MICROPROCESSOR BASED AUTOMATIC IDENTIFICATION AND SORTING SYSTEM

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1. INTRODUCTION

For many years, the goal of the manufacturing industry has been to reduce human labor and if possible to eliminate it completely by automation. One of the main reasons for this is the rising cost of labor and another is to eliminate human error. Automation improves speed and accuracy and the result is higher productivity and better quality.

In industry, sorting of goods is often done manually. As a result, the employees are involved in the tedious task of counting, identifying and recording information from the products that pass by some control point. Human errors in this manual sortation lead to unreliable data base information, misroutings, erroneous shipments and delays. Due to these reasons and the current trend towards automation, manufacturing industries are increasingly leaning towards implementing automatic identification and sorting systems (AISS).

In AISS, it is assumed that all products are identifiable by a code. As the product moves along the conveyor, an identification equipment (e.g. a scanner) "reads" the code. This code is then transmitted for processing to a microcomputer or a minicomputer. Based on the code received, destination for the product is determined by the predesigned logic in the software. The path of the product is then monitored as it moves along the conveyor. When the product reaches the destination, a mechanical diverter placed at this point is actuated by a signal from the computer to complete the sorting process.

In comparison to manual sorting, automatic sorting is faster, cheaper, more accurate and reliable. Labor can now be allocated to more important tasks where the human potential is better utilized.

Originally, AISS was used in warehouses and distribution centers. But advanced scanning and bar code technology has lured many industries to adopt this system even on the production floor. Their implementation has resulted in significant cost savings per year. As technology improves, the cost of installing such systems decreases, thereby making it easier for management to justify purchase of these systems.

1.1 RESEARCH OBJECTIVE

The spirit of the research presented herein was guided by two related objectives.

Firstly, all the elements of an AISS were identifed and reviewed. These elements included conveyors, microcomputer or minicomputer for system control, identifying equipment like scanners to identify the product, label design, bar codes and sorting equipment.

Secondly, a laboratory model of an AISS was designed to simulate the functioning of an actual system. In this simulated model, as opposed to scanners photocells were utilized to identify the product. An MMD-1 microcomputer was used to control the system rather than a minicomputer. A solenoid was used to simulate the action of a mechanical diverter.

1.2 REPORT STRUCTURE

The AISS and its applications on and off the shop floor are discussed in Chapter 2.

When one mentions AISS, one refers to the automatic sortation of goods as they travel along the conveyor. Chapter 3 details the usefulness of conveyors in an AISS.

Either a microcomputer or a minicomputer can be used to control any material handling system. Chapter 4 portrays the role of a microcomputer in an AISS. It further examines the pros and cons of using a microcomputer in an AISS rather than a minicomputer and provides guidelines to determine the feasibility and applicability of a microcomputer for controlling an AISS.

The identifying code information can be entered into the computer's memory either manually or automatically. Chapter 5 describes the various encoding techniques and their limitations. The role of the photocells in the encoding process and their functions in an AISS are briefly explained. The types of scanners (including laser beam scanners and fiber optic photosensors) and scanning techniques are reviewed. A brief outline on selecting a suitable scanning system is also provided.

Each item travelling on the conveyor bears a code, generally a bar code. Chapter 6 describes the various characteristics of a bar code and discusses the most prevalently used bar codes. This chapter also discusses the factors to be considered in the design of bar code labels, bar code printing techniques and various applications of bar codes.

When a product reaches the destination, it is shunted to the accumulation lane by a sorter. Chapter 7 describes the various sorters that are available and the factors that should be borne in mind while selecting a particular sorter.

The factors to be considered while designing an AISS are discussed in Chapter 8.

The AISS model designed and implemented is described in Chapter 9.

Overall conclusions and future directions are given in Chapter 10.

Appendix A gives the circuit diagram, material specifications and the microcomputer software of the designed system that was discussed in Chapter 9.

A glossary of important AISS related terms is given in Appendix B.

Appendix C provides the costs of commercially available AISS equipment.

Appendix D lists the manufacturers for the various types of identifying equipment.

Appendix E is a list of companies that are AIM (Automatic Identification Manufacturers) members and manufacture AISS related equipment.

It should be noted that in this report, the terms product, item, case, and carton are used interchangeably. The terms sorter and diverter are also used in this fashion.

2. THE AUTOMATIC IDENTIFICATION AND SORTING SYSTEM

The functional characteristics of an AISS are as follows :

1. All products passing on a conveyor bear a code for identification purposes. This code can be a product destination code or a product description code.
2. This code on the product is "read" by an identifying equipment and entered in the memory of a computer.
3. If the code is a destination code, the computer's task is merely to actuate the diverter when the product reaches its destination. But if the code is a product description code, then the software in the computer uses this code to determine the destination. Once the destination has been determined, the computer actuates the diverter at the right time.
4. The diverter physically sorts the cases to the accumulation lane.
5. The information on the sorted item is stored in the memory for data collection purposes.

2.1 TYPES OF AUTOMATIC IDENTIFICATION

There are three types of Automatic Identification : Information, Action, and Information-Action (11). Figure 2.1 shows the applications of each of these and the identifying equipment that can be effectively used for their implementation. The characteristics of the equipment are discussed in detail in

System Function	Bar Code Equipment Fixed Beam	Moving Beam	Hand-Held	OCR Equip.	Symbol Generators
Information					
Receipts Processing	X	X	X	X	X
Order Verification	X	X	X	X	X
Inventory Control	X	X	X	X	X
Production Accounting	X	X	X	X	X
Production Monitoring	X	X	X	X	X
Order Processing	X	X	X	X	X
Inventory Control	X	X	X	X	X
Quality Control	X	X	X	X	X
Shop-floor Data Collection			X	X	X
Production/Schedule Control	X	X	X	X	X
Documentation Preparation	X	X	X	X	X
Action					
Conveyor Line Sortation	X	X			X
Tilt-tray Sortation	X	X			X
Towline Control	X	X	X	X	X
Automatic Weighing	X	X			X
Palletizer Control	X	X			X
Prework Measurement	X	X	X	X	X
Order Picking	X	X	X	X	X
Info/Action					
Automatic Storage/Retrieval	X	X			X
Assembly Veritication			X	X	X
In-Process Control	X	X	X	X	X
Shipment Verification	X	X	X	X	X
Order Processing	X	X	X	X	X

FIGURE 2.1 : AUTOMATIC IDENTIFICATION USES AND EQUIPMENT. (5)

Chapter 5.

A) INFORMATION

The identifying equipment reads the code on the product and transmits the information to other computer-related hardware. Such a system is implemented when "what is where" information is required and no sorting is to be performed.

B) ACTION

Here the logical section of the computer with its interface causes action to occur based on predetermined programming logic stored in the memory. The passing item bears a destination address and the computer actuates the diverter when the item reaches its destination.

C) INFORMATION-ACTION

In this system, the code is transmitted to the computer by the identifying equipment and the code serves to store information and prompt action. Such a system can function in any of two ways. In one way, the equipment reads two codes on the item; one code contains the information and the other code contains the action to be taken. In the second way, an information code on the item is read and matched to an internal table to determine the item's destination. This table consists of possible codes and their respective destinations. In many situations, this internal logic and table can easily be overridden by the operator on the floor, to respond to changes in the system.

An AISS can be either an Action System or an Information-Action System depending upon its application.

2.2 THE SYSTEM ITSELF

Figure 2.2 shows the flow chart of a typical AISS (3). The information is received by the computer from the scanner, shaft encoder and the photocells. The scanner identifies the code on each passing carton and enters it in the computer memory. The computer then decides whether the product needs to be sorted or not, and if so, to what destination. A shaft encoder is used to track the precise position of each product as it moves. A photocell is used to initiate the timing sequence for each carton with the shaft encoder. Additional photocells are used to update the location of each product being tracked. First the computer estimates how long it will take for the product to go from the first photocell to the second. When the product actually arrives, the computer recalculates how long it will take for the product to go to the next, and so on. The recalculation is performed to identify and compensate for variance in the system. This variance may be due to two reasons :

a) The items moving ahead of the current item may have already been sorted on the way while the current item was heading towards its destination. The recalculation helps to check the errors that may have occurred, such as failure of sortation, sortation to wrong destination, etc.

b) Changes in the conveyor speed.

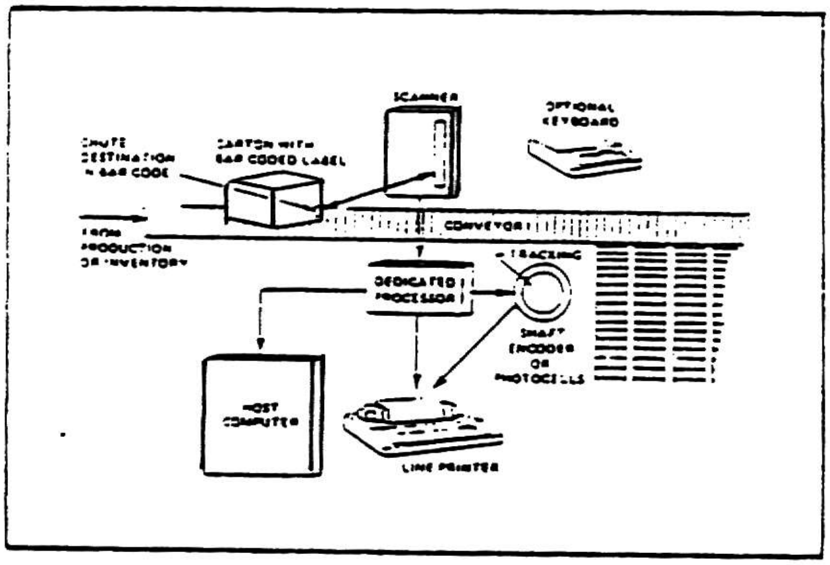


FIGURE 2.2 : FLOW CHART FOR PRODUCT SORTATION. (3)

Thus when the product reaches the final photocell, the software logic calculates the precise moment to actuate the diverter. At the proper time the diverter is actuated and the product reaches its destination. Simultaneously the computer records the occurrence of the transaction.

The scanner also helps to count the number of cartons sent to the destination. The photocells also help to detect overload conditions. When this happens, the lane is closed down, i.e. the diverters are no longer actuated. The boxes either keep recirculating till the lane opens or are diverted to another lane if a change of lane instruction is given by the operator or computer. Any unscannable or mismatched barcodes are sent to an inspection area where they get proper attention.

An AISS speeds physical flow, cuts labor requirements, reduces errors, and provides real-time information for management decision making.

2.3 MISCONCEPTIONS ABOUT AISS

Some common misconceptions (15) are as follows :

1. The reliability of scanning equipment may be in doubt. However, practical applications have shown that no human being can match a scanner's accuracy or speed in a sorting operation.
2. Some do not wish to implement an AISS on account of its high initial cost. But with new developments in computer miniaturization, hardware prices are actually coming down.

An AISS package can now be purchased for under $ 30,000. Such an AISS will eliminate one or more operators per shift and may pay for itself within a year.

2.4 ADVANTAGES OF AISS

The advantages (15) of an AISS are as follows :

1. Scanners and computers can help reduce labor requirements and make dramatic reductions in identification related errors.
2. Identification and counting of items is swift and accurate, enabling faster dispatching to a specified destination.
3. Since continuous tracking of the product is possible, accurate records on work-in-process can be maintained.
4. In assembly operations, the scanners can help send the right components to the right places, thereby making the assembly operation virtually error free.
5. Higher customer service levels are possible.
6. The system pays back in less than a year.

2.5 DISADVANTAGES OF AISS

The following are the disadvantages of implementing an AISS :

1. The codes on the items must be printed accurately and not bear any defects or else they will not be interpreted correctly.
2. The products should always be aligned properly on the conveyor so that the codes are accurately scanned. However, a special type of expensive scanner known as an

omnidirectional scanner is available which can read the code in spite of misalignment.

3. If products are loaded manually, great care should be taken in maintaining a minimum interproduct gap along the conveyor. If the intergap is not maintained, one item being pushed by the diverter may misalign the item following it, throw that item off the conveyor or divert it along with the current item.

2.6 APPLICATIONS

The following industries have successfully utilised AISS (1, 5) : air frame, food, paper products, fiber, pharmaceutical, automotive, government, distribution facilities, tobacco industries, furniture, footwear, electrical and electronics, meat packing, rubber, computer, and health related industries.

Some specific applications are as follows :

1. Warehousing and distribution :
   - i) product sortation.
   - ii) order verification.
   - iii) palletizer control.
   - iv) receipts processing.
   - v) order processing.
   - vi) shipment verification.
2. Production:
   - i) inventory control.
   - ii) production accounting.

iii) production monitoring.

iv) quality control.

v) shop floor data collection.

vi) production/schedule control.

vii) component assembly.

viii) in-process control.

3. Storage

4. Testing

5. Original Equipment Manufacturing applications

The next chapter discusses the part the conveyors play in a material handling system.

3. CONVEYORS

When one talks about an AISS, one generally refers to a system that sorts products as they move along conveyors. Figure 3.1 gives the characteristics of the various types of conveyors. A computer controlled conveyor is ideally suited for an AISS because the sortation conveyor can be automatically stopped when empty and the speed altered when desired.

Conveyors can have two types of drives, constant speed and variable speed. A conveyor with a constant speed drive will move at a constant speed irrespective of whether it is empty or loaded. A conveyor with a variable speed drive will move at varying speeds depending on the burden it carries.

The following are the advantages of using conveyors as part of an AISS (13) :

1. Almost any type of load can be handled, from individual small parts to tote boxes, and from unit loads to large components.
2. Distances cease to be a critical factor because conveyors are practical for moving goods over long as well as short distances.
3. Throughput requirements of almost any feasible rate or volume can be satisfied with the right type of conveyor.
4. Load transfers, either from one conveyor to another, or from a conveyor to a machine or an AS/RS system can be automated.

CONVEYOR EQUIPMENT	Characteristics	Control by Computer?	Description
Accumulation	Any conveyor which allows items to queue at a machine or work station without a significant build-up in line pressure.	Yes	Can be achieved with roller. belt. power and free. and towline.
Belt	An endless fabric supported by a slider bed or roller surface.	Yes	Handles items loose or in flat-bottom containers: not usually recommended for unit loads.
Magnetic	A belt conveyor with a magnitized bed beneath the belt: pulleys may also be magnetized.	Yes	For ferromagnetic materials only
Carrier Chain	Two or more parallel, load-carrying strands of chain.	Yes	Load width must exceed distance between chain. Cost effective for long runs.
Pneumatic	Tubes through which cylindrical parts carriers are transported by air pressure.	Yes	Carriers can be sized to hold items up to about 1-ft long. weighing up to a few pounds: practical for long distances.
Power and free	An endless chain, mounted over-head with grolleys that support load carriers. Trolleys may be from main line to adjacent lines.	Yes	Carriers can hold individual large items or racks of smaller items; in-line surge capability: track can be mounted in three planes.
Roller powered	Series of load-carrying rollers, driven by a belt or chain		For items in flat-bottom containers or pallets; can be sized for small containers or unit loads
Roller gravity	Series of free-turning, load-carrying rollers	No	When pitched, provides automatic feed: when horizontal. Containers must be advance manually
Skate wheel	Series of free-turning wheels spaced on parallel shafts	No	Lightweight loads: less expensive than gravity roller conveyors
Towline	An endless chain, running through an in-floor track, with means for towing carts and switching them to adjacent lines	Yes	Carts may be disengaged from towchain and manually pushed to individual assembly stations
Trolley	An endless chain, mounted overhead with trolleys that support load carriers. Trolleys cannot be switched from the main line.	Yes	Carriers may be fitted with self-dumping trays; track can be mounted in three planes.

FIGURE 3.1 : CONVEYOR EQUIPMENT AND THEIR CHARACTERISTICS. (13).

5. Computer control is practical with many types of conveyors, thereby providing real-time inventory control and routings of materials over complex paths.
6. In-line storage as well as transportation can be accomplished.

4. THE MICROPROCESSOR'S ROLE

The microprocessor, an intelligent control element has emerged as a cost effective control alternative in many systems. The following information has been paraphrased from references 10, 22 and 24. The programmable nature of a microcomputer makes it a very versatile device that can be used in many different types of applications.

A microprocessor is the control unit in a microcomputer. It is an integrated circuit containing the electronic circuitry that provides arithmetic, logic, and program control functions. The microprocessor is small enough to fit in a thimble and replace thousands of standard electronic components (resistors, transistors, capacitors, etc.) which were once available only in room sized computer systems. When memory and Input/Output circuitry are added externally to the microprocessor, it becomes a microcomputer.

A microcomputer has many capabilities normally associated with a minicomputer, i.e. logic functions, data handling capability and arithmetic functions. When one uses the term microprocessor in control related applications, it is normally assumed that one is really talking about a microcomputer.

Basically there are two types of controls in any material handling system, machine control and information control.

As the name implies, machine control deals with the control of machines, more generally, the mechanical devices. Machine controllers monitor inputs from limit switches, photocells, scanners and other sensors to make decisions based upon the state of these inputs. The controller's decision results in the operation of the machine via motor starters, solenoids and other output devices. Machine control applications include conveyors, AS/RS, diverters, palletizers, depalletizers, etc.

Information control deals with control of data and information flow. An information controller accepts entry of data, processes that data thereby producing information, and outputs this information in some usable form. For information to be useful, it is essential to collect and maintain accurate data. Examples of this data are inventory levels, location of an item on a conveyor, etc.

A microcomputer is applicable to both these areas of control. Its arithmetic and logical capabilities suit the needs of real-time controls, while its data handling and communication capabilities allows it to be integrated into data processing systems. Its potential lies in the fact that the microcomputer can be easily interfaced to communicate with other computers and computer peripheral devices. Thus they can serve as a common solution in many cases for both, machine control and data processing.

A microprocessor allows local control that can communicate with a central system. The advantages of local control are simplified debugging, modular installation, savings in field wiring, and simplified maintenance due to the proximity between the device and its controller. The microcomputer allows a two-way communication with a host computer while it operates in a time independent mode. It can be preprogrammed to execute each transaction as an event and store the completed transaction data until polled again by the host computer, thus easing some of the burden placed on the host computer in real-time systems control.

The following describes the role of a microcomputer in an AISS (22). The analog code signals that scanners receive are digitized, validated and matched against the codes in a lookup table which resides in the microcomputer Random Access Memory (RAM). In this manner, the microcomputer evaluates the code and determines the required task to be performed (for example actuating the proper diverter at the proper time). While this task is being executed, the data relating to the task execution is stored in Electrically Erasable Programmable Read Only Memory (EEPROM) for future reporting to the host computer or controller.

Microcomputers have an advantage in systems that are to be built with unknown future modifications. Logic modifications can be easily made either by entering new variables on a keyboard or at the very worst, swapping in a new board.

Microcomputers are also quicker to install, easier to develop, and require less maintenance.

4.1 MICROCOMPUTER VS MINICOMPUTER

The main criteria for evaluation and selection of computers is cost effectiveness. The cost includes purchase price of equipment, installation costs including field wiring, and long term maintenance costs associated with equipment upkeep. Another criteria is in evaluating how well the desired specifications, like throughput, response time and uptime are met. The maintainability of the computer system is another important factor in evaluating its effectiveness.

Microprocessors allow easier implementation at a greatly reduced system cost. High level software in the form of programming languages and operating systems is available to the design engineer, as are many special purpose microprocessors. A microcomputer is small in size and offers capabilities in the area of information processing and interfacing to other types of control equipment. Cost savings occur due to lower initial cost and lower maintenance cost. Field wiring costs are also lower for the microcomputer as compared to a minicomputer. Product reliability is increased due to simplified hardware configuration and self-diagnostic aids. Greater flexibility results in faster maintenance and more predictable field debug. Maintenance costs are usually lower since repairs are normally done by replacing spare parts which are quite inexpensive. When problems occur, instead of diagnosing a circuit board or a wiring diagram, a new board can easily be popped into the microcomputer and the defective board be repaired off the shop floor without delaying the system operation. Program changes can easily be accomodated in a microcomputer by installing new Read Only Memories (ROMs) containing software changes.

The biggest disadvantage with the microcomputer as compared to the minicomputer is the practical infeasibility of using it in severe environmental conditions. For example, applications like those involving high heat and vibrations prohibit the use of a microcomputer. However, the compact packaging of a microcomputer allows the use of simple protective measures like shock mounting and fan cooling,

The minicomputer is relatively expensive. The increased time required for field wiring adds more burden to the overall system cost due to high labor costs.

Microcomputers will never totally fill the minicomputer's role in AISS or other components of automated material handling system; the main reason being the difference in speed and computational power of the two. But microcomputers provide a cost effective replacement and have throughput times which are suitable for AISS.

A rule of thumb would be to use a microcomputer under the following conditions :

1. When one is looking for a low cost alternative.
2. When the basic material handling system is going to remain the same (3), i.e. no siginficant additions, deletions or modifications in the number of products sorted or in the

method of conveying is foreseen.

3. When environmental conditions do not involve severe shocks and vibrations, and high temperatures.

5. ENCODING

Encoding refers to entering a code in the computer memory. Encoding can be done either manually or automatically. In either methods, the encoded code can be used to perform the following functions :

1. display the code for visual check.
2. verify against another code in the memory.
3. transmit the code to a host device (a programmable controller or a master computer).
4. use the logic unit to actuate a relay to divert the product.
5. signal an alarm.

