BAR CODE DETECTOR DESIGN AND CONSTRUCTION

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By
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ABSTRACT

BAR CODE DETECTOR DESIGN AND CONSTRUCTION

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Computer aided encoding using bar code is finding wide spread application in supermarkets and warehouses for stock control, in libraries for the automation of book circulation, in industry for part assembly control. The using of bar code to entire a program to computer is new. In the bar code, logic "zero" is represented by the narrow bars and logic "one" is represented by the wide bars which have double width of narrow bars.

To detect bar code, a light pen which involves an emitter and a receiver is used as a scanner. The output signal of scanner is applied to an interface to produce the digital output. Then a decoder decodes the data encoded with bars by using digital output from interface. Finally, decoded data are observed on the computer screen.

Decoding is independent of both scanning direction and scanning speed. Error detection is also provided by even parity checking for each alphanumeric character code.

Keywords: Bar code, Light pen, Interface, Decoder.

ÖZET

ÇUBUK KOD ÇÖZÜCÜ TASARIMI VE GERÇEKLEŞTİRİLMESİ

ÖZGÖZTAŞI, Mehmet
Yüksek Lisans Tezi, Elektrik ve Elektronik Mühendisliği Bölümü
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Ocak 1986, 53 sahife

Bilgisayar destekli çubuk kodlama, süpermarketlerde ve depolarda stok kontrolu, kütüphanelerde kitap döngüsü otomasyonu, endüstride parça montaj kontrolunda geniş uygulama alanı bulmaktadır. Çubuk kodun, bilgisayara program girişi için kullanılması yenidir. Çubuk kodlamada, mantıksal "sıfır" ince çubuklarla ve mantıksal "bir" ince çubukların iki katı genişliğindeki kalın çubuklarla gösterilir.

Çubuk kodun çözümü için, verici ve alıcıdan oluşan bir ışık kalemi tarayıcı olarak kullanılır. Tarayıcının çıkış sinyali, sayısal çıkış üretmek için bir ara devreye uygulanır. Sonra ara devreden gelen sayısal çıkışı kullanarak barlarla kodlanmış bilgi bir çözücüde çözülür. Sonunda çözülmüş bilgi bilgisayar ekranında gözlenir.

Çözme, her iki tarama yönü ve tarama hızından bağımsızdır. Hata bulma, her alfanumerik karekter kodu için çift eşlik denetimi ile sağlanır.

Anahtar kelimeler: Çubuk kod, Işık kalemi, Ara devre, Çözücü.

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LIST OF SYMBOLS

B	:	Buffer Register
D	:	Address Register
(B)	:	Contents of B Register
<D>	:	Memory Register Number (D)
(D)	:	Contents of D Register
(<D>)	:	Contents of Memory Register Number (D)
⇒	:	Transfer
R	:	Resistor
C	:	Capasitor
s	:	Second

CHAPTER 1

INTRODUCTION

Entering correct data into a computer system has always been fraught with difficulties. The systems which have solved that problem today involve putting data straight into the machine via some kind of teleprocessing, transaction - handling systems. A vital technique, developed in the last few years, has been the application of bar code. Bar codes offer an alternative which is faster, more reliable and cheaper than keyboards and other optic and magnetic systems for putting data into equipment and information systems.

Everyone knows that computers work in binary system, that is to say, all figures are converted into ones and zeros. Ones and zeros of any data can also be encoded with the bar code symbology which is a set of bars. By looking at the bar coded tags, people might be inclined to think the wide bars stand for ones and the narrows for zeros, or vice versa.

The bar coded tags should be scanned by a sensor which involves a light emitter and a receiver combination , to decipher it. Decoding is accomplished by extended digital circuits or especially microprocessor based systems to enter the data into a computer. Some types of decoders also have a display which is usually more important for prompting of next transaction and for confirmation of the previous bar code scan.

Today, bar codes are employed in an increasing number of industrial and commercial applications. Bar code have proven to be an effective means of managing library operations at all levels.

The use of bar coding in industry today has expanded beyond the ralm of warehousing and distrubition to controlling inventory and verification of assembly.

The bar code has become an important means of the supermarket shopper. Managers are discovering that bar code can team up with personal computers for low cost, high accuracy data input. In the on line transaction, a retail salesperson can perform a credit verification automatically through a personal computer while registering the customer's purchases. Meanwhile it can calculate stock balances and also report creative applications.

In all the important applications of bar code mentioned above the data encoded with bar code should be detected firstly. And then required transactions are done on line or off line by using any computer.

