Object Sorter and Counter System

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***Abstract*—In the present era of industrial automation, sorting of objects depending on type, size, colour, defect etc. plays an important role. The objective of this project is to implement a conveyor based sorting system which classifies objects on basis of colour. A feature for counting number of objects of each type has also been implemented.**

I. Introduction

In order to meet the demands for mass production, each and every process in an industry needs to be automated. This is because machines are faster, rugged, efficient and accurate as compared to human beings. Most of the industries in manufacturing sector use assembly line concept. In this manufacturing technique, each task is assigned to individual humans or robots. Every task is dependent on previous one. If any process in assembly line slows down or stops, then entire assembly line stalls. A conveyor belt is the back bone on such manufacturing unit. Each process needs to be fast and error free.

In this project, we have built a small section of conveyor belt and demonstrated sorting and counting of objects. These are some of the most essential processes taking place on an assembly line. We have sorted objects on basis of their colour, but in reality any parameter such as size, shape, weight etc. can be used to classify incoming objects.

89V51RD2 microcontroller is the heart of this system and performs all controlling and decision making tasks. TCS3200 colour sensor is used for sensing colour of the object. An IR pair is used for sensing presence of object. A servo motor rotates the slide whereas a DC motor drives the conveyor belt.

II. The 89V51RD2 Microcontroller

We have used 89V51RD2 microcontroller from NXP (Phillips). 89V51RD2 is an 8051 architecture based microcontroller with many additional features. Some the features are given below,

1. 8051 Architecture Based μc.
2. Operating frequency from 0 MHz to 40 MHz.
3. 64 kB of on-chip Flash user code memory.
4. On-chip boot-loader.
5. PCA (Programmable Counter Array) with PWM.
6. SPI (Serial Peripheral Interface) and enhanced UART.
7. Four 8-bit I/O ports.
8. Three 16-bit timers/counters.
9. Eight interrupt sources with four priority levels.

We have selected this microcontroller because of number of features such as availability of timer 2 with 16-bit auto-reload mode, PCA module with PWM facility, on-chip boot-loader which makes downloading the code into flash memory easier.

III. Object Sensing

An IR Pair is used for detection of presence of object. An IR LED is kept at one end and an IR detector is kept at the other end exactly in front of the IR LED.

Usually when there is no object, light of IR LED falls on the IR detector, and we get low (logic 0,i.e. 0V) at cathode of IR detector. When an object comes in between IR LED and IR detector, the light path is cut and we obtain high (logic 1,i.e. +5V) at cathode of IR detector. The output of IR Pair is passed through two inverting Schmitt Triggers (IC 7414). The logic level of signal remains unchanged, but noise is eliminated.

IV. Colour sensing

A. TCS 3200 Colour sensor

1) Operating Principle: The TCS3200 is a programmable color light-to-frequency converter that combine configurable silicon photo-diodes and a current-to-frequency converter on a single monolithic CMOS integrated circuit. The output is a square wave (50% duty cycle) with frequency directly proportional to light intensity. The full-scale output frequency can be scaled by one of three preset values via two control input pins. Digital inputs and digital output allow direct interface to a microcontroller or other logic circuitry. Output enable (OE) places the output in the high-impedance state for multiple-unit sharing of a microcontroller input line. In the TCS3200, the light-to-frequency converter reads an 8 x 8 array of photo-diodes. Sixteen photo-diodes have blue filters, 16 photo-diodes have green filters, 16 photo-diodes have red filters, and 16 photo-diodes are clear with no filters.

The output of TCS3200 colour sensor cannot drive microcontroller input, because its current supplying capability is only 10μA. So, IC 74244 (octal buffer) is used to drive microcontroller input.

2) Pin Description: Table below shows function of each pin,

Pin name	Description
GND	Power supply ground. All voltages are referenced to GND.
$\bar{OE}$	Enable for fo (active low).
OUT	Output frequency (fo).
$S0, S1$	Output frequency scaling selection inputs.
$S1, S2$	Photo-diode type selection inputs.
VDD	Supply voltage (2.7V to 5.5V).
LED	Supply voltage for LEDs.

S0 and S1 are used to select output frequency scale as per table given below,

$S0$	$S1$	Output frequency scaling (fo)
0	0	Power down
0	1	2%
1	0	20%
1	1	100%

In this project, $S0$ = 1 and $S1$ = 1, i.e. 100% frequency scale is selected.

$S2$ and $S3$ are used to select photo-diode type as per table given below,

$S2$	$S3$	Photo-diode type
0	0	Red
0	1	Blue
1	0	Clear (no filter)
1	1	Green

In this project, $S2$ = 1 and $S3$ = 0, i.e. clear photo-diode is selected.