5.1 MANUAL ENCODING

Manual encoding can be accomplished in two ways. One way is for the operator to use a keyboard panel to enter the code that has been read (Keyboard Encoding). In the other way, the operator speaks the code into the microphone (Voice Encoding). Manual encoding is possible only when the codes on the products are small sized codes. Generally, these small sized codes are numeric codes referring to product destination as opposed to product description.

5.1.1 KEYBOARD ENCODING

This is the most primitive method. The operator reads the code on each item and uses the keyboard to enter the address of the product destination. A good operator can read as many as 30 to 40 cases per minute. But here, there is always the possibility of human error. This method of encoding is used because the equipment is less expensive. It is also used in situations where, irrespective of the encoding method used, an operator is needed in the sortation area to clear the jam-ups and correct other problems which may occur.

5.1.2 VOICE ENCODING

Here the operator speaks into a microphone to enter the sorting address into memory. This voice is then decoded electronically and transmitted to the computer's memory. One advantage in using this method is that since both his hands are free, the operator can easily reorient the cartons and read the code without stopping the conveyor. There are few installations of such voice recognition equipment, since the rate of no-reads (codes that the operator failed to read because of fatigue or distractions) is higher than with other encoding methods. At the end of the day or shift, these no-reads have to be sorted manually.

5.2 AUTOMATIC ENCODING

This is the most effective type of encoding method since it eliminates the possibility of human error. The identifying equipment either recognizes a physical characteristic of the item or reads a meaningful code pattern on the item.

5.2.1 AUTOMATICALLY RECOGNIZING A PHYSICAL CHARACTERISTIC

Identifying can be done by recognizing the physical characteristics of the product such as the size (height), weight or even the image.

A) HEIGHT

If products are of unique heights then simple photocells could serve the purpose of identifying and encoding by placing the photocells in a Y array. (See Figure B.1 in Appendix B for the axis configuration.)

I) PHOTOCELLS

A simple photocell (14) consists of a light source and a light receiver which are positioned opposite and in alignment with the light beam. The object being detected passes between them and the broken light beam creates an output. This output is an electrical signal which is then amplified by the amplifier to produce a change in the current or voltage. This change is then used to drive an output (typically an electromagnetic relay or a solid state device) or stored in memory for future decisions to be taken by the computer. The electromagnetic relay may be connected to the device to be controlled such as a counter, motor, solenoid, actuator, or a lamp alarm. This relay may also be connected to a computer.

Most of the photocells fall into two categories.

1. Phototransistors and photodiodes fall into the first

category. These photocells amplify the input signal defined by the incident light illumination.

2. Secondly, there are the photoresistors. The electrical resistance of these photocells changes when there is a change in incident light illumination.

Phototransistors and photodiodes are small, have moderate sensitivity and operate at very high speeds (i.e. have very low response times). Their use is recommended when the desired response speed in the system is high (25 responses per second). They are stable over a wide temperature range and are recommended for ambient temperatures over 150 degrees Fahrenheit.

Photoresistors are usually made of Cadmium Selenide or Cadmium Sulphide. They are inexpensive but are not quite as small or as fast as phototransistors. They cannot be used at high temperatures. They are more widely used only because they have greater sensitivity to light changes than phototransistors.

The signal detected by these photocells is amplified by a signal amplifier. The amplifier increases the low power signal from the photocell so that it can drive an output device such as a relay, or send the amplified signal to a remote microcomputer or minicomputer. Amplifiers can be classified as either threshold or transition responsive. A threshold responsive amplifier is sensitive to light intensity. It is triggered when light intensity increases or falls below a certain setting. In transition responsive amplifiers, the rate of change is more important than the intensity of the signal. Transition responsive amplifiers are preferred for counting very fast moving small parts that produce little signal change when they pass through the light beam.

The light sources for the photocells (Incandescent and Light Emitting Diodes) will be discussed under scanners later in this chapter. Scanners are special type of photosensors. The basic advantage with photocells and scanners is that they do not have to rely on physical contact between the control unit and the object being detected.

Typical functions performed by a photocell (22) in any Material Handling System are as follows :

1. sense the presence or absence of items on the conveyor.
2. detect over or undersized products.
3. identify the products by size.
4. detect problems or jam-ups in a material flow sequence.
5. detect misaligned parts on a conveyor when precise alignment is required for subsequent machining operations, accurate bar code scanning or feeding the product to the sorter.
6. count the items for inventory and production control.
7. monitor levels of bulk products in tanks or bins.

B) WEIGHT

When a product needs to be sorted by weight as in a meat packaging plant, then an electronic weigh-in-motion scale can weigh the product while it is moving on the conveyor and send the data for future information/action.

C) IMAGE

A highly sophisticated device has been developed which can identify the product by the image it creates (22). It is known as a Charge Coupled Device (CCD), and it performs the same task as the electronics in a television camera. It consists of linear or an X-Y array of photosensitive elements packaged on a single chip and mounted behind an optically transparent window. (See Figure B.1 in Appendix B for the axis configuration.) An object passing under the scanner head excites the photosensitive elements at many different levels of light intensity and the "integrated" image produced on the photosensitive elements is a very accurate representation of the entire object.

A CCD must be mounted behind a camera lens and be focused on specified areas as determined by lens selection. It can have upto 1728 sensitized areas that can be strobed (or pulsed) to give approximately 5800 scans of an area per second. The analog output of a CCD is digitized and fed into the memory. CCDs can give an accurate scan even if the objects are skewed, tipped or randomly oriented on a conveyor. The CCDs are very expensive, and therefore are not widely used.

5.2.2 AUTOMATICALLY READING A CODE

A code pattern applied to a product may contain one or more of the following information : product identification, purchase order or shop order number, customer's name or address, destination lane, product characteristics like weight or size, etc. This code is applied for the purpose of improving material flow, data processing, etc.

The code can be :

1. A bar code which is read by scanners,
2. An alphanumeric code which is read by an Optical Character Recognition (OCR) device, or
3 A magnetic code which is read by magnetic heads.

5.2.2.1 SCANNERS

A scanner is similar in appearance to, but has more features than a photocell. It is a data collection device with photoelectric controls. It performs all the functions that a photocell can perform. In addition, it can read bar codes on the item and transmit the information to the computer which processes the data and takes an appropriate action.

Scanners have the following advantages :

1. The products need not have unique heights since scanners can read the bar codes.
2. They eliminate labor or reduce the man-power needs thereby making dramatic reductions in errors.
3. Identification and counting of items is swift and accurate and the sorting rate is much more than in manual systems.
4. It is possible to monitor the location of an item as it travels in the shop as part of its processing.
5. In assembly operations the scanners can help send the right

components to the right places, thereby making the assembly operation virtually error free.

A) TYPES OF SCANNERS

A scan is a single movement of beam through an angular path. Basically, there are three types of scanners; fixed beam, moving beam, and hand held scanners. The hand held scanners can read either the bar codes or the optical characters.

1. FIXED BEAM SCANNERS

They use a stationary light source to scan a symbol. They depend upon the motion of the object to be scanned to move past the beam. They emit light through an optics package that includes a photodetector for sensing light reflections. Fixed beam scanners are of two types.

One type of fixed beam scanner senses marks or codes consisting of retroreflective material. Retroreflective tapes applied at different elevations on packages are sensed by the scanner positioned at the same elevation levels as the mark on the passing carton. The code is stored in memory and a diverter is actuated at a proper place and time.

Another type of fixed beam scanner uses a digital code on a plate or a paper (label) that is attached to the item. These codes are also made of retroreflective material. A reader is set up to recognize a specific code and send the information to the memory. Some fixed beam scanners use a fluorescent light source to read a bar code. Generally, fixed beam readers are used for high volume sortation and for reading colored bar codes, as they are unaffected by codes printed in different colors. They offer a high degree of accuracy, but they "see" the code pattern only once as compared to the moving beam scanners which perform multiple reads. Another disadvantage is that the retroreflective material has to be located precisely to ensure a valid scan.

2. MOVING BEAM SCANNERS

In moving beam scanners, the light beam traverses an angular path searching for bar codes on objects. They read symbols passing by at speeds in excess of 1000 feet per minute. Typical scanning rates can be as high as 1440 scans per second. This permits multiple scans to be made on the same symbol thereby making the reading more accurate and reliable. The symbol placement is not critical as long as the symbol is within the reader's field of view or its scanning height. Moving beam scanners generally do not permit the use of colored bar codes.

3. HAND HELD SCANNERS

They can be either bar code scanners or Optical Character Recognition (OCR) scanners. They serve as an excellent substitution for traditional data entry and collection methods using keyboards. They are compact and light. A beam of light, incandescent or LED, is emitted through an aperture in the tip of a pen or wand. The light detector measures the signal reflectance when the tip of the wand is manually stroked over the bar code. These signals are then decoded and the information is sent to the memory. They are never used in AISS. They are generally used for eliminating clerical errors and paper work in processing data, inventory tracking, and document tracking or control.

B) SPECIAL SCANNERS

1. LASER SCANNER

Figure 5.1 shows the functioning of a moving beam laser scanner (17).
The scanner head contains a helium-neon laser tube , a set of lenses , an aiming and oscillating mirror , a photo multiplier with filter and an electronic circuitry.

A high voltage from the power supply energizes the laser tube and this generates a thin beam of red laser light. This light beam passes through a focusing lens. A mirror in the scanner oscillates on its axis 150 times a second, and the flickering reflected light beam passes through a target window onto the bar code. The diffused interrupted light rays reflected from the bar code pass into photomultiplier. This has a red filter which allows only red light to pass.

The multiplier amplifies the reflected signals to electronically produce a strong analog image of the bar code. In the analog image, the wave signals above zero-line represent spaces (strong reflections) and those below zero-line represent bars (weak reflections). This analog signal then goes into a signal processor which converts the message into digital

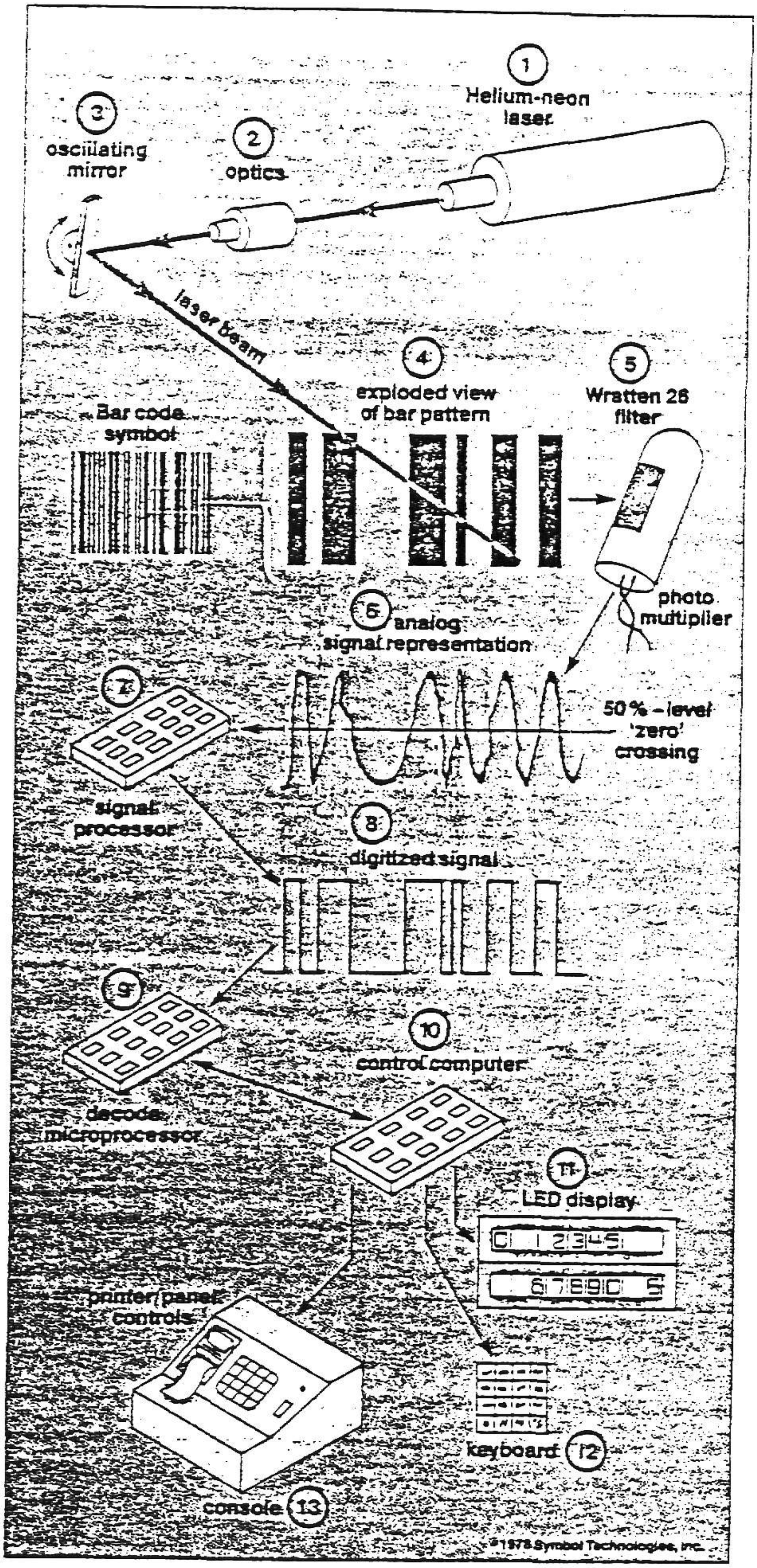


FIGURE 5.1 : FUNCTIONING OF A MOVING BEAM LASER SCANNER (17)

information. A microprocessor then decodes the message, which is subsequently sent to a host computer.

If the bar code has not been oriented properly or if the scanning angles are irregular due to scanner misalignment then sometimes the laser scanners will not function properly. Under such conditions, omnidirectional laser scanners can be used. These scanners are very expensive. There are also low power lasers now available that are relatively inexpensive and reliable.

Generally, laser scanners are more expensive than other types of scanners. However, if laser scanners are used then cheap labels can be used as opposed to expensive retroreflective labels.

2. FIBER OPTIC PHOTOSENSORS

If some applications do not have enough space for mounting sensor bodies, Fiber Optic Photosensors with bendable metal snouts can be used. In fiber optics, the light source and photodetector can be placed remotely from the monitoring area. The light source travels to the target through an outer layer in the fiber optic bundle. This fiber optic bundle surrounds an inner core of fibers that return the signals to the photoreceiving element.

Fibers operate at higher temperatures than either the source or photodetectors can withstand. Hence they are used for high temperature applications. New scanners, detectors and amplifiers which meet the requirements of fiber optics have been developed.

C) SCANNING TECHNIQUES

There are four types of scanning techniques (22) : through beam or direct, retroreflective or reflex, specular reflective, and diffused reflective or proximity. Figure 5.2 shows these techniques.

1. THROUGH BEAM SCANNING

A light source and a photoreceiver are positioned opposite to each other and in alignment with the light beam. When the beam of light is broken by a moving object, an output is created. This technique provides great contrast between light and dark when the object interrupts the beam. Scanning distances of hundreds of feet are practical. However if vibrations are present in the environment, then alignment becomes difficult particularly over large distances.

2. RETROREFLECTIVE SCANNING

In retroreflective scanning, the light source and the receiver are housed in the same unit. This technique can operate in two ways. The light beam falling on the receiver may indicate either the presence or the absence of an object.

In the first technique, a special target is placed opposite to the unit. This target can be either a retroreflector or a mirror. When the object is absent, the receiver receives the reflected light from the target.

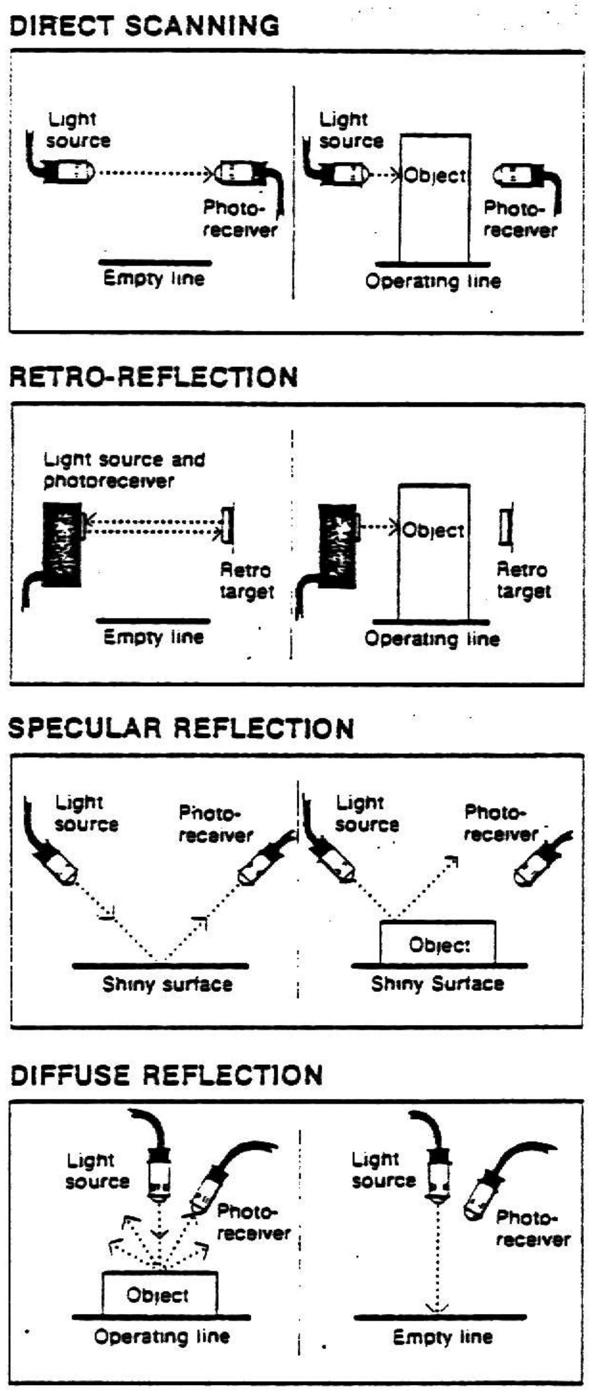


FIGURE 5.2 : SCANNING TECHNIQUES (22).

But when an object passes in front of the unit, the beam is interrupted, and thus the presence of the object is sensed.

In the second technique, the presence of light on the receiver indicates that an object is passing. The passing items are equipped with retroreflective tapes which generally contain the code. A retroreflective tape's surface consists of tiny glass beads and reflects light directly back to its source regardless of the angle at which the light strikes the tape. This non-diffused reflection is upto 900 times brighter than that provided by normal white surface. When the item passes in front of the unit, the light falling on the tape is reflected back and the presence of product is sensed. Scanning distances of thirty to sixty feet are practical for this technique.

3. SPECULAR REFLECTIVE SCANNING

This is also a reflective technique but the beam is reflected from a shiny surface on the object itself or the surface over which the object must pass, like a polished metal conveyor. The light source and photoreceiver should be precisely mounted so that the beam's angle of incidence is equal to the angle of reflection. Detected objects either complete or interrupt this beam angle.

4. DIFFUSED REFLECTIVE SCANNING

A diffused beam is used here to create an output. Depending on the presence or absence of an object and the alignment of the light source and photoreceiver, the diffused beam will create an output. The important factor to be considered in such cases is whether a passing object is going to throw diffused light on the receiver or whether the empty conveyor is going to throw this light on the receiver when the object is absent. Scanning distances are generally limited to six or seven feet.

D) LIGHT SOURCES

The scanners and photocells can have two types of light sources, incandescent and LED (14, 20, 22)

1. INCANDESCENT LIGHT

This was the first type of light source used in photoelectric sensors. It has advantages like familiarity, availability, visibility in operation and low cost, but disadvantages like short lamp life and limited usefulness in very bright environments. Its life is rated in terms of average hours of life. Today, units with lamp life averaging 50,000 hours are available. An incandescent lamp produces light over a broad band - ultraviolet to visible to infrared. This light source is especially used when colored bar codes need to be scanned.

2. LIGHT EMITTING DIODES

A light emitting diode (LED) is a semiconductor chip that emits light energy when stimulated by a low voltage DC current. This emitted light is monochromatic in nature since its radiation output is in an extremely narrow band. The frequency or color of the light depends upon the diode material. Infrared, the "invisible light" is most commonly used in sensing applications.

An LED has a longer life compared to an incandescent lamp and is also less susceptible to damage from vibrations. An LED is rated in terms of half-life, which is the time at which the power output of the LED is one-half the value it emitted when new. It is typically 100,000 hours. But LEDs do degrade exponentially in time depending on how much the unit is used and the amount of power involved.

E) SELECTING A SUITABLE SCANNING SYSTEM

To select a scanning system, the following elements need to be considered :

i) Selecting a location for placing the scanning unit. The location can be either direct or remote with respect to the object.

ii) Selecting a scanning technique.

iii) Selecting a scanner model for the system.

i) SELECTING A LOCATION FOR THE UNIT

The unit is said to be directly located when it is placed in close proximity to the object being identified. It is said to be remotely located when it is placed away from the object at a considerable distance. The scanning unit is placed remotely when the operating temperatures are high, or space limitations prevent the use of conventional electronic devices. In this situation, a fiber optic scanner is used. Irrespective of the location of the scanning unit, one can select any one of the following scanning techniques.

ii) SELECTING A SCANNING TECHNIQUE

The following material has been paraphrased from reference 8.