In this thesis, a bar code detector have been designed and constructed. A theoritical background about any bar code and its detection was given in Chapter 2. Chapter 3 involves design and construction procedures of bar code detector system for HP41C bar code version. Discussion, conclusions and results have been presented in chapter 4.

CHAPTER 2

BAR CODE AND ITS DETECTION

2.1 INTRODUCTION

It is known that, the most time consuming and error prone portion of any computer operation is during data collection and program entry. Typically a computer can perform millions of instructions per second, yet during data entry, it is only as fast and accurate as the data entry clerk.

There are some forms of symbology provide an error free and automated way to get information into your computer. The most well-known data entering symbologies are bar coding, magnetic coding, keyboard, optical character recognition (OCR) , voice recognition system (VRS) [1].

OCR has overcome initial technical obstacles and is quickly becoming a factor in the automated data collection and data entring industry. A real benefit with OCR is quick user acceptance due to its human readable format.

Voice Recognition System provides one more type of data collection devices. One adventage of the VRS is that does not require the use of a person's hand. These are most expensive systems.

Various types of terminals with keyboard provide for great flexibility than the bar coding or magnetic coding devices. Virtually unlimited visual feedback can be provided to the operator, but the opportunity for error is increased when discretionary input is allowed.

Bar code and magnetic code devices share many of the same advantages:

* Data are embedded in the bar code or magnetic strip, eliminating data entry errors.

* Data entry is fast and user friendly. Many numeric and alphabetic digits can be incorporated with either vertical or horizontal redundancy into one coded symbol or strip.

* They are easy to use, requiring little training and minimal direct computer interaction.

* The cost is relatively low, permitting optimized placement of data entry devices near exiting work station. Bar coding system is cheaper than the magnetic coding system.

Bar code data with an error rate of 1 in 6 million can be considered error free. Time savings are also achieved because scanning is 5 to 10 times as fast as key punch entry. The mounds of paperwork associated with traditional key punch entry are also eliminated [2].

At the bar code applications, generally bar coded labels are placed onto the object. Inventory is accomplished by scanning the labels with a bar code scanner. Upon completion of the inventory, the data are fed directly into the computer. So that the reports can be generated immediately. A major benefit of this type of inventory is that reconciliation of lost items can take place on the same day as the inventory [2].

2.2 WHAT IS A BAR CODE ?

Bar codes are messages with data encoded in the widths of printed bars and spaces on a piece of paper. If you consider that standard characters are two dimensional, then bar codes are one dimensional characters that have been stretched in the vertical dimension. From this perspective, bar code scanning can be seen as the one dimensional version of OCR. The symplicity of scanning and decoding of one dimensional patterns is one main reason that bar code systems are more prevalent than OCR systems and are expected to remain so for sometime. An analogy for how bar code systems work is to consider a printed bar code as a Pulse - Duration - Modulated (PDM) signal where linear distance on the paper is equivalent to time and the white and black reflectance levels of the bar code pattern on the paper are equivalent to the high and low logic levels of the electrical signal [3].

The number of different possible coding schemes for bar codes is endless. However, the majority of schemes now in use can be classified with respect to level:

1. Two level code,

2. Multi level code.

In a two level code, a wide bar or a wide space represents a binary one and a narrow bar or a narrow space represents a binary zero (or vice versa). The width of a narrow bar is always called the X dimension of bar code. Wide bars and spaces are based on the X dimension, usually 2X, 2.5X or 3X. These factors enable the decoding unit to distinguish between narrow bars/spaces and wide bars/spaces and successfuly read bar code.

Usually the first bar of a tag is used to define the initial value of X, than all bars and spaces read by the light pen are compared to this standard value and assigned values of either one or zero depending on their respective widths.

An alphanumeric code Code 39 and a numeric code 2 out of 5 code are exampels of two level bar codes.

Code 39 is a much more complicated system. Here there are nine symbols (bars or spaces) per character, three of which are wider as can be seen in Figure 2.1. In other words, this is a "3 out of 9" code which is referred to as "39". The space between two characters has a fixed which of about one and half times the size of a narrow space [3].

2 out of 5 code is a bar only code which is no information in the spaces with ten digit character, a start symbol and a stop symbol. Each numeric character is a set of five consecutive bars of which two bars out of the five are wide [3]. The character table and coding for

CHAR.	PATTERN	BARS + SPACES	CHAR.	PATTERN	BARS + SPACES
1		100100001	M		101000010
2		001100001	N		000010011
3		101100000	O		100010010
4		000110001	P		001010010
5		100110000	Q		000000111
6		001110000	R		100000110
7		000100101	S		001000110
8		100100100	T		000010110
9		001100100	U		110000001
0		000110100	V		011000001
A		100001001	W		111000000
B		001001001	X		010010001
C		101001000	Y		110010000
D		000011001	Z		011010000
E		100011000	–		010000101
F		001011000	.		110000100
G		000001101	SPACE		011000100
H		100001100	*		010010100
I		001001100	$		010101000
J		000011100	/		010100010
K		100000011	+		010001010
L		001000011	%		000101010

→ Start / Stop

Figure 2.1 CODE 39 Code configuration.

this code is shown in Table 2.1 and a typical character and a tag for 2 out of 5 code can be seen in Figure 2.2.

