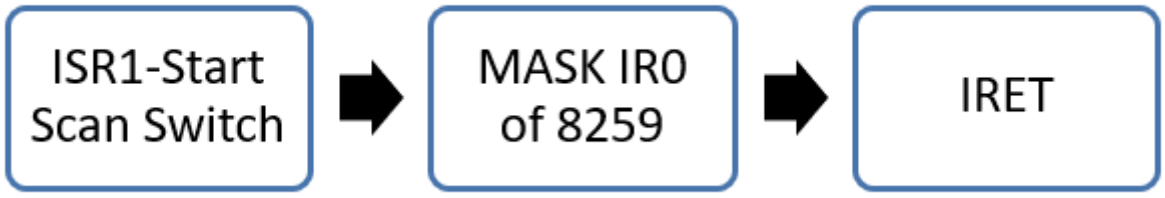


6.2 Interupt Service Routine for INTR



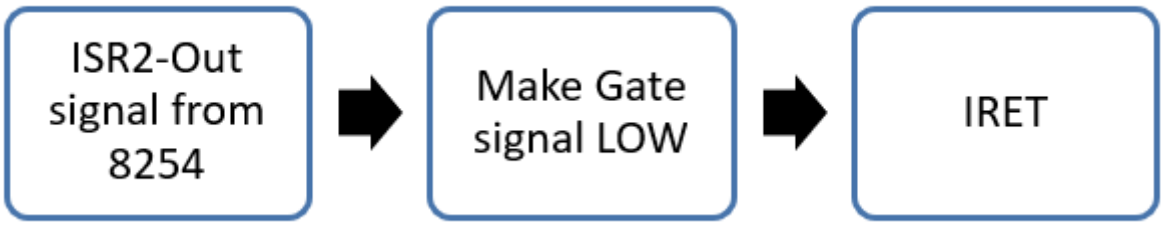
6.3 Flowchart of ISR1

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.



6.4 Flowchart of ISR2

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



List Of Attachments

Datasheets of all components used
Hardware Design