1. DIRECT SCANNING

It is generally used in long range applications. It is used in short range applications when dirty operating conditions prevent use of other scanning methods. It is also preferred where surface reflections from the object may render retroreflective or diffused reflective techniques less reliable. It should not be used for transparent or semi-transparent objects, but can effectively be used for opaque objects.

2. RETROREFLECTIVE SCANNING

It is used in short and medium range applications where it is convenient to provide a seperate emitter and a receiver. It is most reliable with opaque objects. It can also be used for semi-transparent objects particularly when the amplifier sensitivity is reduced or the reflector is masked. It should not be used to sense glass bottles or count objects with shiny surfaces.

3. SPECULAR REFLECTIVE SCANNING

This should be chosen only if the conveyor or the object is shiny. The problem here is the necessity of precisely aligning the photoreceiver with the light source.

4. DIFFUSED REFLECTIVE SCANNING

It is not used to detect objects in short range applications without the use of a retroreflector. The modulated infrared light reflects off nearly any object, transparent or opaque. Diffused reflective scanning is difficult to be employed if the light diffused from a background object like guide-rail, a machine member or a person standing on the opposite side of the conveyor has a possibility of creating erroneous outputs. In such systems, the designer has to keep in mind two criteria :

1. The environment between the object/belt and the receiver should be clean.
2. The receiver should be placed at a sufficient distance from the object. It should not receive any stray light so as to ensure a good reception of the diffused light. The criteria becomes more important when the background is more reflective than the object.

iii) SELECTING A SCANNER MODEL

Every manufacturer provides broad guidelines on the choice of a particular scanner model. The information is generally on the relationship between the ratio of light signal being received to the signal necessary to operate receiver, and the light source to receiver or object to receiver distances required for the scanner to function effectively. This information can be in the form of curves or tables, and this should be used to determine the applicable scanner models. From this set of applicable models, one should select a model which has simple alignment procedures. In choosing a model, one should also take into account the factors like build up of dirt, dust, moisture and other contaminations.

The following provides a comprehensive list of scanning requirements that should be considered in selecting a particular model (8) :

1. operating distances.
2. reliable temperature ranges.
3. environmental conditions. (extreme dirt, fog, dust, etc.)
4. type of object to be detected (transparent, translucent or opaque).
5. size of objects.
6. ability to detect black and white or colored codes.
7. ability to arrange multiple scanners in parallel or series.
8. ability to interface with other electronic controls, programmable controllers or microprocessors.

9. ability to sense presence of absence of product movement.
10. ability to sense the product while ignoring the background.

5.2.2.2 OPTICAL CHARACTER RECOGNITION

Here, the printed characters are read by people and machines, but machine reading is not so flexible or reliable as the scanning of bar codes. An inkspot or void can obscure or transpose an OCR character, while bar codes are much more resistant to such defects because of their vertical redundancy and internal checking. It is impractical to read OCR on rapidly moving items with high speed, non-contact scanners. <u>Optical Character Recognition devices are never used in AISS</u>.

5.2.2.3 MAGNETIC CODE READING

To describe a magnetic code reading system, a typical operation of a magnetic belt sorting system (25) is given below. In this method, the codes are transformed into magnetic codes which are carried in the solid carbon steel conveyor belt along with the item.

As the item passes the control, the code is first fed into electronic memory and the signal is stored temporarily until the leading edge of the item passes through a light barrier located at the beginning of the sorting belt. A trigger signal from the light barrier is then sent to the electronic center, which activates the belt magnetizing units. A magnetic code corresponding to the code on the item is registered at a fixed distance ahead of the conveyed item. When this code reaches the selected station, a diverter is automatically actuated discharging the item. This method is reliable for upto 3000 sorts per hour.

The advantages of magnetic recording of data are :

1. data can be recorded at higher density than bar codes, and
2. the recorded data can be altered if desired.

Bar code reading is better than magnetic code reading because of the following reasons :

1. data security is ensured in bar code reading.
2. bar codes can be read from a distance by high speed beam scanners.
3. bar codes can be printed or be reproduced inexpensively.

Appendix C gives the price ranges of various types of scanners mentioned in this chapter. The names of the companies that make a particular type of scanner are shown in Appendix D. Appendix E provides brief information on several companies that are involved in the manufacture of AISS related equipment.

6. BAR CODES

If a code is applied to an item, it becomes easier for the system to process the information and take appropriate action. A code can be of two types : action or information.

6.1 SELECTION OF A BAR CODE CLASS

The primary factor in the selection of a bar code class is the intended use for the bar code (21). If action alone is desired then the action code is used. If action and information both are desired, the information code is used.

6.1.1 ACTION CODES

These codes are employed for action and control purposes and bear a direct relationship only to their desired function, such as the destination in an AISS. They are typically short and contain only one item of data. They may be abbreviated or be symbolic in data and in most applications they provide no information about the product. These codes are predominantly used for AISS and order picking applications. Figure 6.1 (21) shows a typical Action Code.

6.1.2 INFORMATION CODES

These codes contain product numbers or description. They provide data and opportunity for multiple uses through unique identification of the product.

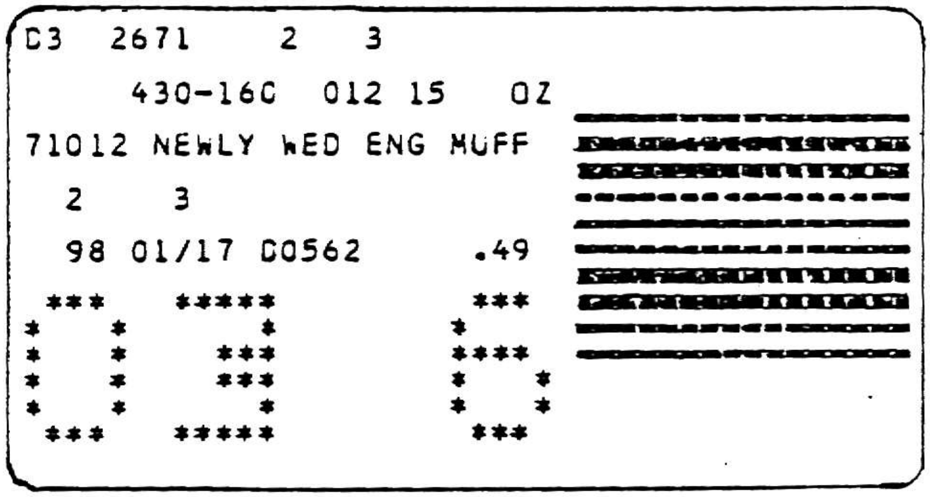


FIGURE 6.1 : TYPICAL ACTION CODE ON A WAREHOUSE ORDER PICK LABEL (21).

By suitably designing the software, one can also use these codes for action. For example, the action could be actuating a sorter for a particular product or products after the validity of the code has been checked.

Once the designer has selected one of the two bar code classes, the next step is to design the bar code label.

6.2 DESIGNING A BAR CODE LABEL

The label should be so designed that apart from having the bar code, it should also contain in human readable form, any information which the system designer thinks is vital.

The following factors should be taken into account while designing the label :

1. tradeoff between more information on the label versus the size of the label. The information provided on the label should be short and precise for the sake of convenience and economy. Also, the information should be vital for the sake of better label utilisation.
2. the size of the characters.
3. the visual clarity provided by the label.
4. fixed versus variable code length for the products.
5. numeric code versus alphanumeric code.
6. size (height and width) of the coded bars and spaces.

A basic label format (23) is shown in Figure 6.2. It has 3 segments, A, B and C. Segment A contains one or more of the following information in human readable form :

1. product description.
2. size of the package.
3. size of the product.
4. item code.
5. department. (manufacturing, originating, etc.)
6. customer name and address.
7. destination address. (accumulation lane, etc.)
8. weight.
9. quantity per case.
10. date manufactured.
11. expiration date.

Segment B contains the bar code.

Segment C contains one or more of the following human readable information :

1. sale price.
2. list price.
3. unit price.

After having designed the label, a proper label material should be selected.

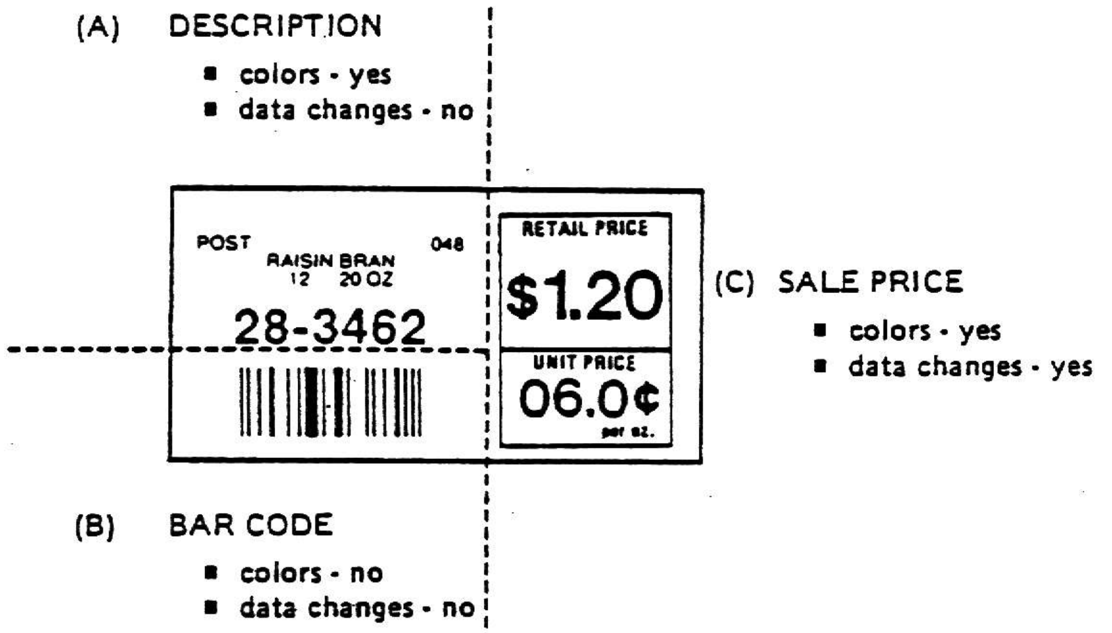


FIGURE 6.2 : BASIC LABEL FORMAT (23).

6.3 BAR CODE MATERIALS

The common requirement for all codes is that they should provide a contrast of light and dark areas. A presence or absence of a mark in a code is sensed by the code reader and interpreted in binary form. Combining eight of these information "bits" produces an eight bit word that is easily introduced as input to a computer, memory control, programmable controller, or some other type of logic control.

The bar code material may be reflexive in nature, such as retroreflective tapes, mirrors affixed to the containers, etc. The codes may be preprinted on the labels which are then applied to the containers. The bar codes may be printed on the product itself, as in case of packages.

The printing materials for codes include labels, tabs, ribbons, ink and transparent protective coverings. Using inappropriate materials for printing codes can prevent proper decoding of the bar codes.

A label and ribbon material should be chosen based on its compatibility with the printing equipment. Great care should be taken in selection of materials when high density codes need to be printed.

An important criteria in the choice of a bar code material is its durability. Factors like handling frequency and abrasion involvement should be considered along with the environmental conditions like heat, moisture, solvents, and chemicals. Along with these factors, the permanent or temporary nature of the codes should also be considered (9). Permanent codes are shipped along with the product after being scanned, and sorted. Removable or temporary codes are disposed of or reused after they have served their purpose of supplying information and/or prompting action. If the code is removable, the durability of the face material and the adhesive is not important. Face materials for the bar codes should possess special characteristics that will promote excellent adhesion, and bar code image resolution and stability.

Codes are generally printed on pressure sensitive labels. Such a label consists of five sandwich layers :

a) the backing paper which serves as a carrier and protects the adhesive from contamination,

b) the release lacquer which allows seperation of the label from the backing paper,

c) the adhesive consisting of varied formulations for permanence or removability under differing environmental conditions,

d) the primer which binds the adhesive to the face material, and

e) the face material into which the graphics and/or code is printed.

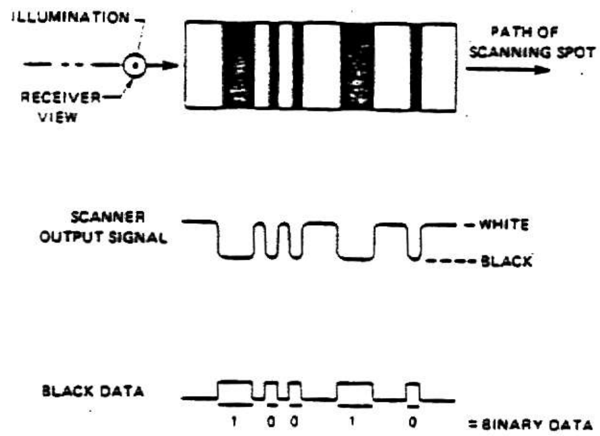
Mostly, high quality papers are used for labelling purposes. Plastic labels (made of vinyl,polyester or mylar) are used when heat, moisture and chemical environment prevent the use of paper labels. But the problem here is transluency of the plastic labels, which may sometimes affect the proper decoding of the code.

Some systems use simple low cost photosensors which read binary data from slotted metal plates. These may be mounted on slave pallets, towline carts, monorail carriers, power and free conveyors, or other captive transport services. After necessary information has been transmitted and/or verified, the slotted plate is removed for further use.

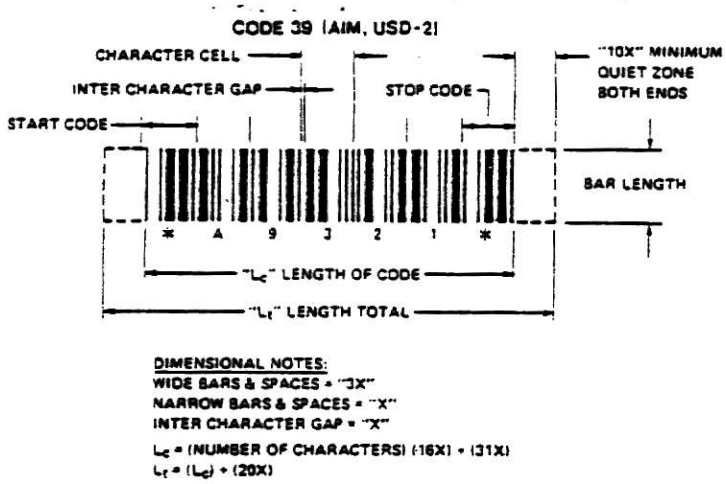
After having selected the materials, one should now choose a bar code. In the following section, the various aspects of the bar codes will be discussed in detail.

6.4 THE BAR CODE STRUCTURE

A bar code symbol is a graphic (printed or photographically reproduced) bar code composed of parallel bars and spaces of various widths. Figure 6.3A (21) shows a typical bar code symbol, which we shall refer to as a bar code in the future.



A) SAMPLE BAR CODE.



B) TYPICAL CODE FORMAT

FIGURE 6.3 : THE BAR CODE SYMBOL (21).

The bar codes offer key-entry bypass, keystroke elimination, factory data collection, increased productivity, accurate maintenance of inventory records, service level improvements, etc.

A bar code may contain one or more of the following information :

1. product description.
2. destination address.
3. size of the package.
4. size of the product.
5. department.
6. date of manufacturing, manufacturing lot number, etc.
7. name of the manufacturer.
8. pallet number.
9. move ticket number.
10. sale price, list price, unit price.
11. weight.
12. customer identification.

A bar code has quiet zones, start-stop zones and the code itself including a check digit if required (21). Figure 6.3B shows these bar code segments.

1. Quiet zones at each end of the code format permit the optical system to recognize the "black" from the "white".
2. "Start" and "Stop" zones in bar codes permit the electronics to decode the data properly, regardless of the direction from which it was scanned.

3. The code consists of wide and narrow bars and spaces. The ratio between the width of these wide and narrow elements is usually 2:1 or 3:1.
4. A module or the "X" dimension is the narrowest nominal bar or space in the code. The term module is used in UPC code whereas the "X" dimension is used universally for all other codes. Wide bars or spaces are specified as multiples of a module or "X" dimension. High density codes have small modules. An "X" dimension is probably the most important dimension and factor in a successful bar code symbol application and it is on this base level of reference that all comparisons have been made. It is selected to suit both the optical requirements of the scanner and the capability of the selected printing process.

   For High density codes, "X" = .010 inch or less
   For Medium density codes, "X" = approx. .020 inch
   For Low density codes, "X" = excess of .030 inch

   Figure 6.4 shows the values of smallest reliable "X" that can be printed by various techniques.

A code can be either of continuous or discrete type and a fixed beam scanner is capable of reading a code in two ways; sequentially or in parallel (22).

I) CONTINUOUS AND DISCRETE BAR CODES

In a continuous bar code, an intercharacter gap (or space) is a part of the code.

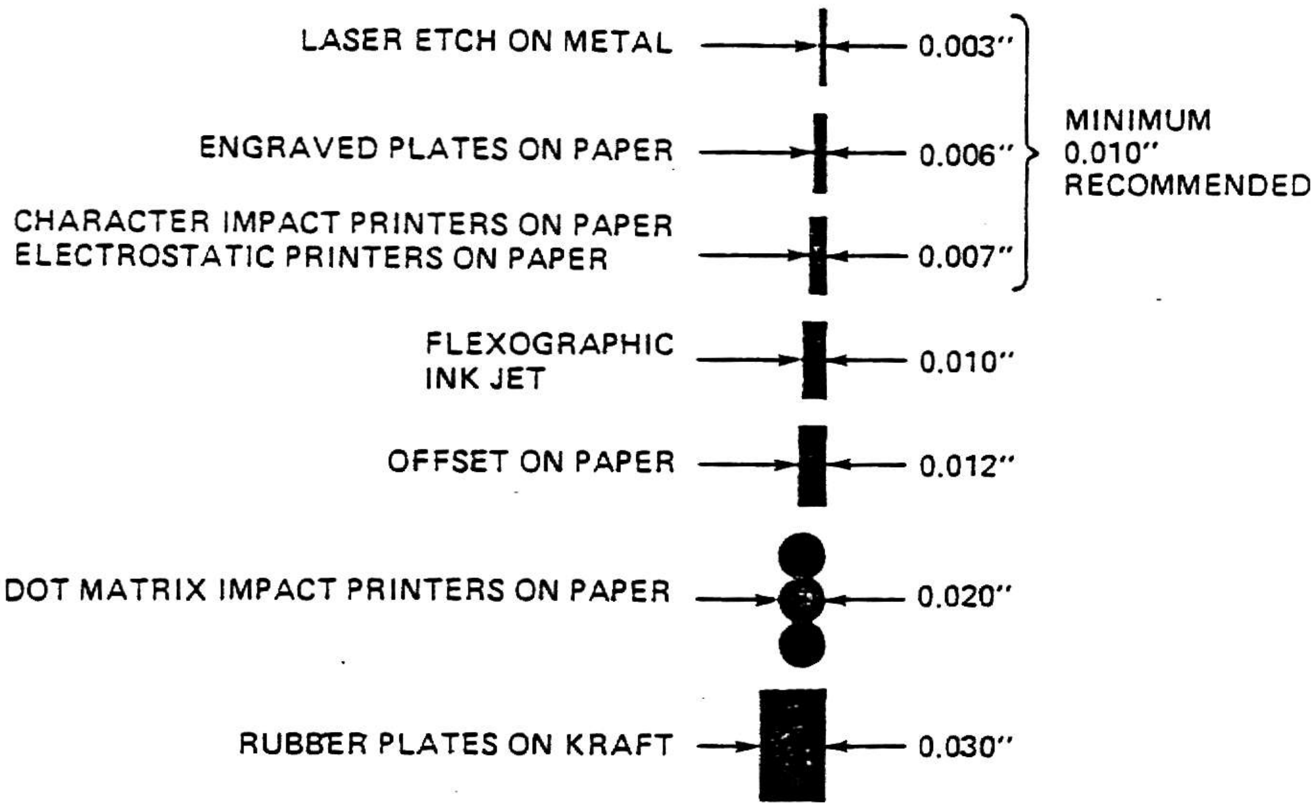


FIGURE 6.4 : SMALLEST RELIABLE "X" THAT CAN BE PRINTED BY VARIOUS TECHNIQUES. (21).

In a discrete type of bar code, the intercharacter gap is not a part of the character.

II) SEQUENTIAL AND PARALLEL CODE READING

In sequential code reading, the code marks are read one at a time on one or more code tracks. This format requires a scanner for each code track to be read and some type of memory or buffer to differentiate the marks, a bit at a time.

In parallel code reading, the entire code is read at one time. This requires a number of scanners, one for each mark to be read.

A) BAR CODE INTERPRETATION

Every character in a bar code has a unique combination of bars and/or spaces. Hence the information is encoded into the bars and/or spaces by varying their individual widths. The bar code interpretation (23) thus requires the comparison of these related bars and spaces. There are at least four types of bar to space relationship comparisons used in the interpretation of the bar codes.