Bar Code Pattern	Character
00110	0
10001	1
01001	2
11000	3
00101	4
10100	5
01100	6
00011	7
10010	8
01010	9
M110	Start
010M	Stop

Table 2.1 2 out of 5 bar code character decoding. (0=narrow bar, 1=wide bar, M= margin)

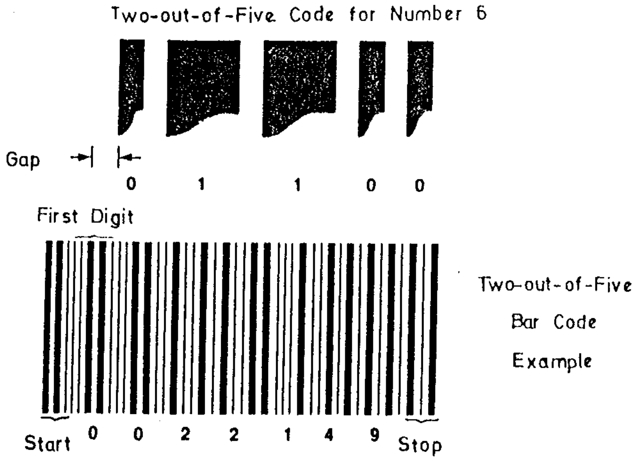

Figure 2.2 Illustration of 2 out of 5 bar code. Each character is represented by a combination of five bars. Each of them is one or three units wide.

In a multilevel code, generally four level, each bar and space can be either one, two, three or four modules wide. For example, Universal Product Code (UPC) is a four level numeric code that is used for identifying grocery products [3]. In this code, the total width (bars plus spaces) for one digit is fixed at seven units (7X). This can be for instance a double bar, then a single space, then a tripple bar and a single space = 2+1+3+1 = 7 units. An example of this case is shown in Figure 2.3. Table 2.2 provides a survey of the code.

Character	UPC Bar Code
0	3-2-1-1
1	2-2-2-1
2	2-1-2-2
3	1-4-1-1
4	1-1-3-2
5	1-2-3-1
6	1-1-1-4
7	1-3-1-2
8	1-2-1-3
9	3-1-1-2
start/stop	1-1-1

Table 2,2 That table indicates the number of width units for the two bars and two spaces used in each character,

Figure 2,3 An example of product coding, Bars and spaces may have four different widths, Two bars and two spaces make up a single digit,

Both Code 93 and Code 128 are four level alphanumeric code [1].

To get a better idea of exactly how a bar code works let's examine the HP41C bar code more closely. HP41C code is an alphanumeric code with all characters and signs. This code is bar only code with no information in the spaces. Narrow bars represent logic zero bits and wide bars (typically two times the width of the narrow bars) represent logic one bits. Each character is a set of eight consecutive bars of which the number of wide bars are even or odd for parity checking. The encoding of each character is possible in the HP41C with respect to ASCII (American Standard Code for Information Interchange), EBCDC (Extended Binary Coded Decimal Interchange Code). A typical tag in HP41C bar code with respect to ASCII is presented in Figure 2.4.

In addition to the data bars in that bar code system, it requires four additional bars - one unit width bar at each end of a row of

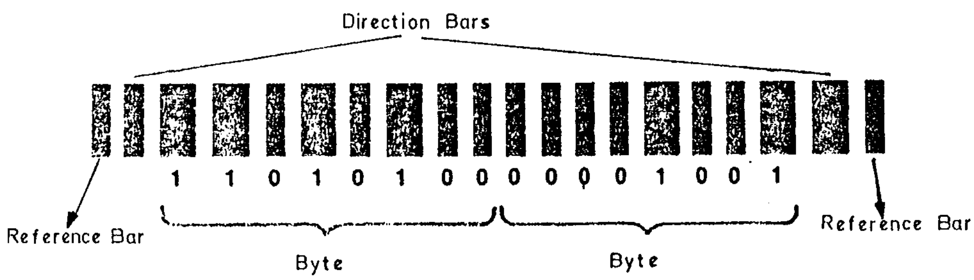

Figure 2.4 Illustration of HP41C bar code. Each character is represented by a combination of eight bars. Each of them is one or two units wide.

bar code to be used in conjunction with the adjacent space to establish an initial reference and another bar next to each reference bar to determine scan direction. The direction bar encountered first in a right to left scan is two units wide; in a left to right scan, it is one unit wide. The direction bars are used to determine which direction the user is scanning and therefore in what order the decoded data should be send back to computer system. The system always receives the most significant bit of the leftmost bit first.