B. Frequency Measurement

1) Direct Frequency Measurement: This is the most straight-forward method of frequency measuring. Direct Frequency Measurement (DFM) uses a Time-Base Oscillator (TBO) which generates pulses at regular intervals. The number of pulses of input signal accommodated in one time period of TBO determines frequency of input signal. The lowest input frequency possible should be greater than TBO frequency to minimize errors.

2) Timer 2: The Timer 2 of 89V51RD2 is used as a Time base oscillator (TBO). Timer 2 is used in Mode 0 (16-bit auto reload). The TBO frequency calculation is as given below,

Oscillator frequency = $11.0592MHz$

Timer 2 input frequency (F) = $\frac{11.0592*10^6}{12}$ = $921.6KHz$

T = $\frac{1}{F}$ = $1.085\mu s$

Timer 2 Loaded Count = 0

Timer 2 Delay = 65536

$\therefore$ Total delay = $2 * 65536 * 1.085\mu s$ = $142ms$

The rate is doubled because every alternate roll over of timer 2 resets the internal counter.

So, The output frequency of TCS3200 is sampled at the rate of $7Hz$ i.e. every $142ms$.

3) External Interrupt 1: The output signal (square wave) of TCS3200 is connected to INT1 pin (P3.2). Whenever there is a high-to-low transition on this pin, an interrupt is triggered. This interrupt will increment an internal counter.

V. Object Sorting Mechanism

A. Servo Motor

1) Operating Principle: A 180 deg servo motor is used for rotating the slide so that objects can be sorted. A servo motor has three terminals, which are described below,

Pin no.	Terminal	Colour	Description
1	Signal	Orange	PWM signal input
2	Supply	Red	+4.5V to +5.5V supply
3	Ground	Brown	Ground reference

A servo motor has an internal DC motor and a potentiometer. Microcontroller sends PWM signal to servo and the servo aligns its shaft to the angular position corresponding to that pulse width. The range for pulse width is from $1000\mu s$ to $2000\mu s$, where $1500\mu s$ aligns the shaft to the center position.

2) Programmable Counter Array (PCA): We have used the module 0 of Programmable Counter Array (PCA) to generate PWM signal for servo motor. Timer 0 roll over flag is used as the clock source for PCA timer. The servo internal circuit expects a pulse of suitable width every $20ms$. A battery eliminator circuit (BEC) is used to provide pure +5V DC supply for servo motor operation.

B. Slide

A slide is used to sort objects. It is connected to the shaft of servo motor. Objects from conveyor belt will fall onto the slide and depending on angular position of slide, the objects will get sorted.

VI. Display

We have used a 16x2 LCD screen to display number of objects passing. The LCD controller is used in 8-bit mode. Busy flag is checked before sending data to LCD controller.

Table below shows function of each pin,

Pin no.	Pin name	Description
1	VSS	Ground
2	VCC	Supply voltage(+5v)
3	VEE	Contrast adjustment
4	RS	Data/Command register selection
5	R/W	Read/Write selection
6	E	Enable
7-14	$DB0 - DB7$	8-bit data bus.
15	$L+$	Back-light anode (+5V).
16	$L-$	Back-light cathode(0V)

VII. Conveyor Assembly

A 12V 60RPM DC motor is used to drive the conveyor belt. The belt has two rollers, one of which is connected to the motor. The other roller is kept free. Rollers are connected to body of conveyor using flanges. A rubber conveyor belt has been used. The TCS3200 colour sensor is mounted on top of the conveyor belt, at the slide end. An IR pair (IR LED and IR Detector) is mounted parallel to the conveyor belt, below the colour sensor.

VIII. Block Diagram

The 89V51RD2 microcontroller is the main controlling element. It will take input from IR sensor and TCS3200 colour sensor and perform necessary control action. The output of colour sensor is fed to the microcontroller through current amplifier (IC 74244) as it is incapable of driving the microcontroller input. Output of IR detector is passed through Schmitt trigger (IC 7414) so as to eliminate noise. The microcontroller will generate PWM signals for servo motor. It will also control the 16x2 LCD. DC motor is not controlled by microcontroller. Power supply section will supply +12V to DC motor and +5V to rest of the circuit.

IX. Features

1. Three colour sorting system.
2. Individual object counter (one counter for each type of object).
3. Ambient light rejection upto certain value.
4. This system will sort objects without stopping the conveyor if distance between consecutive objects if greater than or equal to 3 cm. So, it will not slow down the assembly line.
5. +12V supply for conveyor motor and +5V supply for rest of the circuit.
5. Future addition of more colours (types of objects) is possible without and change in hardware.

X. Conclusion

By measuring the intensity of reflected light, we are able to achieve sorting of three different coloured objects. This system can be further modified to classify more number of objects, i.e. 5-colours etc. The counter output can also be connected to any other controlling element, for performing controlling action depending on number of objects passing through the sensor.

References

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