1. Bar to bar module comparison (Two of Five). In this case, the combination of various bar widths is used to interpret a character. The spaces are ignored.
2. Light and dark bar to bar comparisons (Code 39). Here, bars and spaces together make up a character. (See Figure 6.8)

3. Bar to bar and space to space comparisons (Interleaved Two of Five) A combination of bars make up one character and a combination of spaces make up another character. The two characters are thus interleaved. (See Figure 6.6)
4. Combined light and dark bar to combined light and dark bar module comparison (UPC). A bar coded character is divided into two segments, a left hand segment and a right hand segment. A combination of bars and spaces on the left hand side of the character segment and the combination of bars and spaces on the right hand side of the segment together make up the character. (See Figure 6.11)

B) ALGORITHMS

The bar code can be decoded in many different ways. There are two algorithms (23) involved in the decoding process - a primary algorithm and a secondary algorithm. The primary algorithm is usually binary based and defines how "Ones" and "Zeros" are to be assigned to bars and spaces. Generally a narrow bar or a space is specified as a zero and a wide bar or a space is specified as a one. Applying the secondary algorithm to the primary algorithm gives the final decoded symbol.

Secondary alogorithm can be one of the following :

1. STRAIGHT BINARY

Each digit starting from right to left is multiplied by the ascending power of 2, beginning from zero. The code is the arithmetic sum of the above product, e.g.

$$1010100 = 0*(2**0) + 0*(2**1) + 1*(2**2) + 0*(2**3) + 1*(2**4) + 0*(2**5) + 1*(2**6) = 84$$

2. BINARY CODED DECIMAL (BCD)

This is similar to straight binary, except it is limited to four bits to represent a decimal digit, e.g.

$$1010 = 0*(2**0) + 1*(2**1) + 0*(2**2) + 1*(2**3) = 10$$

3. MODIFIED BCD

This is also similar to straight binary except it is limited to three bits. In addition, the fourth bit is multiplied by 7, e.g.

$$1010 = 0*(2**0) + 1*(2**1) + 0*(2**2) + 1*(7**1) = 9$$

4. LOOK UP TABLE

The primary algorithm is used as a pointer to a table containing the resultant characters. The secondary algorithm is the table.

Now that the structures have been described, the next section discusses the most prevalently used bar code types.

6.5 TYPES OF BAR CODES

A variety of bar codes have been developed by various users, companies, and commissions to suit various applications.

Figure 6.5 shows various bar codes and their alternate names. It should be noted that all Uniform Symbol Description (USD) codes were developed by AIM (Automatic Identification Manufacturers) which is a subdivision of the Material Handling Institute. The text in the following section has been compiled from references 2, 11 and 23.

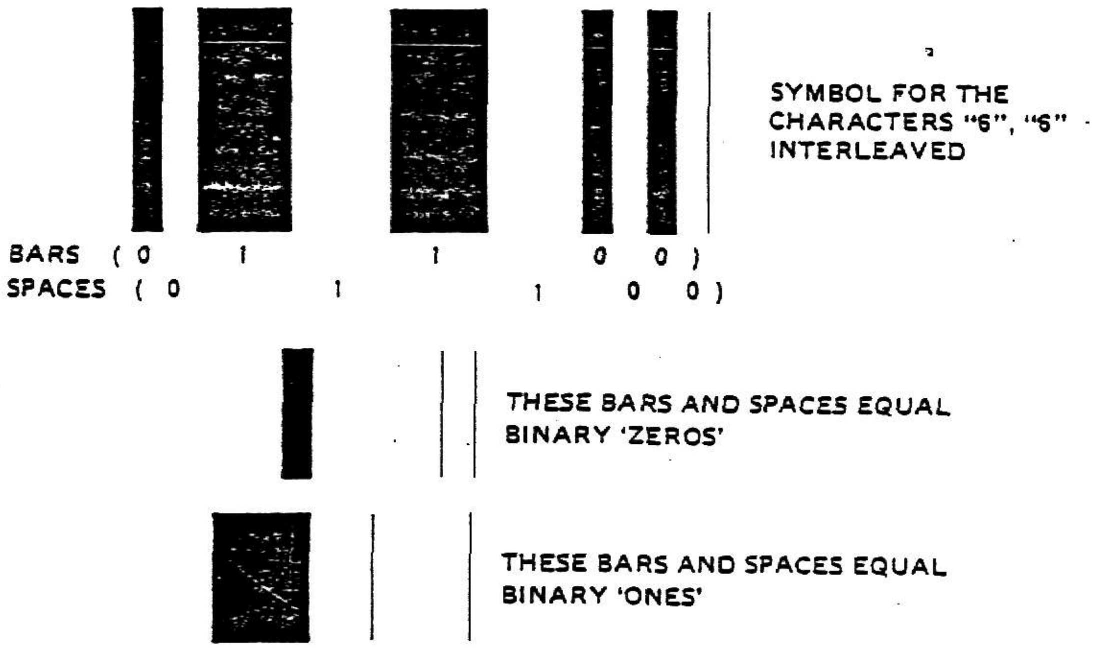
6.5.1 INTERLEAVED TWO OF FIVE (USD-1)

One character is made up of 5 bars, and the second character is made up of 4 spaces that seperate them plus the space following the last bar, i.e. a total of 5 spaces. The two characters are thus interleaved and hence the name Interleaved Two of Five. The primary algorithm is binary, applying to both bars and spaces. The bars and spaces are of two widths. A narrow bar or space is assigned a "0" and a wide bar or space is assigned "1". Figure 6.6A shows the bar code characteristics and Figure 6.6B shows the decimal conversion of the acceptable modified BCD codes. The start and stop codes are unique, thus permitting bi-directional scanning.

It is the most widely accepted numeric bar code and is used predominantly in warehousing, heavy industrial applications, automobile industries and in wholesale distribution of groceries.

Name of Symbols (Alphabetic order)	Alternate names
3-of-9 BAR CODE	CODE 39, USD-3
AGES	
Ames	
Anker Code	
AS-6	
AS-10	
Codabar	USD-4
CODE 11	USD-8
CODE 39	3-of-9 Bar Code, USD-3
CODE 93	USD-7
CODE 128	USD-6
Delta Distance A	
EAN-European Article Number	WPC, IAN
F2F	Norand
Fujitsu	
IAN-International Article Number	
Interleaved Two-of-Five	USD-1
Matrix Two of Five	
MSI Bar Code	MSI Plessey Code
Nixdorf Code	
Norand	F2F
Plessey Code	
RTC	
Telepen	
Toshiba	
Two of Five	
UPC-Universal Product Code	
USD-1	Interleaved Two-of-Five
USD-2	Subset of Code 39
USC-3	Code 39, 3-of-39
WPC-World Product Code	EAN-IAN

FIGURE 6.5 : VARIOUS BAR CODES AND THEIR ALTERNATE NAMES (2).



A) INTERLEAVED TWO OF FIVE BAR CODE CHARACTERISTICS

Decimal	Modified BCD
0	00110*
1	10001
2	01001
3	11000
4	00101
5	10100
6	01100
7	00011
8	10010
9	01010

	START CODE	STOP CODE
2 of 5 Interleaved	00	10

B) INTERLEAVED TWO OF FIVE CHARACTER SET.

FIGURE 6.6 : INTERLEAVED TWO OF FIVE (AIM USD-1) BAR CODE (23).

The following are the advantages of using Interleaved Two of Five code :

1. moderate print density.
2. variable length.
3. self checking.
4. can easily be seperated from graphics.

The disadvantages of using Interleaved Two of Five bar code are :

1. numeric only, used for simple systems.
2. even character length.

6.5.2 SUBSET OF CODE 39 (USD-2) AND CODE 39 (USD-3)

These codes are also known as Three of Nine. Each character is composed of 9 bars and spaces and three of every 9 successive elements are wide, hence the name Three of Nine. They have a unique start and stop code pattern which cannot be duplicated in any one or any adjoining character segments, thus permitting the bidirectional reading of variable length codes. Figure 6.7 shows a USD-2 code. USD-2 was derived from USD-3. To read a USD-2 code which is discrete, the scanner must read a bar and a space alternatively. Figure 6.8A shows the code characteristics of USD-3 and Figure 6.8B shows its character set.

These codes are broadly accepted in inventory control, monitoring work-in-process goods, wholesale distribution, hospitals, government agencies, libraries, and in corrugated shipping containers.

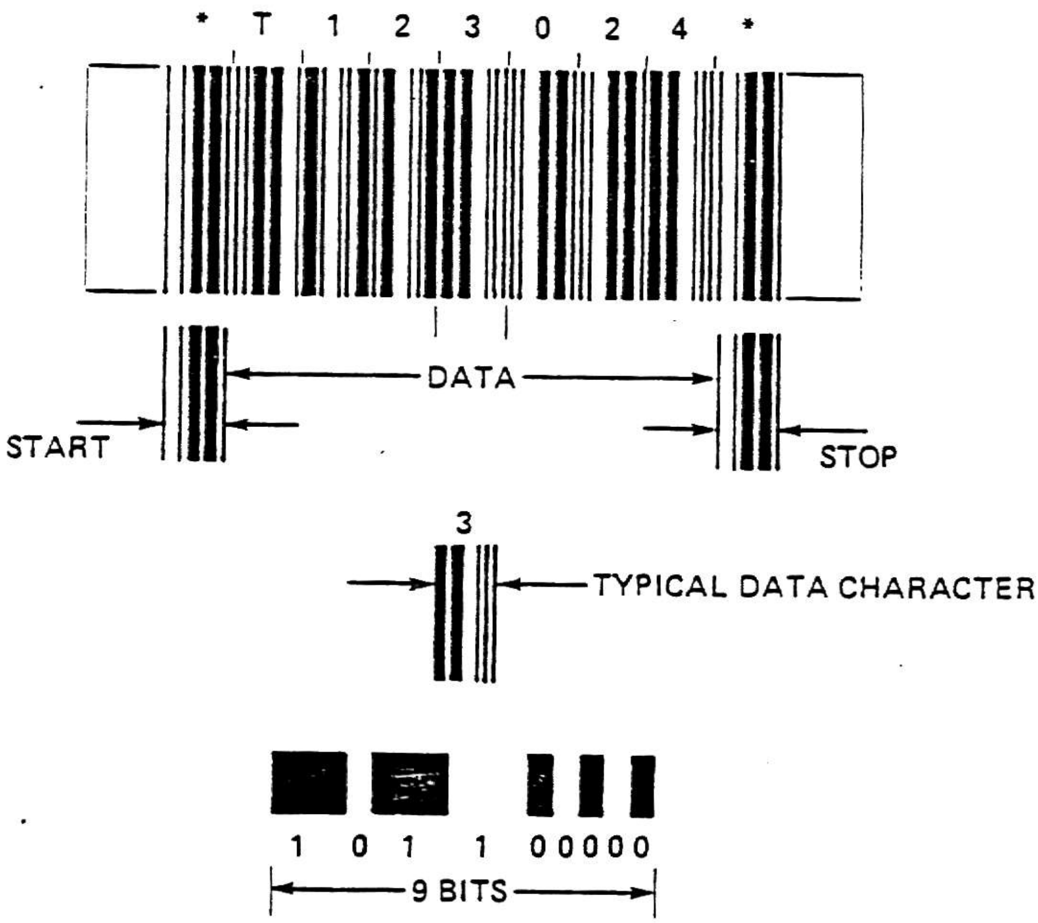
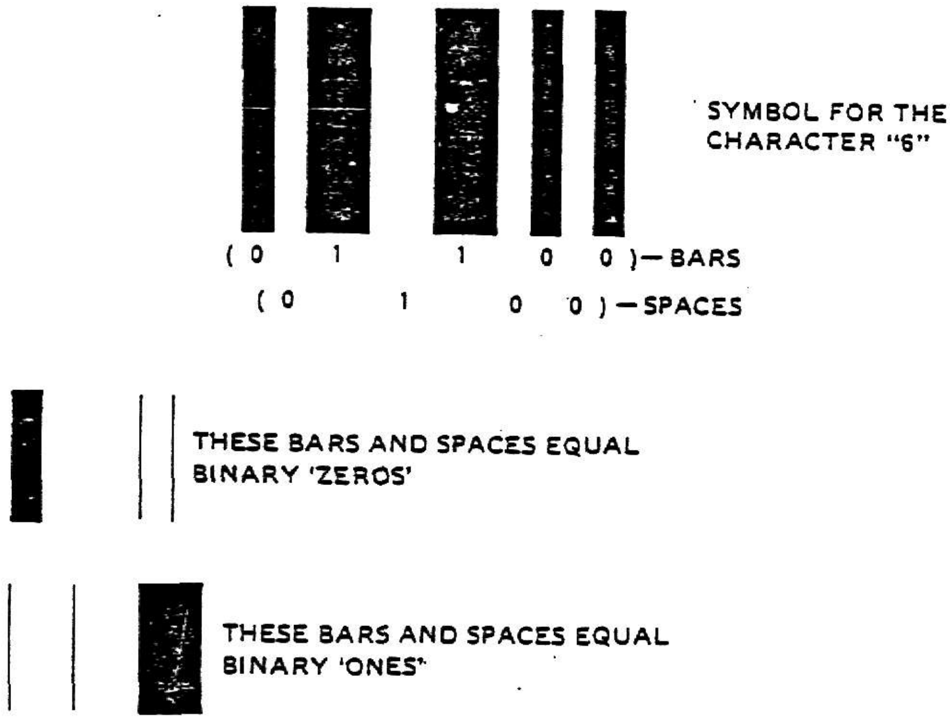


FIGURE 6.7 : CODE 39 (AIM USD-2) (21).



A) BAR CODE CHARACTERISTICS

Character	Bars	Spaces	Character	Bars	Spaces
1	10001	0100	M	11000	0001
2	01001	0100	N	00101	0001
3	11000	0100	O	10100	0001
4	00101	0100	P	01100	0001
5	10100	0100	Q	00011	0001
6	01100	0100	R	10010	0001
7	00011	0100	S	01010	0001
8	10010	0100	T	00110	0001
9	01010	0100	U	10001	1000
0	00110	0100	V	01001	1000
A	10001	0010	W	11000	1000
B	01001	0010	X	00101	1000
C	11000	0010	Y	10100	1000
D	00101	0010	Z	01100	1000
E	10100	0010	–	00011	1000
F	01100	0010	.	10010	1000
G	00011	0010	Space	01010	1000
H	10010	0010	$	00000	1110
I	01010	0010	/	00000	1101
J	00110	0010	+	00000	1011
K	10001	0001	%	00000	0111
L	01001	0001			

START: 00110 1000
STOP: 00110 1000

B) CHARACTER SET. FIGURE 6.8 : CODE 39 (AIM USD-3) (23).

The advantages of using USD-2 and USD-3 codes are :

1. alphanumeric, can be used for complex systems.
2. variable length.
3. does not require check digits.
4. easily seperated from graphics.
5. self checking.
6. bidirectional.

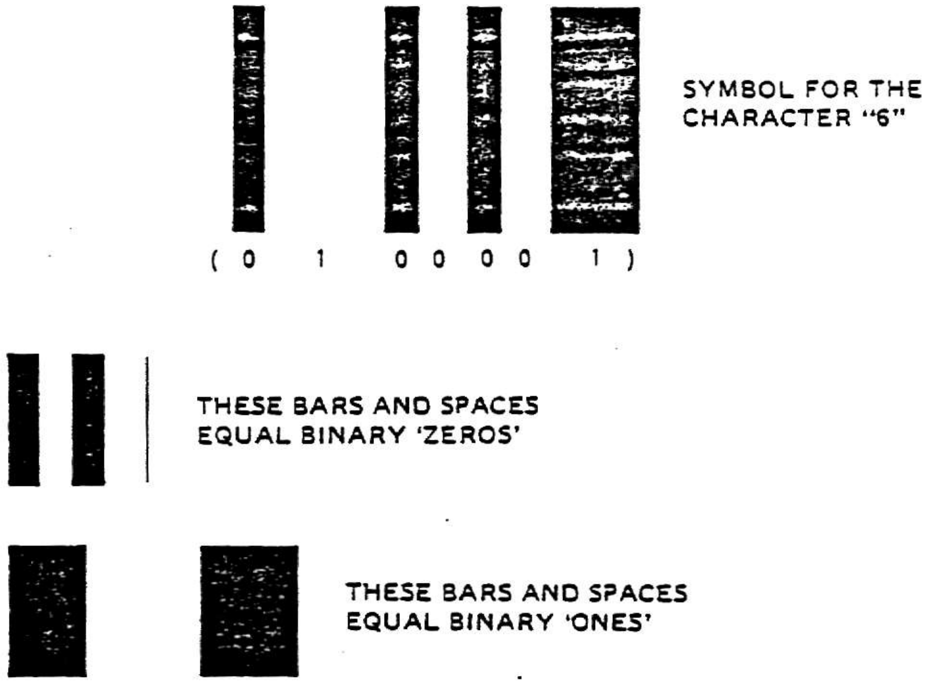
The following is the disadvantage of USD-2 and USD-3 codes :

1. dot matrix printers cannot accomodate high density specifications.

6.5.3 CODABAR (USD-4, CODE-A-BAR, TWO OF SEVEN)

The bars and spaces in Codabar are irregular and therefore cannot be considered in a modular makeup. The code is interpreted in terms of narrow bars and spaces, and wide bars and spaces. Each character is made up of seven elements, four bars and 3 spaces. Figure 6.9A shows Codabar characteristics and Figure 6.9B shows its character set. The primary algorithm is binary, and the characters are encoded through the look up table in Figure 6.9B.

It is used in libraries, medical applications and for photofinishing envelopes and preprinted air bills. To a lesser extent it has been used in industry.



A) BAR CODE CHARACTERISTICS.

Character	7-Bit Code	Character	7-Bit Code
0	0000011	:	1000101
1	0000110	/	1010001
2	0001001	.	1010100
3	1100000	+	0010101
4	0010010	a	0011010
5	1000010	b	0101001
6	0100001	c	0001011
7	0100100	d	0001110
8	0110000	5	0011010
9	1001000	n	0101001
–	0001100	*	0001011
$	0011000	e	0001110

B) CHARACTER SET. FIGURE 6.9 : CODABAR (23)

The advantages of using Codabar are as follows :

1. easily seperated from graphics.
2. variable length.
3. moderate print density.
4. can accomodate numeric as well as special characters.
5. self checking.

The disadvantage of using Codabar is as follows :

1. bar widths are not compatible with dot matrix printers.

6.5.4 CODE 128 (USD-6)

This code encodes 128 different data characters. It offers higher density (at constant size) than that of the established industrial symbols, but is achieved by sacrificing desirable properties. Each character is 11 units wide and consists of 3 bars and 3 adjacent spaces. Bars and spaces are 1, 2, 3 or 4 modules wide.

This code was established recently in the Fall of 1981. As a result, it has yet to gain wide acceptance. However, the following advantages of this code indicate its potential for wide acceptance in the future :

1. compactness, or higher density in modules per alphanumeric character.
2. capable of reading all ASCII characters.
3. self checking code.
4. alphanumeric.
5. variable length.

6. ignores ink spread and dot matrix overlap.

6.5.5 CODE 93 (USD-7)

Code 93 is a continuous type of code and each character in the code is 9 units wide and consists of 3 bars and 3 adjacent spaces. The advantages of this code are similar to those of Code 128 except that it can read only 56 of the 128 ASCII characters. Figure 6.10 shows the code 93 character set.

Like Code 128, this code was also established recently (in April 1982), but it is expected that this code will also become widely accepted.

6.5.6 CODE 11 (USD-8)

This code consists of 11 characters. Those characters are the 10 digits and the dash symbol. Each character consists of 3 bars with 2 included spaces.

The advantage of using Code 11 is :

1. high density code.

The disadvantages of using Code 11 are as follows :

1. not self checking.
2. numeric.
3. precise printing is essential else highly prone to error.

6.5.7 UPC AND EAN CODES

The bars and spaces in these codes are integer multiples of the module or the narrowest bar or space.

Character	Value (for Check Digit Purposes)	Pattern	Encodation	Character	Value (for Check Digit Purposes)	Pattern	Encodation
0	0		100010100	O	24		100101100
1	1		101001000	P	25		100010110
2	2		101000100	Q	26		110110100
3	3		101000010	R	27		110110010
4	4		100101000	S	28		110101100
5	5		100100100	T	29		110100110
6	6		100100010	U	30		110010110
7	7		101010000	V	31		110011010
8	8		100010010	W	32		101101100
9	9		100001010	X	33		101100110
A	10		110101000	Y	34		100110110
B	11		110100100	Z	35		100111010
C	12		110100010	-	36		100101110
D	13		110010100	.	37		111010100
E	14		110010010	Space	38		111010010
F	15		110001010	S	39		111001010
G	16		101101000	[illegible]	40		101101110
H	17		101100100	-	41		101110110
I	18		101100010	[illegible]	42		110101110
J	19		100110100	$	43		100100110
K	20		100011010	[illegible]	44		111011010
L	21		101011000	[illegible]	45		111010110
M	22		101001100	[illegible]	46		100110010
N	23		101000110	[illegible]			101011110

FIGURE 6.10 : CODE 93 CHARACTER SET. (2).

The bars and spaces can vary from one to four modules in width. Figure 6.11A shows the UPC/EAN characteristics and Figure 6.11B shows the character set. Each character is made up of two adjacent sections of bars and spaces. Each of these two sections contain 7 dark modules and 7 light modules. There are five versions of UPC code and two versions of EAN code. The encoding of all versions is the same. However, the configuration of the character set in each version may be different.
These codes are excellent for use in supermarket point of sale systems and related applications.