There are typically two levels of self checking that insure that the decoded HP41C data is valid before it is entered into the computer. First, each character is checked to see that there are only even wide bars (or odd). Second, the last character should be a software determined checksum number to verify that the decoded data is the same as the encoded data. For example, if the last digit of the sum of the data values is encoded as checksum digit, then it should also be the last digit of the sum of the decoded data values. If it is not, then the read is invalid.

The main application for bar codes are as alternatives to keyboards. Bar codes allow fast and accurate hand entry of small amounts of data by minimally trained operators.

The commercial market for bar codes are currently into three major types of users.

1. The first and most widespread application of bar codes is in point of sale (POS) computer system in grocery stores. Merchandise

labeled with bar codes are scanned at the checkout counter to automatically enter the price and item on the customer's bill and update the store's inventory. This system allows faster checkouts, fewer errors and more effective inventory management.

2. The second major application of bar code is in industrial data entry. This category includes warehouse inventory control, idenfication of assemblies for process monitoring or work scheduling and data remote data collection. The purpose of bar code in these indrustrial environments is to provide a simple error-proof means to hand-enter data into the central computer.

3. The third and newest area of bar code applications is low cost data entry for microcomputers. Computer sofware in bar code form can be mass produced inexpensively by the printing industry and distrubuted to a board base of users. Bar code formatted sofware can be used for programming appliances, intellegent instruments or personal computers. The most reliable bar code for this aim is HP41C bar code system. HP41C bar code has been discussed previously[3].

2.3 BAR CODE READING SYSTEM

The bar code reading systems scan and decode the bar code which is as units of data affixed to an item or on the paper. There are three elements unique to any bar code reading system:

1. Scanner (Sensor),
2. Interface,
3. Decoder.

The block diagram of any bar code reading system is illustrated in Figure 2.5.

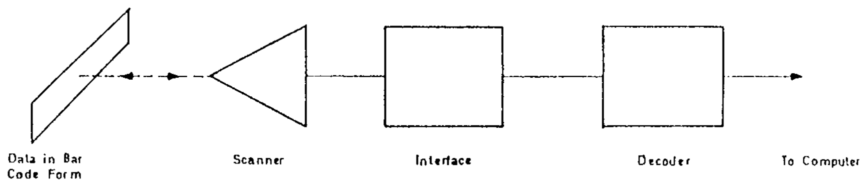

Figure 2.5 The block diagram of bar code reading system.

Bar coding is usually noting in itself. It is simply a way of assigning and recording information about any number of items or data, one at a time.

Bar coding system is a useful system when it is used with computer or microprocessor based systems.

The general introduction with bar codes have been completed in section 2.2. Now, bar code scanner and decoder will be examined.

2.3.1 SCANNER

The scanners are reliable interface between printed bar codes and a decoding system. Bar codes are read by four basic types of scanning devices [1]:

1. Hand-held fixed beam scanners (Wands or Light pens),
2. Hand-held moving beam scanners (often called "Guns"),
3. Stationary fixed beam scanners,
4. Stationary moving beam scanners.

2.3.1.1. Hand-Held Fixed Beam Scanners

Hand-held readers scan bar codes with the aid of an operator who places the tip of the scanner on one side of the bar code symbol then draws the tip fully across the entire code in one swift motion. These devices have a very small depth of field which means they must come in contact with the bar code. This characteristic seperates it from the other three categories which are types of non-contact readers. The minute depth of field is necessary to read through clear laminates. The scanner must be held at a certain angle during the scanning motion because light reflects away from, rather than into, the readers' sensitive optics.

Hand-held scanners are available with white or red or infrared light source. White source is not suitable for portable operation because they require more power than the others. However, they are excellent for reading black and white bar codes only.

The infrared light source is reliable for general purpose light pen. It reads bar codes printed in all colours.

After a few moments of experimentation the operator will find that using a hand-held scanner is mere child's play. However, two critical spesification tolarances are required for good scanning result: the print contrast ratio between black bars and spaces and so called X dimension of the bar code.