The advantages of using UPC/EAN codes are as follows :

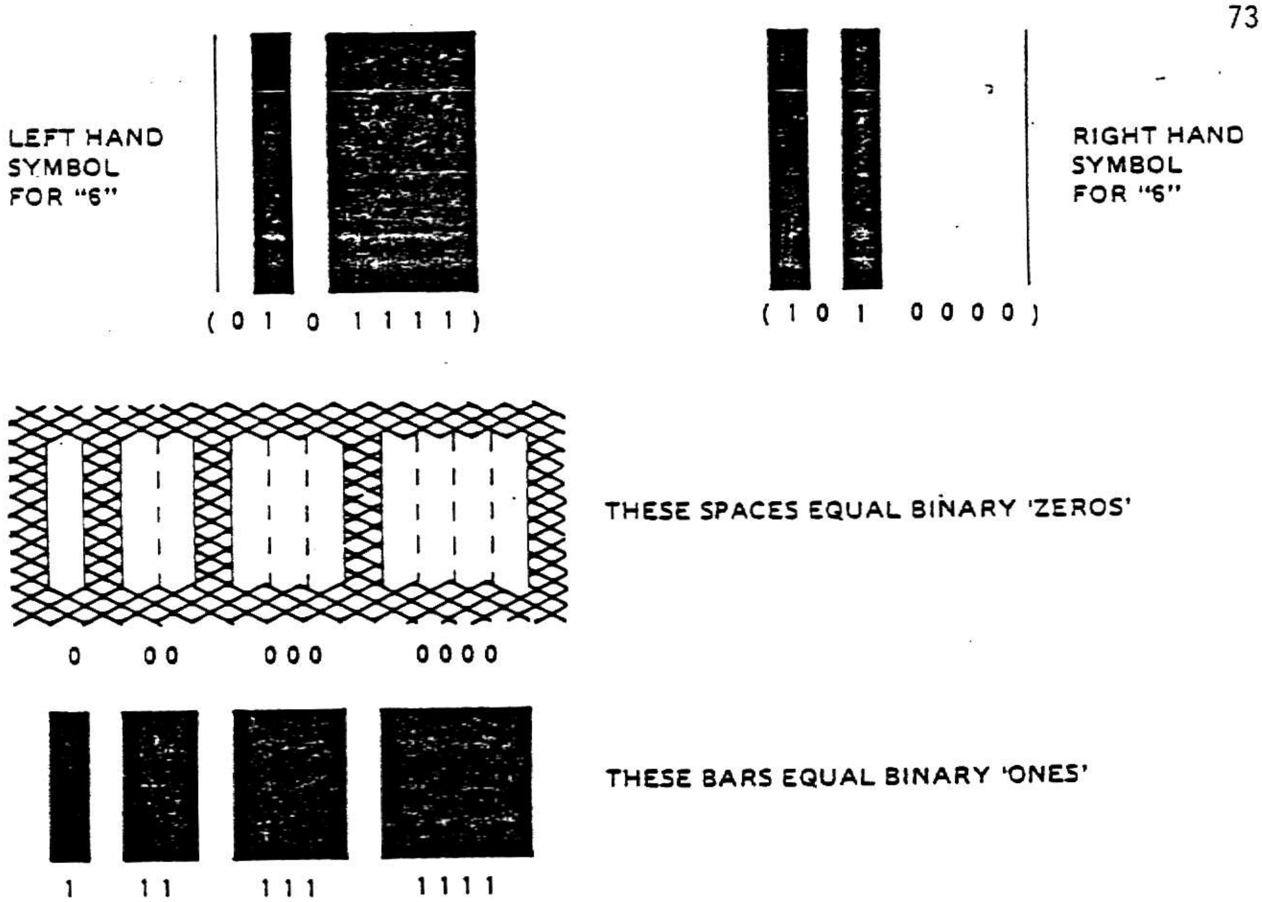
1. tolerant to specifications.
2. less sensitive to print flaws.
3. easily seperated from graphics.

The disadvantages of using UPC/EAN codes are the following :

1. numeric only.
2. fixed lengths of 6 or 12 information characters (8 to 13 for EAN).
3. requires a check digit.
4. controlled usage.

6.5.8 MSI

In this code, each character is composed of four data bits. The primary algorithm is binary and is applied only to the dark bars. The secondary algorithm is BCD.



A) UPC/EAN CODE CHARACTERISTICS.

Decimal Character	Left Characters (odd parity)	Right Characters (even parity)
0	0001101	1110010
1	0011001	1100110
2	0010011	1101100
3	0111101	1000010
4	0100011	1011100
5	0110001	1001110
6	0101111	1010000
7	0111011	1000100
8	0110111	1001000
9	0001011	1110100

B) CHARACTER SET.

FIGURE 6.11 : UPC/EAN BAR CODE. (23)

Figure 6.12A shows the MSI code characteristics and Figure 6.12B shows the MSI character set.
This code is primarily applied to shelved items in retail stores. Subsequently scanning these codes with a portable device helps in achieving inventory reordering. The MSI Code has been used extensively in libraries.

The advantages of using MSI Codes are :

1. simple specifications.
2. easily printed with dot matrix.
3. variable length.

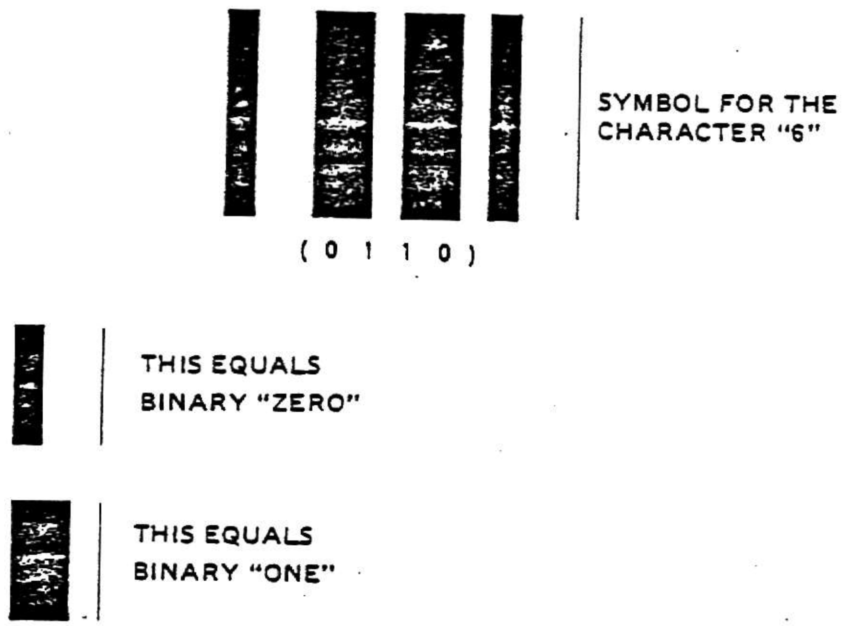
The disadvantages of using MSI Codes are :

1. sensitive to print flaws.
2. requires 2 check digits.
3. numeric only.
4. low print density.

6.6 GENERATING BAR CODES

After having selected the bar code, the designer should now decide on how to generate the code. Bar code generation falls into three categories : batch, sequential and random.

In batch generation all the codes have the same value. The codes are sequentially numbered in sequential generation. Batch and sequential labels can be preprinted off-line or generated on-line with a keyboard activated variable printer.



A) BAR CODE CHARACTERISTICS.

Decimal	BCD
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
Start Symbol	1
Stop Symbol	0

B) CHARACTER SET.

FIGURE 6.12 : MSI BAR CODE (23).

Off-line printing may lead to problems in finding the right label at the right time.

Random generation is adopted to give unique codes to items. It is usually performed on-line with input from a computer. Random code printers are the most complex ones and can be preprogrammed to print bar codes, human readable information or a combination of both.

6.7 BAR CODE PRINTING

In this section, the various printing processes will be described briefly. Figure 6.4 (21) shows the most reliable "X" that can be printed by various techniques. It is on this basis that one should select a particular printing process. This section has been developed from references 19 and 21.

6.7.1 CONVENTIONAL BAR CODE PRINTING METHODS

These processes are most economic for large production quantities of single products, but require prepurchase and scheduling for use.

There are three conventional methods of printing codes :

A) Offset.

B) Letter press.

C) Flexographic.

A) OFFSET

In this process a flat image is first transferred to a rotating drum. As the drum rotates, ink from a container is automatically applied to the image on the circumference of the drum. This inked image is then transferred to the paper label material. It is a sheet-fed process capable of producing at rates of 26-50 feet in a minute.

B) LETTER PRESS

In this method, raised images of the information to be printed on the label are relief etched on flat plates. The plates are inked and then transferred to the label stock. The typical feeding rate of stock is 25 feet of sheet per minute.

C) FLEXOGRAPHIC

A raised image on a polymer or rubber plate is wrapped on a cylinder. The plate is inked as it rotates and transfers the image to the paper which is fed at about 200 feet per minute. Most of the flexographic machines have multiple print stations for printing different colors on label. They can also cut the finished label to its proper size and shape. Label vendors selling preprinted bar codes generally use this printing process. The implementation of minicomputer and microcomputer controlled plotters have eliminated the distortion problem occuring on the elastic plate in the flexographic process. This printing also prevents the ink spread.

6.7.2 LATEST METHODS IN BAR CODE PRINTING

Most of these utilize a microprocessor to control a printing mechanism which can print human readable characters and bar codes. These printers can either be keyboard operated or be interfaced to material handling equipment, weigh-in motion scales or host processors to produce bar code labels when required. These new printers have the advantages of :

1. printing identification labels on demand,
2. providing variability in size of the bar codes and human-readable text,
3. ability to include illustration graphics and logos, and
4. ability to communicate with other machines and computers.

Latest methods in bar code printing include the following :

A) Preformed character impact printing.

B) Electrostatic printing.

C) Dot matrix printing.

D) Ink jet printing.

E) Laser etching.

A) PREFORMED CHARACTER IMPACT PRINTING

The printer used in this method is similar to a typewriter. It uses a carbon ribbon to make a mark on label stock. A rotating drum has a raised image of the characters and the bar code elements engraved on it. The ribbon and the label stock pass between a hammer mechanism and this rotating drum. As many as 100 labels (paper, vinyl or mylar) can be printed per minute.

A microprocessor interfaced to the printer performs the following functions :

1. it selects the image element to be imprinted and controls the hammer to impact on the element at the right time.
2. it controls the ribbon and the label movement in an incremental motion.

B) ELECTROSTATIC PRINTING

In electrostatic printing, images on the label material are formed with powder ink and fused with heat to bond the image to the label.

Characters are formed on the surface of a rotating drum by patterns of electrical charges generated by a microprocessor controlled character generator. As the drum rotates, the electrically charged patterns are coated with dry powdered ink or toner. When the drum contacts the label material, the dry ink is transferred to the top surface of the label. Either the ink powder or the label material has been provided with a binder or adhesive, and when the label is transported to the heater, it reacts with the heat to fuse the ink to the substrate surface.

These printers are used as on-line demand printers, receiving instructions from either manual keyboard entries or data interfaces from scales and host processors. High quality bar codes are printed with speeds of about 15-25 feet per minute.

C) DOT MATRIX PRINTING

This process produces human-readable information and bar codes by selective printing of overlapping dots with an array of individual pins striking an ink ribbon against paper labels.

These printers generally do not have integral keyboards and are employed remotely from their instruction terminal or host processor. They can be easily interfaced to other system elements.

D) INK JET PRINTING

In this method, each ink drop is directed to a position in a matrix by electromagnetic field deflection. This printing can be done in two ways.

In one design, the "wanted" drops are electrically charged and directed to the paper forming the individual characters.

In another design, the "unwanted" drops are electrically charged and directed away from the paper.

In this method, the printing rates are as high as 800 feet per minute. Bar codes and human-readable text can be generated from a minimum "X" dimension of .010 inch to as large as .010 + .008N inches where N is an integer.

E) LASER ETCHING

Engraving bar codes on metallic or non-metallic substrates is called laser etching and it is an evolving technology. The marking is permanent and is most practical when permanent bar codes need to be printed with permanent human readable text on metallic or non-metallic surfaces.

Because of the harm that a laser beam can do to a human being if in direct contact, proper care should be taken to enclose the laser etching station. This will prevent accidental misdirection of the beam into a human work area.

6.8 BAR CODE RELATED ORGANIZATIONS

Various organizations have been involved in research for setting bar code standards, identifying applications, etc. for different industries. They are briefly described below (4, 17).

1. AUTOMATIC IDENTIFICATION MANUFACTURERS (AIM)

AIM is a subgroup of the Material Handling Institute. Leading bar code companies are members of this organization. They have developed the USD (Uniform Symbol Description) codes ranging from USD-1 through USD-8.

2. DOD (DEPARTMENT OF DEFENSE) LOGMARS (LOGISTICS APPLICATION OF AUTOMATIC MARKETING AND READING SYMBOL) PROGRAM

They have developed exhaustive data relating to bar code technology, including test results for bar codes and scanning devices. They published the standards MIL-STD 1189 and MIL-STD 129H.

3. UPC (UNIFORM PRODUCT CODE) CASE SYMBOL PROGRAM

Formerly it was known as UCS (Uniform Case Symbol) and it was the result of years of work conducted by DSSG (Distribution Symbology Study Group). UPC recommended the use of Interleaved Two of Five for shipping containers carrying the UPC (the supermarket code). DSSG recommended that Code 39 should be used for representing alphanumeric data on corrugated containers.

4. ANSI (AMERICAN NATIONAL STANDARDS INSTITUTE)

This institute published the article "Specifications for bar code symbols on Transport Packages and Unit Loads". This publication contained three codes of which Code 39 was the only alphanumeric code.

5. AIAG (AUTOMOTIVE INDUSTRY ACTION GROUP)

It is comprised of professionals from APICS (American Production and Inventory Control Society) and enjoys the support of all major U.S. auto manufacturers. It has identified the following application of bar codes in the automotive industry :

1. manufacturing process monitoring.
2. broadcast component requirements.

3. assembly verification.
4. production status reporting.
5. shipping and receiving.
6. inspection.
7. warehouse storage.
8. AISS.

They found that the bar code presented a great potential in the exchange of information between manufacturers and dealers, e.g. warranty claims, recalls, and product quality and availability.

6.9 BAR CODE APPLICATIONS

Apart from AISS the following are the bar code applications (18) :

1. tracking work-in-process.
2. controlling inventory.
3. inventory checking and recording.
4. controlling quality.
5. controlling engineering changes.
6. controlling shipping.
7. employer identification.
8. controlling and retrieving documents.
9. capital asset accounting.
10. freight management.
11. lottery ticket control.
12. meal service accounting.
13. piece work payroll.

14. process parameter input.
15. radiation badge accounting.
16. rental equipment control.
17. retail point-of-sale control.
18. security access.
19. specimen identification.
20. warehouse control.

7. SORTING EQUIPMENT

After having identified the product, it should be sorted when it reaches the destination. Sorting can either be done manually or automatically as in AISS. In manual sorting, the worker reads an address on each case and physically pushes the case to its destination. Manual sorting permits a sorting rate of only 15-25 cases per minute and is highly labor intensive. Therefore, manual sorting is more expensive than automatic sorting.

Sorting is done automatically in AISS. After the computer has determined the destination for the product, the computer monitors the path of the product as it moves along the conveyor. When the product reaches its destination, the computer actuates the diverter, so that the diverter can physically sort the product to the accumulation lane. In AISS, sorting rates of more than 100 cases per minute are often observed.

The diverting mechanisms may be either built-in as in the case of a tilting tray conveyor, or they may be made up of components like pusher diverters on roller conveyors.

Several types of mechanically powered sorting devices are available, from paddle pushers to pop-up wheels. Figure 7.1 (16) shows the characteristics of the most commonly used diverters.

In addition to diverting products by mechanical devices, pneumatic based diverters and electrical or electronically based diverters are also used for sortation.

Type of diverter	Maximum sorts per minute	Load range (lb)	Type of code reader	Type of encoder	Minimum distance between spurs (ft)	Impact of diverter on load	First cost	Maintenance cost
Manual	15-25	1-75	Visual	Manual	Touching	Gentle	Lowest	Lowest
Pusher	30-35	1-75	Visual automatic	Keyboard, voice, scanner	5-7	Medium	Low to medium	Low
Puller	30-40	10-100	Visual, automatic	Keyboard, voice, scanner	2-3	Medium to rough	High	Medium
Rotating paddle pusher	50-70	1-75	Visual, automatic	Keyboard, voice, scanner	9	Medium	High	High
Chain in pusher/roller conveyor	50-70	1-75	Visual, automatic	Keyboard, voice, scanner	Touching	Medium	High	High
Pop-up roller	15-20	10-200	Visual, automatic	Keyboard, voice, scanner	Almost Touching	Gentle	Low to medium	Low
Pop-up wheels	65-150	3-300	Visual, automatic	Keyboard, voice, scanner	4-5	Gentle	High	Medium
Tilting tray or slat	65-300	1-300	Visual, automatic	Keyboard, voice, scanner	7	Medium to rough	Very High	High

FIGURE 7.1 : SORTING EQUIPMENT (16).

In pneumatic based sortation, the product can be diverted either by an indirect impact between the diverter and the product, or by a direct impact.

In indirect impact, the compressed air is blown over the product to divert it. In direct impact, the compressed air is used to power a pneumatic arm which diverts the product.

Solenoids and electrical gates fall in the category of electrical and electronically based diverters. Solenoids give high sorting rates. Normally, their stroke lengths are of the order of a few inches only and they provide a strong impact. Commercially available solenoids cannot be used for diversion and so when one wishes to use solenoids, one has to order very special types of solenoids which may be very expensive. Electrical gates rotate when actuated and the product lying on the gate is pushed down by gravity to the chute.

While selecting a suitable diverter for the system, the following factors should be considered carefully :

1. maximum sorting speed,
2. minimum spacing between accumulation lanes, particularly when a space constraint exists, and
3. load impact.

The impact between the sorter and the item is important when fragile or lightweight goods are handled. Once a sorter has been selected to suit the system's requirements, the designer has to determine the minimum interproduct gap. This distance should be such that the action of the diverter on one case at a particular time should in no way interfere with the movement of its neighbours.

Now that all the elements of an AISS have been reviewed, the factors that need to be taken into account while designing an AISS will be considered in the next chapter.

8. SYSTEM CONSIDERATIONS

Many factors need to be considered (2, 4, 12, 14, 18, 21, 25) in designing an AISS. In the following discussion of factors, the chapters indicated in parenthesis provide further details on those particular factors.

1. Data collection and analysis. Proper data related to the system should be accurately maintained. This data should be used in the simulation studies of the proposed system design.
2. Choice of a conveying system. The following should be considered:

   i) Type of conveyor : The conveyor can be an overhead conveyor, belt driven conveyor, etc. A conveyor should be selected based upon the space constraints, the characteristics of the product being transported such as weight and temperature, etc.

   ii) Size of conveyor : The conveyor should be big enough to transport the biggest object. If a push type diverter is used, then the conveyor size should be compatible with the stroke length of the diverter. This diverter must also meet the requirements of the desired sortation speed of the system.

   iii) Speed of the conveyor : The operating speed of the conveyor should be less than the response speed of the scanner. The conveyor speed should also match the requirements of the desired sorting speeds. The conveyor can either have a constant speed drive, or a variable speed drive. (Chapter 3)

3. Choice of system control. A system may be

i) controlled by a microcomputer,

ii) controlled by a minicomputer, or

iii) locally controlled by a microcomputer with minicomputer as the host computer.

The choice of a particular computer is also governed by the size of internal memory required to process the data, and the size of the auxiliary memory required to store the data. (Chapter 4)

4. Data communication requirements. This is related to how an AISS is to communicate with the host computer. This can be done as follows :

i) Real-time communication : The data is transmitted to the computer as soon as it is collected. In this situation, most of the decisions (like actuating a diverter, etc.) are made by the host computer.

ii) Batch communication : Data collected by the local computer is sent to the computer after significant intervals of time, e.g. 4 hours, 8 hours, etc. The main decisions are taken by the local computer.

iii) A combination of Real-time communication and Batch communication : Here the local computer collects the relevant data in batches till polled again by the host computer. The polling is done whenever the host computer is ready to take the data from the local computer. Here also, as in the batch communication case, the decisions are taken by the local computer.

The data collected locally is transferred in batches. In this sense, it has the overtones of a batch communication. This transfer also has the overtones of a real-time communication since it takes place in seconds or fractions thereof.

5. Encoding technique. Codes can be entered into the memory by keyboard, voice or automatic input. (Chapter 5, Sections 5.1, 5.2)
6. Choice of an Identifying Equipment. An object can be identified by a scanner, photocells, CCD, weigh-in-motion scale, etc. (Chapter 5, Section 5.2)
7. Choice of a light source for scanners and photocells. Either an incandescent light or an LED can be used as a light source. (Chapter 5, Section 5.2.2.1)
8. Location of the scanning unit with respect to the object. The location can either be direct or remote. (Chapter 5, Section 5.2.2.1) If the location is direct, then the unit can be placed either above or at the side of the conveyor.
9. Choice of scanning techniques. One or more of the following scanning techniques can be selected : retroreflective, through beam, specular reflective, and diffused reflective. (Chapter 5, Section 5.2.2.1)
10. Choice of type of scanner. A scanner can be a fixed beam scanner, moving beam scanner, laser scanner, fiber optic scanner, or an omnidirectional scanner. (Chapter 5, Section

5.2.2.1)

11. Interspace of a monitoring device. Usually photocells are used as monitoring devices. As the distance between two consecutive monitoring devices tends to zero, continuous monitoring is achieved at the expense of more photocells. If the spacing is increased, then fewer photocells are used. However, the monitoring becomes discrete.

12. Label design. Factors like data contents, operating environment, selection a bar code, etc. should be considered. (Chapter 6, Sections 6.2, 6.5)

13. Generation of the bar code. The following should be considered :

    i) Batch, Sequential or Random generation. (Chapter 6, Section 6.6)

    ii) Manual versus automatic entry of the codes to the printer. (Chapter 6, Section 6.7.2)

14. Bar code printing. The following factors should be borne in mind :

    i) Bar codes can be printed on-line where the labels are printed and applied to the product as they move along the conveyor. The labels can also be printed off-line. In off-line printing, the codes can be printed in the plant itself or be bought from vendors.

    ii) If the code material is cheap then impact printers cannot be used. However if the material is of good quality, impact prirters can be used.

    iii) Character printer versus line printer.

iv) Either conventional printing processes (providing no interface to the computer) or sophisticated printing processes (providing computer interface) can be used to serve the purpose of printing the codes as well as human readable information. (Chapter 6, Section 6.7)

15. Presentation of the symbol with respect to the scanner. The presentation can be tilted, pitched, or skewed. (Figure B.1, Appendix B)

16. Orientation of the symbol on the object. The orientation can be either ladder (where the bars and spaces on the label are parallel to the surface of the conveyor), or pitch fence (where the bars and spaces on the label are perpendicular to the surface of the conveyor).

17. Location of the bar code symbol on the object. If fixed beam scanners are used, the location should be so chosen that it should be unique for all the variety of products that need to be sorted, i.e. same symbol elevation for all objects. However, if a moving beam scanner is used, then the symbols can be placed anywhere within the scanning area of the scanner.

18. Selection of a minimum distance between the two products along the conveyor. This distance should be such that the sortation of one item should not affect the movement of its neighbors.

19. Design of accumulation lanes. Here, the designer should consider the number of lanes the system should have, and the distances between each of these lanes.

20. Type of sorter. In this case, the desired sortation speed, the minimum distance between accumulation lanes, and the impact of the sorter on the items should be considered.

21. Destination lane assignment. Here, the designer should be concerned with the assignment of destination to the item. In some cases, where a choice of multiple destinations for the same product exists, the designer may consider either meeting the requirements of one lane at a time, or uniformly feeding each destination.

22. Handling of error conditions and recovery. Here the system designer is concerned about how the system should respond to error conditions. These conditions may occur due to the following reasons :

    i) The codes scanned by the scanner may be misread, invalid, etc.

    ii) A lane may become full while being fed.

    iii) A jam-up may occur along the coveyor.

23. System cost. One should consider the one-time cost of installation, integration and training. In addition, recurring costs in maintenance and repair should also be considered.

24. System expansion and growth. The designer should choose a system design that provides for vertical integration and horizontal expansion.

9. DESIGN AND SETUP

A laboratory model of an AISS was designed, fabricated, and implemented. Due to financial constraints, it was decided that the total cost of system should be as low as possible. The cheapest commercially available identifying equipment is a photocell. Hence it was decided to use the photocell for the purpose of identification. As discussed in Chapter 5, Section 5.2.1, the photocells can be used as identifying equipment only when the products can be identified by their difference in heights. Thus it was decided to set up an AISS which sorted products by heights.

Two objects of different heights were chosen. The objects were cardboard boxes. The bigger boxes were 20 cms long, 4 cms wide and 13.5 cms high. The smaller boxes were 14 cms long, 7 cms wide and 6 cms high.

A small belt-driven conveyor was used to move the boxes. The motor of the conveyor was connected to a rheostat so that the speed of the conveyor could be varied.

As discussed previously, the photocells were used as identifying equipment as opposed to a scanner due to economic reasons. These photocells were Cadmium Selenide photocells. Two photocells were used to identify the two products.

A single incandescent lamp was used as a light source, and was placed by the side of the conveyor. The photocells were aligned opposite to this source in such a way that when the small object passed through the light beam, only the bottom photocell was blinded. However, when the larger object passed, both the top and bottom photocells were blinded. The bottom photocell was placed 3 cms above the conveyor, and the top photocell was placed 9.5 cms above the conveyor. (The smaller object was 6 cms high and the larger object was 13.5 cms high.)

A circuit for the photocells was designed in such a way that each photocell gave 5 volts in the presence of light and 0 volts in the absence of light. This circuit is shown in Figure A.1 (I) in Appendix A.

An MMD-1 microcomputer was used to control the system. MMD-1 is an 8080A microprocessor based microcomputer. It contains a built-in keyboard that permits one to load programs into the microcomputer. It has twenty-four lamp monitors that represent the three output ports. The breadboarding socket on the top permits one to construct interface circuits to the microcomputer.

Instead of designing and installing a diverter, it was decided to merely demonstrate the principle of sortation. An inexpensive solenoid was therefore used to demonstrate the principle of sortation. The photocells were placed 30 cms away from this solenoid. The solenoid operated at 12 volts DC while the microcomputer was capable of only giving a 5 volt output. Hence a circuit was designed so that a 5 volt output from the MMD-1 actuated the solenoid connected to 12 volts. This circuit is shown in Figure A.1 (III) in Appendix A.

The specifications of the various equipment used in the laboratory model is shown in Figure A.2 in Appendix A.

9.1 SYSTEM ASSUMPTIONS AND CHARACTERISTICS

The system characteristics are as follows :

i) photocells are as close to the diverter as possible, and

ii) one transaction is processed at a time.

It was decided to place the photocells as close to the diverter as possible. This helped to make an important assumption that the speed of the object on the conveyor remained constant when the object traversed the distance between the photocells and the diverter. The distance between the photocells and the diverter was then limited by the largest length (the dimension of the object which corresponds to "x1" in Figure 9.1) of the object. Thus the minimum distance between the photocells and the diverter should at least be greater than the object with the largest "x1".

It was also decided to process one transaction at a time. Processing a transaction in the designed model requires the system to identify a product, determine the action to be taken, and carry out the action. This brought about another limitation in the system. The minimum distance between the objects (product to product interspace) should at least be greater than the distance between the photocell and the diverter.

No devices were used to either monitor the path of the product or to account for the variation in the speed of the conveyor as the product travelled along the conveyor. This was because of the fact that the above mentioned two characteristics ruled out the necessity of using a monitoring device.

In the model, one object was 20 cms long and the other object was 14 cms long. The conveyor was 300 cms long. It was decided to place the photocells at a distance of 30 cms from the diverter. The product to product interspace was selected to be 40 cms.

9.2 SOFTWARE LOGIC

When one wishes to estimate or compute the real time for various functions in an AISS, one has to first define a system time unit. This system time unit is really the reciprocal of the frequency at which the microcomputer monitors the status of the photocells. The elapsed real time is measured in system time units. The estimated or computed real time can then be expressed as an integral multiple of the system time unit. Henceforth, the system time unit will be referred to as the time unit. The smaller the selected time unit, the better is the accuracy. But in microcomputer programming, one cannot choose very small time units. If small time units are chosen, the arithmetic computations may give abnormally large values which cannot be stored by the registers in the software. In the MMD-1 microcomputer, each register can store a maximum of 8 binary bits, i.e. a maximum decimal value of 255.

The software was designed in such a way that a provision was kept to vary the time unit as desired. First of all, a reasonable range for the system time unit was selected for the system. This range was arrived at in such a way that when the time units within that range were used, the values of the various registers involved in the computation at no time exceeded the decimal value of 255. This range was 1/25 second to 1 second.

After the system was installed, a specific time unit of 1/9 second was chosen from the above acceptable range by trial and error. This time unit was established by varying the conveyor speeds for a particular time unit within the range, and then observing the efficiency of the sorter activation. The nearer the object was to the diverter when the diverter was actuated, the better was the time unit.

The system time unit (1/9 second) thus established was used to calculate the time to elapse before the diverter was to be actuated. This time to elapse was based on the speed of the conveyor, the distance between the photocells and the diverter, and the length of the object. Figure 9.1 shows the derivation of the formula that was used to compute the time to elapse before actuating the diverter.

Before starting the system operation, the following should be specified.

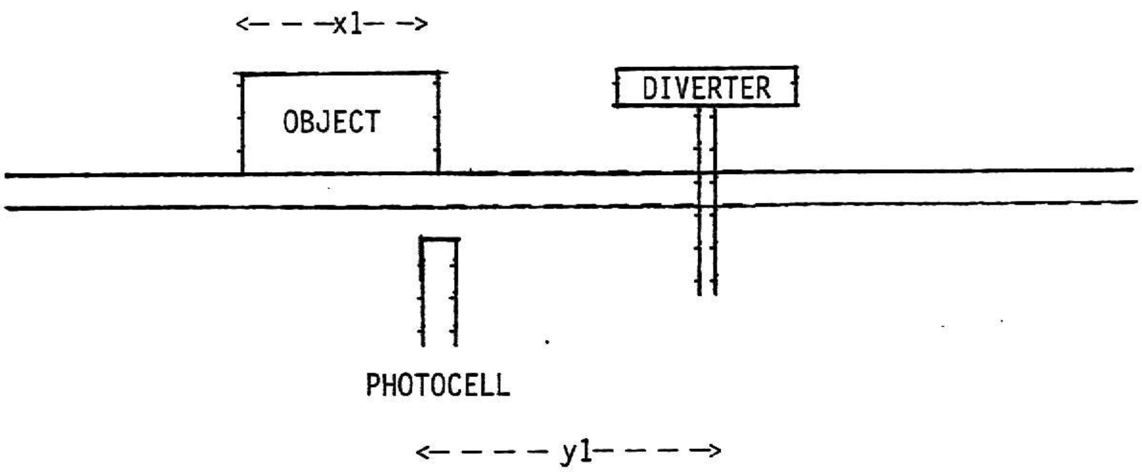
1. The characteristics (in this case, the height) of the object to be sorted.
2. The distance that the object to be sorted has to travel from

x1 = size of the object in cms.

y1 = distance of the sorter from photocell (30 cms).

t = time units the object needed to pass the photocell.

t1 = time units after which the diverter has to be actuated.



y1-x1/2 = distance in cms the object needs to travel after having noted "t".

x1/t = speed of the object in cms/time unit.

$$t1 = \frac{(y1 - x1/2) * t}{x1} \quad \text{time units.}$$

FIGURE 9.1 : DERIVATION OF FORMULA USED FOR THE DESIGNED SYSTEM SOFTWARE

the time it passes the photocell to the time when it reaches the diverter.

3. The length of the object.

The following explains the logical sequence of steps in the functioning of the designed system.

1. The system constantly checks to see if any product on the conveyor needs to be identified.
2. A product passing in front of the photocell triggers the system to uniquely identify it.
3. After the identification, the system decides whether to sort the product or not.
4. The system then constantly monitors to see if the object has passed the photocells.
5. Once the object has passed the photocells and if the object is to be sorted, the time to elapse before the diverter is to be actuated is computed.
6. The system actuates the diverter after this computed time is elapsed.
7. The system again constantly checks to see if any object on the conveyor needs to be identified (reverts to the step 1 condition). This process continues till the operator decides to stop the system.

Figure 9.2 is a flow diagram depicting the above sequence of steps for software development. Appendix A details the actual microcomputer software. Figure A.1 in Appendix A shows the interface circuit diagram.

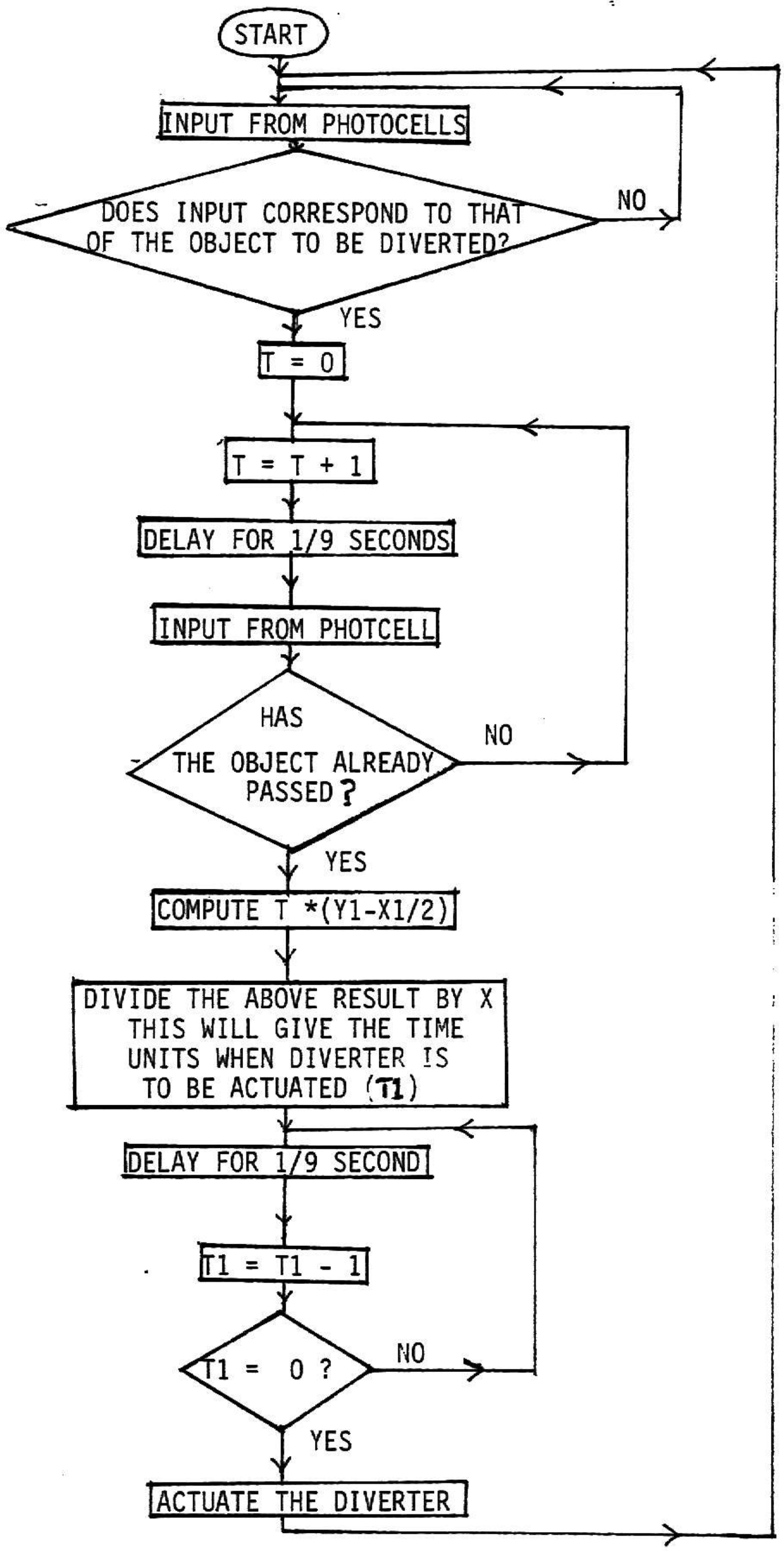


FIGURE 9.2 : FLOW DIAGRAM OF THE DESIGNED SYSTEM

10. CONCLUSIONS AND FUTURE DIRECTIONS.

In conclusion, as a result of this study the following can be stated :

1. A comprehensive description of the functioning of a commercial AISS and its components was presented.
2. A simple cost effective AISS model was designed, fabricated and implemented.

Also as a result of this research, areas for further study were identified. These areas were as follows :

1. The software was based on the use of 8 bit registers. A similar software logic can be developed by using 16 bit registers. This way, one can establish a smaller system time unit, thereby increasing the accuracy and precision of the sortation.
2. As opposed to a solenoid, the practical and economic feasibility of other forms of diverters can be evaluated. Such diverters might include pneumatic and mechanical types.
3. The system can be equipped with monitoring devices using additional photocells. This way, one can monitor the path of the product along the conveyor, and account for the variations in the conveyor speed. The monitoring devices will also help the system to process more than one transaction at a time. Further, this will eliminate the requirement of close proximity between the photocell and the diverter.

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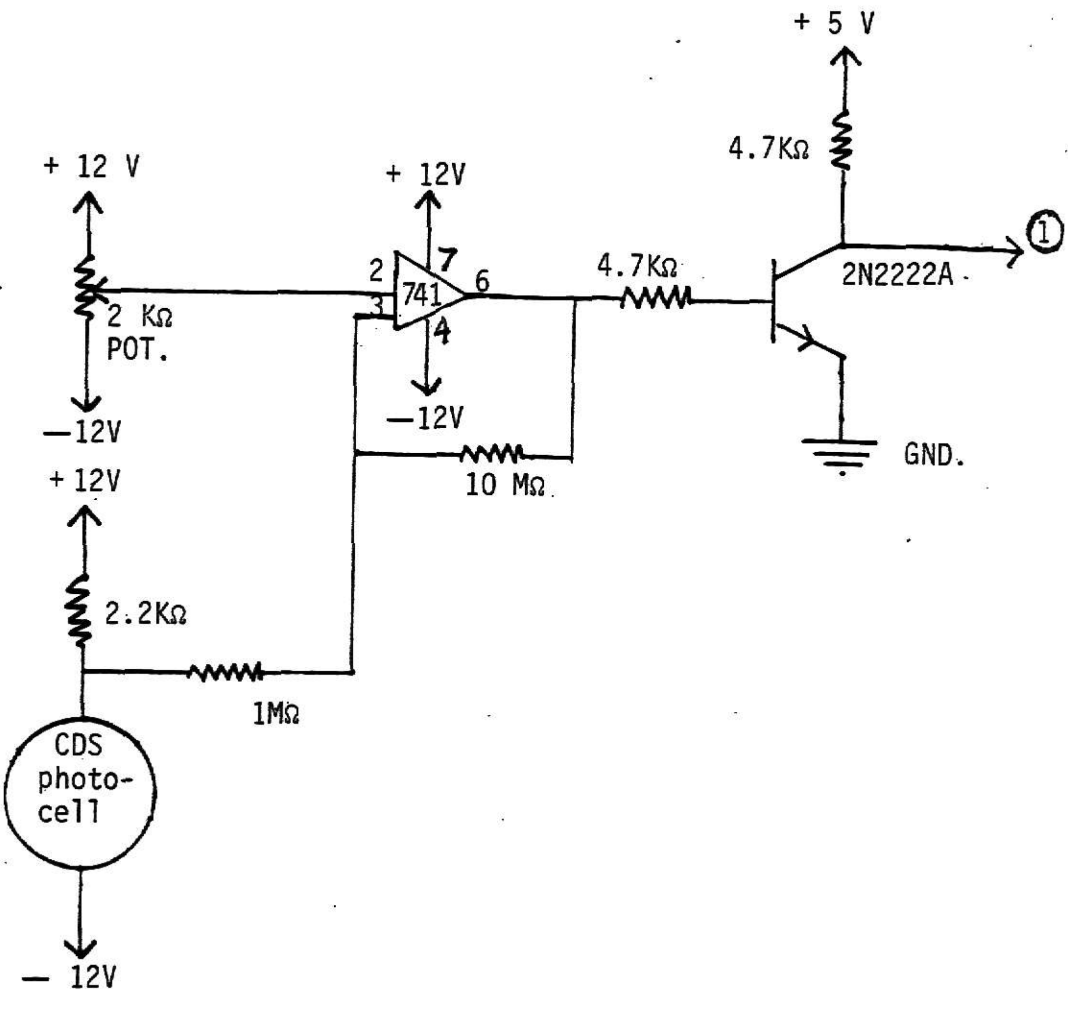
APPENDIX A

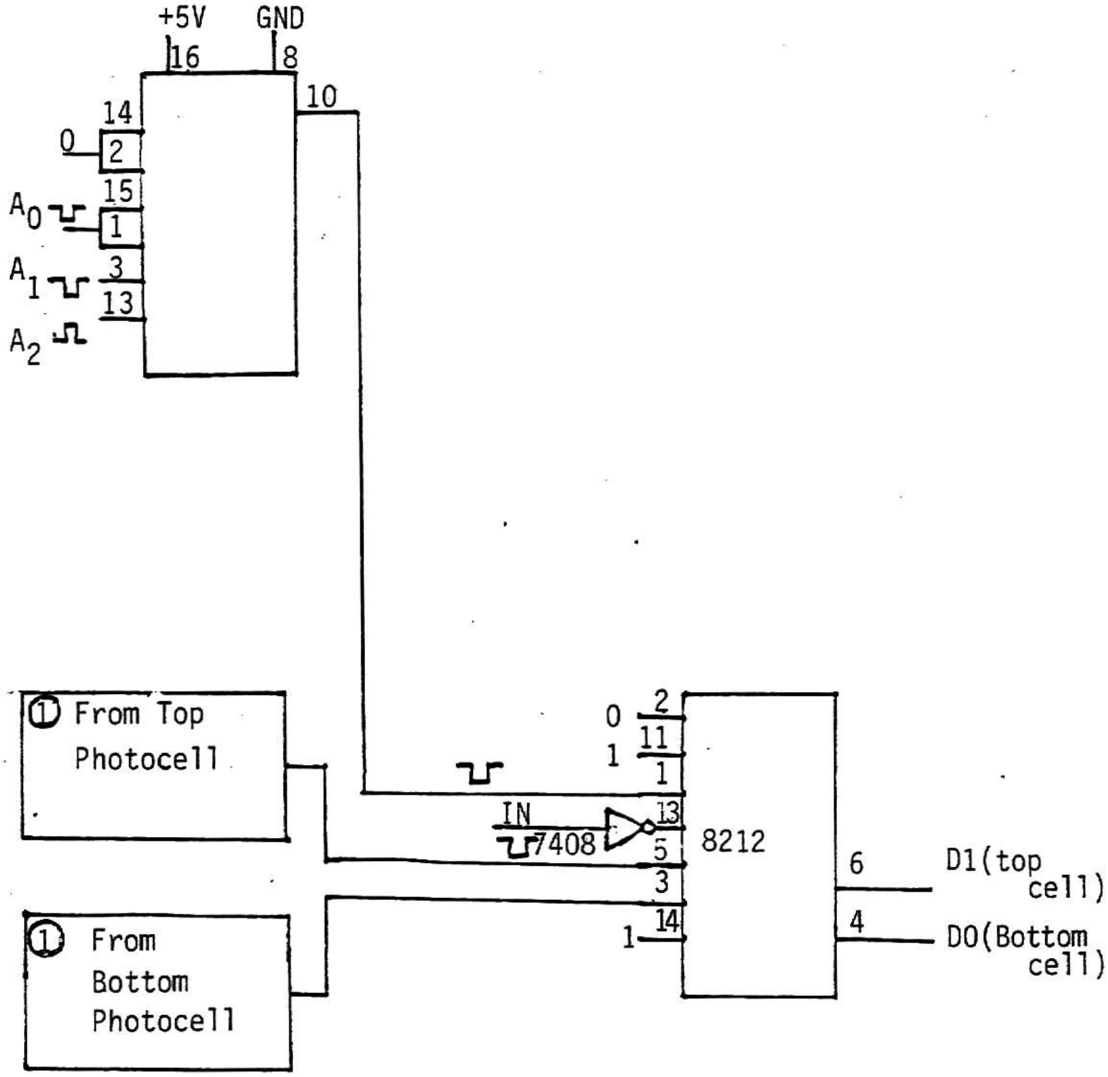
```
/*      This program operates the AISS system.
/*      Two types of objects were chosen.
/*      Object dimensions :
/*      Small Object :
/*      14 cms. (along conveyor), 7 cms. wide,   6  cms. high
/*      Large Object :
/*      20 cms. (along conveyor), 4  cms. wide, 13.5 cms. high
/*      y1 = distance between photocells and diverter.
/*         = 30 cms.
/*      x1 = length of the object.
/*         = 14 cms. for small object.
/*         = 20 cms. for large object.
/*      (y - x/2) = (y1 - x1/2) in octal.
/*                = 027 for small object.
/*                = 024 for large object.
/*       x = x1 cms. in octal
/*         = 016 for small object
/*         = 024 for large object
/*      Hi addr.   Lo addr.      Data
/*      003        350           photocell status for sortation
/*                               376 for small object sortation
/*                               374 for large object sortation
/*      003        351           (y - x/2)
/*      003        352           x
```

```
/*        1 TIME UNIT = 1/9 SECOND.
/*        SELECTING A SUITABLE TIME UNIT :
/*        The time unit should be such that the product of the
/*        approximate time units "t" required for the
/*        object to pass the photocell, and "(y - x/2)" of the
/*        object to be diverted should be less than or equal
/*        to 256.
/*        THE SOFTWARE LOGIC :
/*        The program finds the time units "t" it took for the
/*        object to pass the photocell.
 *        The program then multiplies "t" with "(y-x/2)" and then
/*        divides the result by "x".
/*        This gives  "t1", the time units after which the object
/*        will reach the diverter. This "t1" is stored at
/*        location 003 354.
/*        After a delay of "t1" time units, the microcomputer
/*        will create an output to actuate the diverter.
/*        FORMULA :  t1  = ( (y - x/2) * t ) / x
/*        The derivation of this formula is shown in Figure 9.1,
/*        and the flow diagram of this software is shown in
/*        Figure 9.2 in Chapter 9.
/*        Figure A.1 shows the circuit diagram for the system
/*        and Figure A.2 shows the materials used for the designed
/*        system and their specifications.
```



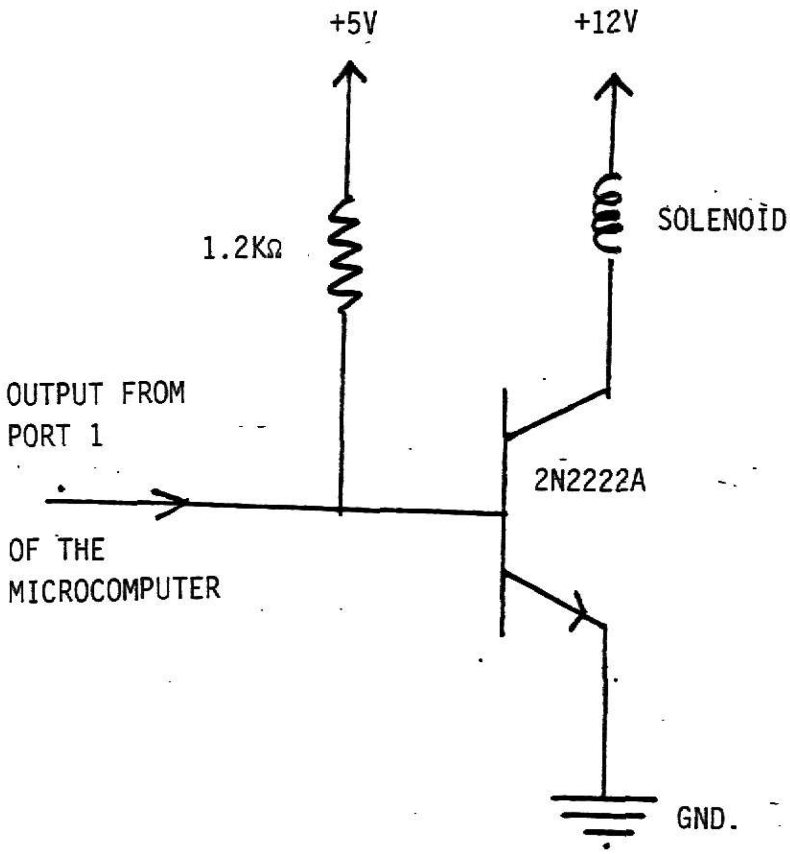
I) PHOTOCELL CIRCUIT

FIGURE A. 1 : CIRCUIT DIAGRAM.



II) INPUT OF THE PHOTOCELL STATUS TO THE MICROCOMPUTER.

FIGURE A. 1 : CIRCUIT DIAGRAM (Cont.d)



III) OUTPUT FROM THE MICROCOMPUTER TO ACTUATE THE SOLENOID

FIGURE A.1 : CIRCUIT DIAGRAM (cont.d)

<u>Conveyor</u>

Motor	: 1/5 HP
RPM	= 5000
Length	= 300 cms
Width	= 27.5 cms
Maximum conveyor speed	= 60 cms/sec
Minimum Conveyor speed	= 6 cms/sec

<u>MMD-1 microcomputer was used to control the System</u>

<u>Two Cadmium Selenide Photocells were used for identifying the Object</u>

Manufacturer	: Radio Shack
Resistance at 10 Lux (2854 deg. K)	= 15 K + 40 %
Typical Resistance at 100 Lux (2854 K)	= 3 K ohms
Resistance Dark Minimum (1 minute)	= 0.5 M ohms

<u>Two 2N2222A NPN transistors.</u>

Manufacturer	: Motorola
BVcco Voluts Min.	= 40
Min. Frequency 300 Mhz @ 20 mA	
Max IC	= 800 mA

<u>1 TIP 31 Transistor.</u>

Manufacturer	: Texas Instruments
Rated IC	= 3 Amps
Rated Vceo	= 40 volts
Min. hFe	= 10 volts
Max hFe	= 50 volts

<u>Two 741 op. Amps</u>

<u>One 74155 chip</u>

<u>One 8212 chip</u>

<u>One Solonoid was used to simulate the diverter.</u>

Manufacturer	: Dormeyer Industries
Part number	: P10-201L
Volts	= 12 (D. C.)
Duty	= Pulse

FIGURE A.2 : EQUIPMENT USED IN THE DESIGNED SYSTEM.

Hi addr.	Lo addr.	Instruction	Mnemonic	
003	000	076	MVI A	
	001	000	data byte	
	002	323	OUT	CLEAR
	003	000	port 0	
	004	323	OUT	THE
	005	001	port 1	
	006	323	OUT	PORTS
	007	002	port 2	
	010	041	LXI H	
	011	350	Lo addr. Photocell status	
	012	003	Hi addr.	
	013	333	IN	
	014	004	device 4	
	015	323	OUT	
	016	001	port 1	
	017	256	XRA M	
	020	312	JZ	
	021	026	Lo addr.	
	022	003	Hi addr.	
	023	303	JMP	
	024	013	Lo addr.	
	025	003	Hi addr.	
	026	006	MVI B	

```
Hi addr.  Lo addr.     Instruction     Mnemonic
  003       027            000         initialize t
            030            004         INR B
/*       Check after an interval of one time unit to see
/*       if the object is still passing.
            031            315         CALL SUB 1
            032            150         Lo addr
            033            003         Hi addr
            034            333         IN
            035            004         device 4
            036            323         OUT
            037            001         port 1
            040            256         XRA M
/*       If result is zero, the object is still passing
            041            312         JZ
            042            030         Lo addr.
            043            003         Hi addr.
/*       B contains "t" time units.
/*       Multiply "t" with "(y - x/2)" which is stored at 003 351
/*       Move B, the multiplier to Register D.
/*       Move "(y - x/2)" from 003 351 to register E.
            044            120         MOV D B
            045            041         LXI H
            046            351         Lo addr.
            047            003         Hi addr.
            050            136         MOV E M
```

Hi addr.	Lo addr.	Instruction	Mnemonic
003	051	315	CALL SUB 2
	052	200	Lo addr.
	053	003	Hi addr.

/* Now multiplication is over. B contains the most
/* significant bits and C contains the least significant
/* bits. Ignore B. Divide the result by x which is at
/* 003 352. Move x the divisor to D, and C the
/* dividend to E. Divide E by D.

	054	131	MOV E C
	055	041	LXI H
	056	352	Lo addr. of x
	057	003	Hi addr. of x
	060	126	MOV D M
	061	315	CALL SUB 3
	062	250	Lo addr.
	063	003	HI addr.
	064	104	MOV B H

/* Division is over. Store the result "t1" which is in
/* H at location 003 353. Actuate the diverter after
/* "t1" time units.

	065	041	LXI H
	066	353	Lo addr.
	067	003	Hi addr.
	070	160	MOV M B
	071	315	CALL SUB 1
	072	150	Lo addr.

Hi addr.	Lo addr.	Instruction	Mnemonic
003	073	003	Hi addr.
	074	005	DCR B
	075	302	JNZ
	076	071	Lo addr.
	077	003	Hi addr.
	100	076	MVI A
	101	377	byte to acutate diverter
	102	323	OUT
	103	002	port 2
	104	075	DCR A
	105	323	OUT
	106	002	port 2
	107	315	CALL SUB 1
	110	150	Lo addr.
	111	003	Hi addr.
	112	303	JMP
	113	000	Lo addr.
	114	003	Hi addr

/* Transfer the control to the top of the program

/* so that another transaction can be processed.

SUBROUTINE 1

/* This is a time delay subroutine for 1/9 second.

Hi addr.	Lo addr.	Instruction	Mnemonic
003	150	365	PUSH PSW
	151	305	PUSH B
	152	006	MVI B
	153	350	timing byte
	154	016	MVI C
	155	030	Timing Byte
	156	015	DCR C
	157	302	JNZ
	160	156	Lo addr
	161	003	Hi addr
	162	005	DCR B
	163	302	JNZ
	164	154	Lo addr
	165	003	Hi addr
	166	301	POP B
	167	361	POP PSW
	170	311	RET

SUBROUTINE 2

/* This subroutine multiplies two 8 bit registers.

/* D should contain the Multiplier

/* E should contain the Multiplicand

/* C contains the Least Significant Bits of the result.

Hi addr.	Lo addr.	Instruction	Mnemonic
003	200	001	LXI B
	201	000	
	202	000	
	203	056	MVI L
	204	010	
	205	172	MOV A D
	206	037	RAR
	207	127	MOV D A
	210	322	JNC
	211	216	Lo addr
	212	003	Hi addr
	213	170	MOV A B
	214	203	ADD E
	215	107	MOV B A
	216	170	MOV A B
	217	037	RAR
	220	107	MOV B A
	221	171	MOV A C
	222	037	RAR

Hi addr.	Lo addr.	Instruction	Mnemonic
003	223	117	MOV C A
	224	055	DCR L
	225	302	JNZ
	226	205	Lo addr
	227	003	Hi addr
	230	311	RET

SUBROUTINE 3

/* This subroutine divides one 8 bit register by another

/* 8 bit register.

/* D should contain the Divisor

/* E should contain the Dividend

/* H contains the Result after execution of the subroutine

Hi addr	Lo addr.	Instruction	Mnemonic
003	250	041	LXI H
	251	010	
	252	000	
	253	016	MVI C
	254	000	
	255	173	MOV A E
	256	027	RAL
	257	137	MOV E A
	260	171	MOV A C
	261	027	RAL
	263	222	SUB D
	263	322	JNC
	264	267	Lo addr.
	265	003	Hi addr.
	266	202	ADD D
	267	117	MOV C A
	270	077	CMC
	271	174	MOV A H
	272	027	RAL

Hi addr	Lo addr.	Instruction	Mnemonic
003	273	147	MOV H A
	274	055	DCR L
	275	302	JNZ
	276	255	Lo addr
	277	003	Hi addr
	300	311	RET

APPENDIX B

AIM GLOSSARY OF TERMS

ADDRESS - 1. A character or group of characters that identifies a register, a particular part of storage, or some other data source or destination.

2. To refer to a device or an item of data by its address.

AIM - Automatic Identification Manufacturers, a subdivision of Material Handling Institute.

ALPHANUMERIC, ALPHAMERIC- The character set which contains letters, digits, and usually other characters such as punctuation marks.

ASPECT RATIO - The ratio of height to the width of a bar code symbol.

BAR - The dark element on a printed symbol.

BAR CODE - An array of rectangular bars and spaces which are arranged in predetermined pattern following unambiguous rules in a specific way to represent elements of data which are referred to as characters.

BAR CODE DENSITY - The number of characters which can be represented in a lineal inch.

BAR CODE LABEL - A label which carries a bar code and is suitable to be affixed to an article.

BAR LENGTH - The dimension perpendicular to bar width.

BCD, BINARY CODED DECIMAL - A numbering system using base 2, that represents each decimal digit by four binary bits, with the place values equal to 8, 4, 2 and 1, reading from left to right.

BIDIRECTIONAL READ - A bar code Symbol which permits reading in complementary (2) directions.

BINARY CODE - A "powers of two" code in which each bit position has a weighted value. Example 1, 2, 4, 8.

BIT - An abbreviation for binary digit. A single character in a binary number.

CCD - Charge couple Device is a linear image sensor that scans at high speeds (Approx. 4000 times a second) and detects the presence or absence of marks passing under the device.

CHARACTER - 1. A single group of bars and spaces which represent an individual number, letter, punctuation mark or other graphic fonts.

2. A graphic shape representing a letter, numeral or symbol.

CHARACTER DENSITY - The dimension in lineal inches, required to encode one character.

CHECK DIGIT - A digit included within a symbol whose value is based mathematically on other characters included in the symbol. It is used for the purpose of performing a mathematical check to ensure the accuracy of read.

CLOCKING - A standard time reference against which code signal inputs are measured.

CONTINUOUS CODE - A bar code where the space between characters (intercharacter gap) is part of the code.

DECODER LOGIC - Electronic package which receives the signals from the scanner, performs the algorithm to interpret the signals into meaningful data and provides the interface to other devices.

DEPTH OF FIELD - The distance between the maximum and minimum plane in which a symbol can be read.

DISCRETE CODE - A bar code or Symbol where the space between characters (intercharacter gap) is not a part of the code.

ELEMENT - 1. A single binary position in a character.

2. Dimensionally the narrowest width in a character: bar or space.

FIELD - It is a group of characters defined as a unit of information. A line contains several fields.

FILM MASTER - A photographic film representation of a specific symbol from which a printing plate is produced.

FIRST READ RATE - The percentage representing the number of successful reads per 100 attempt to read a particular symbol.

FONT - A specific size and style of printer's type.

FORMAT - The geometric construction rules which define a particular bar code or symbol.

GUARD BARS - The bars which are at both ends and center of a UPC or EAN symbol, thereby creating a left hand segment and a right hand segment. They provide reference point for scanning.

HANDHELD/WAND SCANNER - A handheld scanning device used as a contact bar Code or OCR reader.

HEIGHT-OF-SCAN - The maximum vertical scanning dimension of a moving beam scanner at a specific distance from the face of the scanner.

HORIZONTAL BAR CODE/PICKET FENCE - A bar code presented in such a way that its overall length dimension is parallel to the horizon.

INTERCHARACTER GAP - The space between two adjacent bar code Characters.

INTERLEAVED BAR CODE - A bar code in which characters are paired together using bars to represent the first character and spaces to represent the second character.

MISENCODATION - When the characters which were to be represented in symbol are not correctly encoded.

MISREAD/SUBSTITUTION ERROR - A condition where the data output of reader does not agree with the encoded data presented.

MODULE - It is the narrowest unit of measure in the code and is used in describing a UPC Code. Contiguous modules are used to form bars or spaces which are wider than one unit, e.g. a four module wide bar will represent binary 1111.

MODULO CHECK DIGIT/CHARACTER - A calculated character within a data field which is used for error detection.

The calculated character is determined by applying a code algorithm to the data field contents.

NO-READ, NONSCAN, REJECT - The absence of data at the scanner output after an attempted scan due to no code, defective code, scanner failure or operator error.

NUMERIC - A machine VOCABULARY which includes only the numbers.

OPTICAL THROW - The distance from the face of the scanner to the beginning of the depth of field (Figure B.1).

ORIENTATION - Alignment of bars and spaces to the scanner.

OVERHEAD - The fixed number of characters required for start, stop and checking in a given symbol.

PARITY BAR/BIT/MODULE - A parity bit is added to a binary array to make the sum of all the bits always odd or always even for a fundamental check.

PITCH - See Figure B.1.

RESOLUTION - 1. The measure of the ability of a lens, or a photographic system to distinguish in detail under certain specific conditions.

2. The dimension of the smallest element which can be printed employing particular technique.

3. The narrowest element dimension which can be distinguished by a particular reading device.

REVERSE IMAGE - Symbol in which dark areas are represented in the light areas.

SCAN - The search for a symbol which is to be optically recognized by the recognition unit of the optical scanner.

SCANNER, BAR CODE READER - A device that examines spacial pattern, one part after another and generates analog or digital signals corresponding to

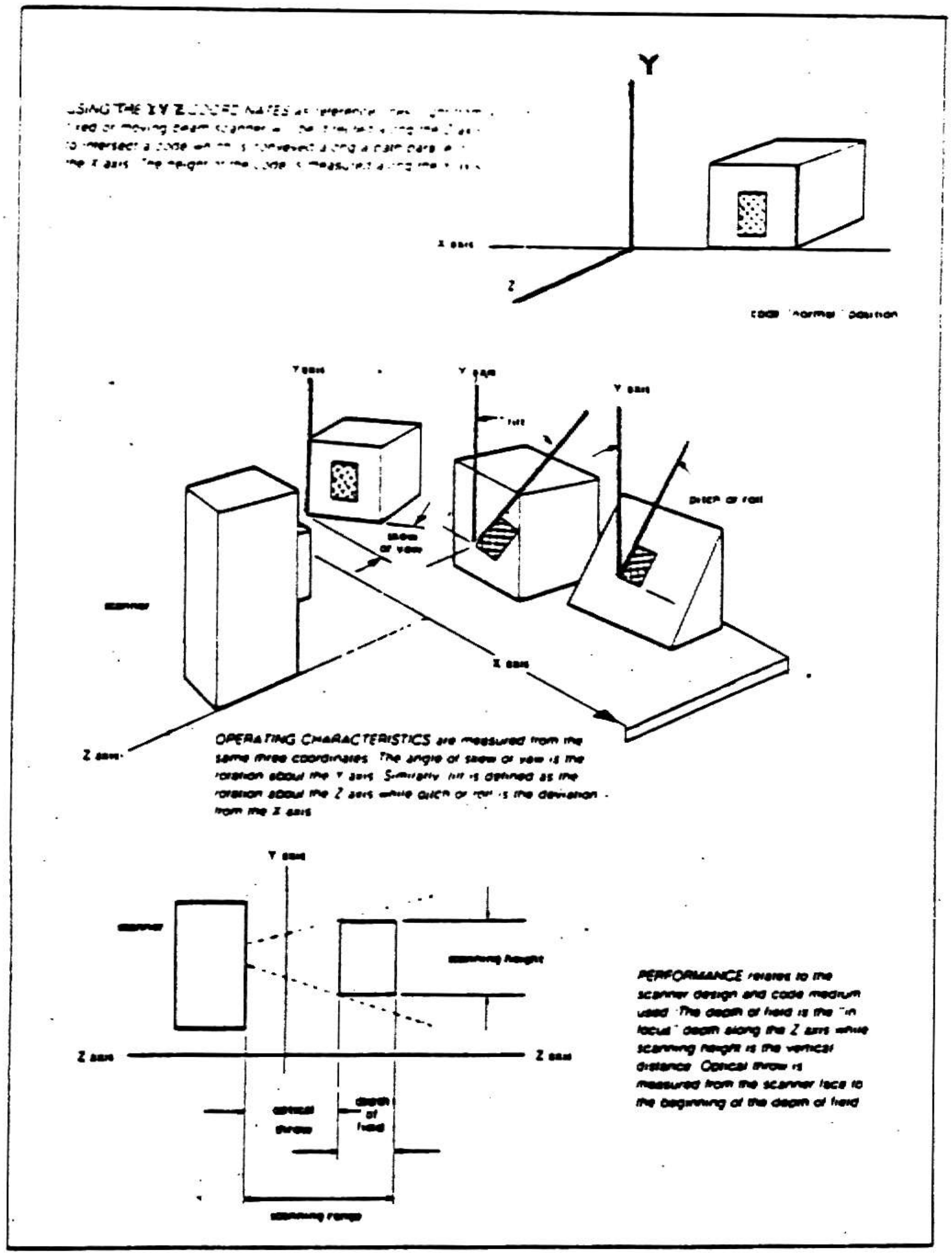


FIGURE B.1 : PITCH, SKEW, AND TILT. (1).

the pattern.

SCANNING CURTAIN - The effective reading area (width*height) of a moving beam scanner, which is equal to its depth-of-field and height-of-scan at a specific operating range.

SELF CHECKING - A bar code using a checking algorithm which can be applied to each character to guard against undetected errors.

SKEW - See Figure B.1.

SPACE - The lighter element of a bar code found between bars.

SPECTRAL RESPONSE - The variation in sensitivity of a device to light of different wavelengths.

SPOTS - Ink or dirt spots within spaces that may reduce firstread rate.

STROKE - A straight line or curve between two nodes of a character.

SYMBOL - A combination of characters including start/stop characters and check characters, as required, which form a complete scannable entity.

SYMBOL DENSITY - Number of characters per lineal inch.

SYMBOL LENGTH - The length of the symbol measured from the beginning of the quiet area adjacent to the start character to the end of the quiet area adjacent to the stop character.

TILT - See Figure B.1.

VERTICAL BAR CODE/LADDER - A code pattern presented in such orientation that the overall coded area from start to stop is perpendicular to the horizon.

VOID - Absence of ink within printed bars.

"X" DIMENSION - The dimension of the narrowest bar or space in the bar code.

APPENDIX C

COSTS OF AISS EQUIPMENT

Equipment	Cost ($)
Lightpens/wands	200
Slotreaders	250
Hand-held Laser Scanners	2000
Terminals :	
Without keyboard/display	1000
With keyboard/display (light duty)	1200 - 1500
With keyboard/display (heavy duty)	1500 - 2000
Portable Units (industrial quality)	1800 - 2500
Dynamic Scanners :	
Lasers (remote)	4000 - 10000
Omni-directional	50,000 - 70,000
Code Printers :	
Impact, pre-formed character	2000 - 4000
dot matrix	4000 - 12000
electrostatic (non-laser)	6000 - 10000
Laser (electrostatic)	50,000 - 100,000

APPENDIX D

PRODUCT CATEGORY GUIDE (5).

Symbol Readers

Fixed Beam

- Accu-Sort Systems, Inc.
- Identicon Corporation
- Intermec
- MEKontrol, Inc.
- Photoswitch Division, Electronics Corp. of America
- Skan-A-Matic Corporation

Moving Beam

- Accu-Sort Systems, Inc.
- Computer Identics Corporation
- Control Module Inc
- Identicon Corporation
- MRC Corporation
- Photographic Sciences Corporation
- Skan-A-Matic Corporation
- Symbol Technologies, Inc.
- Welch Allyn, Inc

Hand Held

- Accu-Sort Systems, Inc.
- Computer Identics Corporation
- Identicon Corporation
- Intermec
- MRC Corporation
- Photographic Sciences Corporation
- Skan-A-Matic Corporation
- Symbol Technologies, Inc.
- Teknekron Controls, Inc.
- Welch Allyn, Inc.

Charge Couple Device

- Teknekron Controls, Inc.

Symbol Generators

Bar Code

- Dennison Manufacturing Company
- Intermec
- Lord Label Systems, Inc.
- Marsh Stencil Machine Co.
- Matthews International Corp.
- Mead Digital Systems
- Photographic Sciences Corporation
- Scanmark Division, Markem Corporation
- Symbol Technologies, Inc.
- Weber Marking Systems, Inc.

OCR

- Dennison Manufacturing Company
- Intermec
- Matthews International Corp.
- Mead Digital Systems
- Photographic Sciences Corporation
- Scanmark Division, Markem Corporation
- Weber Marking Systems, Inc.

Presence Sensing

- MEKontrol, Inc.
- Micro Switch
- Photoswitch Division, Electronics Corp. of America
- Skan-A-Matic Corporation

Pre-Printed Labels

- Computype, Inc.
- Data Composition, Inc.
- Uarco Incorporated

APPENDIX E.

INDUSTRY GUIDE (22).

ACCU-SORT SYSTEMS INC
511 Schoolhouse Road. Telford, PA 18969
Telephone. 215 723-0981
Contact: Benny Tafoya

Manufacturers of moving beam, fixed beam and pen scanners. Suppliers of management information and material management systems, including interfaces and mini-computers or microprocessors. Scanners employ microprocessor logic sections which provide the ability to read virtually any code pattern. Scanners are available with laser and non-laser light sources.

COMPUTER IDENTICS CORPORATION
31 Dartmouth Street Westwood MA 02090
TWX: 710-348-7593
Telephone: 617-329-1980
Contact: Marketing

Moving beam and handheld bar code readers for automatic identification systems. Single source supplier of turnkey, computer-based information and control systems featuring order processing, production control, assembly verification, inventory management, shipment verification and sortation control. Nationwide field service support. Worldwide distribution.

CONTROL MODULE INC.
380 Enfield Street
Enfield, CT 06082
Telex: 64-3167
Telephone: 203/745-2433
Contact: Peter C. DiMaria

Designers and manufacturers of versatile electronic equipment utilizing optical scanners and magnetic readers for development of work-in-process, inventory control, controlled access, time and attendance, and quality control systems. CMI specializes in systems design and support for the hostile industrial environment as well as commercial applications. CMI employs national sales and service centers providing extensive support worldwide.

DENNISON MANUFACTURING COMPANY
300 Howard Street, Framingham, MA 01701
Telephone: 617/879-0511
Contact: Systems Division

Dennison offers a complete line of ALPHA/NUMERIC/CODED label generation, application, and verification systems for coded information identification. Supporting services range from on-site consultation to total solution assistance for label/code design, code reader selection and coded information processing requirements.

IDENTICON CORPORATION
One Kenwood Circle, Franklin, MA 02038
TELEX: 98335 Telephone: 617/528-6500
Contact: Marketing Services

Optical bar code scanning equipment utilizing light pens, fixed beam readers and moving-beam readers. Microprocessor-based decoders handle all present or future codes. Multiplexer systems handle up to 16 remote pen or fixed beam readers. Total computer based system utilizing above equipment. Contractual maintenance and field service support.

IDENTRONIX INC.
1718 Soquel Avenue
Santa Cruz, CA 95062
Contact: Matthew Lezin

Manufactures and markets remote electronic identification systems used in computer automation of manufacturing plants, warehouses, public transportation, railroads and livestock. The system consists of a reader and electronic tags attached to objects to be identified. The reader contains an active UHF transmitter and receiver that can identify tags in extremely hostile conditions. The tag is inexpensive, has no battery or power source, and contains a LSI chip (Large Scale Integrated Circuit) which generates a digital identification code. Using extremely low power, the tag is turned on by the reader, then transmits back a unique digital code. The reader can operate with a terminal as a logging device or can be used and controlled from any standard computer.

INTERMEC
4405 Russell Road, P.O. Box N, Lynnwood, WA 98036
TWX: 910-449-0870
Telephone: 206/743-7036
Contact: Sales Department

Bar code printers, portable, on-line readers; portable concentrators, and wands. Satellite wand stations for wands remote from readers. Printers capable of producing labels with both bar code and human readable words. Intermec products support all popular bar codes and custom codes are available on request. Over 40 nationwide sales and service offices.

LORD LABEL SYSTEMS, INC.
3029 East Randol Mill Road
Arlington, TX 76011
Telex: 758661 (LL System ARTN)
Telephone: 817/261-4441
Contact: R. Michael White

Manufacturers of automatic pressure-sensitive labeling machines and special labeling systems, which can include, among other features, product handling, positioning and sortation equipment, wrap-around labeling, imprinters, and conveyor systems. The new LPA/80 is a micro processor controlled high speed label printer-applicator capable of generating variable copy and machine readable bar code symbols on line, on demand. Off-line computer controlled label printing systems are also available to print readable copy and symbols using most bar code structures in virtually any sequence, size or pattern the customer requires. Complete system responsibility from one source from plain labels to automated product identification and inventory control systems via bar code.

MARSH STENCIL MACHINE CO.
P.O. Box 388, Belleville, IL 62221
Telephone: 618/234-1122
Contact: Mgr. Ink Jet Systems

Marsh offers a large character, dot matrix, direct-to-carton marking system that is capable of coding variable information in either human-readable characters, or in many of the standard USD machine-readable codes. Custom software is available for printing special symbology. The microprocessing unit can interface with many electronic devices to create a customized, automatic container coding and material handling system.

MATTHEWS INTERNATIONAL CORPORATION
Penn Circle East
Pittsburgh, PA 15206
Telephone, 412/363-2500

Matthews International Corporation manufactures and sells a broad line of printing equipment and supplies to apply bar codes to practically any product. With over 130 years of experience in marking products, we offer film masters and printing plates to preprint bar codes on packages, labels and containers, offset printers, direct printers and custom inks that can print bar codes directly on products; micro-processor based ink jet printers that allow for non-contact printing of alpha-numeric information and bar codes from 1/2" to 2-1/2" high at speeds up to 200 feet per minute; micro-processor based label printing systems and label printers that can accept variable data input from a keyboard, computer, or bar code wand, store the label information, and print labels on demand.

mead DigitalSystems

MEAD DIGITAL SYSTEMS
3800 Space Drive, P.O. Box 3230
Dayton, OH 45431
513/898-3644

Manufacturers of high-speed ink-jet printing systems for business forms, tags, and pressure sensitive labels. The systems are capable of printing variable bar codes and human readable information in a wide range of sizes and configurations and with any desired degree of variability

MEK

MEKontrol, Inc.
56 Hudson St., Northboro, MA 01532
Telephone, 617 393-2451
Contact: A. R. King

Fixed beam code readers: retroreflective adjustable or permanent code plates for tote boxes, pallets, overhead power and free carriers, tow line carts, AS/RS position controllers, engineered control systems

Presence sensing controls including reflex scanners, photoelectric proximity scanners and through beam scanners for stand alone relay operation or interface operation with logic systems in material management applications.

MICRO SWITCH
a Honeywell Division

MICRO SWITCH, A Honeywell Division
11 W. Spring Street
Freeport, IL 61032
Telephone: 815/235-6600
Contact: J. R. Pilson

MICRO SWITCH manufactures and distributes worldwide a variety of proximity sensors and photoelectric controls. Solid state proximity sensors are offered in self-contained and modular configurations and are available in all-metals sensitive or ferromagnetic versions, both AC and DC. Photoelectric controls include modulated and non-modulated versions operating in thru-scan, retroreflective, specular and diffuse scan modes. LED and incandescent light sources permit outdoor and indoor scanning flexibility. MICRO SWITCH produces large and small basic precision snap acting switches, diecast, heavy duty limit switches, explosion proof switches, oiltight pushbuttons, lighted and unlighted pushbuttons for commercial applications and mercury switches. MICRO SWITCH is also the inventor and world's largest manufacturer of Hall effect solid state keyboards.

MRC CORPORATION
A SUBSIDIARY OF SCOPE INC

MRC CORPORATION. A Subsidiary of Scope. Inc..
Scanner Systems Division
1860 Michael Faraday Drive
Reston. VA 22090
Telephone: 301/628-1300
Contact: Vito Brigida

Manufacturers of microprocessor-based single package bar code scanning systems offer intelligent identification and control for industrial and government applications. Pre-engineered central processors for controlling up to 32 scanners or stand-alone scanner/controller provide verification. sortation or management information systems. Moving beam laser and hand-held scanners read all standard or custom codes. Single turnkey source for total computer-based systems. printers. recorders. software design. installation. International distribution and field service.

Photographic Sciences Corporation

PHOTOGRAPHIC SCIENCES CORPORATION
Box 338. Webster. NY 14580
Telephone: 716/265-1600
800/828-6489
TWX: 510-253-3036
Contact: Sales Dept.

Manufactures unlimited range of bar code film masters. to exacting and precise specifications. in any symbology. at multi-plant locations in US and Europe. Markets low cost go-no-go light pen verification units with switch selectable symbology: medium range laser verifiers: full scale laser verifiers measuring to published specifications: and on-line moving beam laser control systems for in-process control. sortation and other material handling applications.

PHOTOSWITCH DIVISION. ELECTRONICS
CORPORATION OF AMERICA
One Memorial Drive. Cambridge. MA 02142
Telephone: 617 864-8000
Contact: S. L. Davis

Presence Sensing Controls for industry including High Resolution Scanners for interfacing with systems designer's and manufacturer's conditioning and decoding logics for bar code or other product identification applications in material handling. production. inventory control and other material management functions.

Scanmark
MARKEM CORPORATION

SCANMARK DIVISION
ELECTROPRINT. INCORPORATED
150 Congress St.. Keene. NH 03431
Telephone 603-352-1130
Contact—Scanmark

Manufacturers of bar code printers using non-contact electrostatic. full character impact. and hot stamping technology. Standard and custom printers to laminate. rewind. cut and stack or automatically apply any standard bar code label from ½" x ½" to 4" x 6". Customer label service to produce bar code labels. Convertors of paper. vinyl and mylar labels. Manufacturer of Scanblack CSI impact printing ribbons. Sales and service from six U.S. and two Canadian offices. World wide sales and service through Markem offices.

SKAN-A-MATIC CORPORATION
P.O. Box S. Route 5 West. Elbridge. NY 13060
TWX: 710-545-0220 L-TRON WELB
Telephone: 315/689-3961
Contact: David J. Czaplicki

Manufacturer of photoelectric/bar code components and systems. Photoelectric line includes thru-beam pairs, reflective and retro-reflective scanners, electronic controls and custom industrial systems. Bar code products include fixed beam scanners, moving beam scanners, hand held code pens and a gun type moving beam scanner; also, a data entry terminal, microcomputer decoders and reading systems designed for all popular bar codes. National and international sales representative network.

SYMBOL TECHNOLOGIES, INC.
90 Plant Avenue
Hauppauge, New York 11787
Telephone: 516/231-5252
Contact: Marketing Services

Manufactures and sells products addressing both the bar code symbology and the laser scanner market. Symbology—Film Masters and Laserchek® enabling accurate printing and verification of bar code symbols. Laser scanning of bar code symbols for automatic data entry. Desk-top, mountable and portable data terminals for product identification, inventory control, warehousing, distribution and manufacturing applications. On-line communications with data processing systems.

TEKNEKRON CONTROLS INCORPORATED
2121 Allston Way
Berkeley, CA 94704
TELEX: 336440
Telephone: 415/843-8227
Contact: George J. Einfeldt

TCI manufactures a family of optical label readers that read a presence-absence code on computer generated labels that allow 360° rotation of the label and codes that are pre-printed in color on corrugated cartons. A hand-scanner is also supplied for most applications. TCI also supplies microprocessor based control systems for total warehouse tracking and standard and custom inventory control software programs.

WEBER MARKING SYSTEMS, INC.
711 West Algonquin Road, Arlington Heights, IL 60005
Telephone: 312/364-8500
Contact: Electronic Products Department

Label printing equipment and systems for in-plant production of shipment addressing, product identification and product flow control labels, including bar code and OCR labels. Sequential numbered labels in both human and machine readable printing can be also produced on in-plant equipment. Custom labels can be supplied in a wide range of sizes and adhesives.

Welch Allyn
INDUSTRIAL PRODUCTS DIVISION

WELCH ALLYN, INC
INDUSTRIAL PRODUCTS DIVISION
Jordan Road
Skaneateles Falls, New York 13153
TWX: 710-545-0203
Telephone: 315/685-8351
Contact: C. N. Benoit

Manufacturers of a very comprehensive line of bar code scanners. Included are Hand Held, Machine Mounted and Laser Scanners. Microprocessor Based Decoders and Custom Terminals that are capable of handling all existing codes. experienced application engineering assistance is available.

Computype, Inc.

COMPUTYPE, INC.
2285 West County Road C
St. Paul, Minnesota 55113
(612) 633-0633/(800) 328-0852
Contact: Marketing Department

With special adhesives, high-technology coatings, and unique base material constructions, Computype, Inc. produces bar code labels, tags, and forms that work consistently in harsh environments and demanding applications. Capabilities include: production of any bar code or OCR symbology; sequentially-numbered labels; single and double adhesives; permanent and removable adhesives; symbology masters; heat-applied and reflective labels; freeze-proof and fade-resistant labels; security labels; special die-cutting; and format design services.

DATA COMPOSITION, INC.

DATA COMPOSITION, INC.
1099 Essex
Richmond, CA 94801
Telephone: 415/232-6200

Data Composition, Inc. manufactures high quality labels under computer control. In addition to standard symbols and formats, labels may be customized to your specifications. Each label is an original photocomposed image which assures long life and first scan readability. Supported applications include printed circuit boards, material control, library circulation, shelf labels, record management and security access.

Other optical scanning products include personnel identification cards and scannable program and transaction code menus.

SPS TECHNOLOGIES Automated Systems Division

SPS TECHNOLOGIES
AUTOMATED SYSTEMS
Township Line Road
Hatfield, Pennsylvania 19440
(215) 721-2100

SPS Technologies Automated Systems is a supplier of automated systems for total material management control in manufacturing, distribution, or parts handling applications.

The heart of a number of the systems supplied is an automatic identification subsystem which SPS Automated Systems has developed. These subsystems, include bar code readers, labels and computer hardware and software.

THE STANDARD REGISTER COMPANY
P.O. Box 1167
Dayton, Ohio 45401
Telephone: 513/223-6181
Contact: Equipment Marketing Service

The Standard Register Company, one of the country's major producers and marketers of business forms, also markets a line of data systems equipment including an intelligent-printer-only product, an off-line label preparation and generation system and a wide range of custom, turnkey data collection systems. All printer products are capable of imaging large characters, bar codes and OCR/A characters anywhere on a form or label. Support services include pre- and post-sales systems analysis along with forms management programs to meet the needs of large and small companies.

uarco

UARCO INCORPORATED
West County Line Road, Barrington, IL 60010
Telephone: 312/381-7000
Contact: C. P. Newman—Product Development

Manufactures and markets a complete line of business forms and systems for electronic or manual data processing. Among them are continuous forms, unit sets, pressure sensitive labels, stencils and tags. Manufacturing capabilities include printing of sequential or specific bar code symbols or optical characters in a wide variety of sizes and configurations on products used in material handling and marking systems.

YORK TAPE AND LABEL CORPORATION
1953 Stanton St.
P.O. Box 1309
York, PA 17405
Telephone: 717/846-4840
TWX: 510-657-4244
Contact: Roger E. Stabley, Marketing Director

York is involved with comprehensive industrial bar coding projects both as a supplier of pressure-sensitive bar code labels, and as a full symbology systems coordinator. With 35 years of pressure-sensitive experience, York provides custom stocks and adhesives to assure performance even in problematic marking applications. Added to this is the technical preparation, printing and inspection expertise needed to accomplish quality, close-tolerance, durable bar coding. The York Symbology Systems department is available to assist with the implementation and coordination of various aspects of bar code programs; a full line of label imprint and application equipment is also offered by York Machine Systems.

A MICROPROCESSOR BASED AUTOMATIC IDENTIFICATION AND SORTING SYSTEM

by

Pankaj Fulchand Ajmera

B.Tech., Indian Institute of Technology, Bombay, India, 1980

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering
KANSAS STATE UNIVERSITY
Manhattan, Kansas

August 1983

ABSTRACT

In recent years, the goal of the industries has been to reduce manual labor and if possible to eliminate it completely.

Sorting of goods in industries is often done manually. Human labor is thus involved in the monotonous task of counting and identifying items, and recording information. Above all, there is always the possibility of human error.

Automatic Identification and Sorting System (AISS) is a system which can help reduce the labor. In this system, each product moving along the conveyor has a label which bears a code (generally a bar code). This code on the label is identified by an identifying equipment (such as a scanner) and sent for processing to a microcomputer or a minicomputer via communication channels. The computer then compares this code with the set of data residing in its memory and decides where the product is to be sent. The computer monitors the path of the product as it moves along the conveyor. When the product reaches the destination, the computer sends a signal to actuate the diverter, and the sorting is thus complete. The diverters are placed at accumulation lane entry points and other points along the conveyor where a choice of routes exists. The gathered data is further processed for the purposes of updating inventory, recording information, etc. By implementing an AISS, the sorting function is accomplished faster, cheaper, and with better reliability than in manual sorting systems.

In this research, all the elements of AISS (AISS in general,

microcomputer's role, conveyors, identifying equipment, bar codes, and sorting equipment) were reviewed.

Then a model AISS was designed and controlled successfuly in the laboratory by a microcomputer.