The light pen contains a precision optical sensor. Emitter, receiver and optics of optical sensor are generally integrated into a single package. Figure 2.6 illustrates the cross sectional diagram of an optical sensor that is manufactured by Hawlett Packard, series number of HEDS1000. The emitter is a small infrared LED and the sensor itself is made up of a photodiode and a transistor fraternally combined into a single chip. The circuit diagram is drawn in Figure 2.7 that also indicates how to construct an effective sensor by adding resistors.

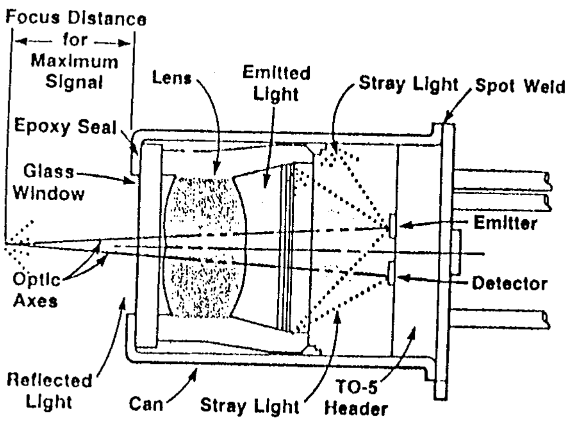

Figure 2,6 Cross sectional diagram of HEDS1000,

2.3.1.2 Guns

Hand-held moving beam scanners are operated by aiming the 'gun' at the bar code (usually within a foot) and pulling the trigger. The code is then read a number of times by a moving beam of light which is either laser or incandescent.

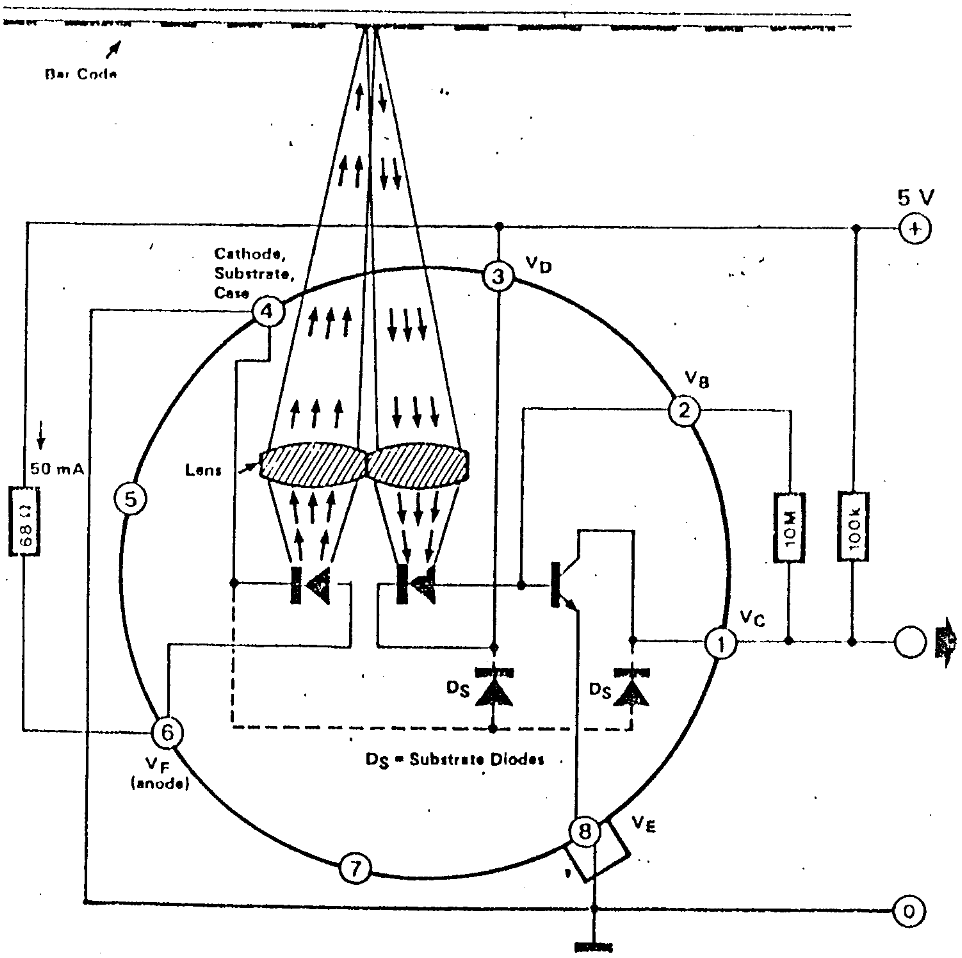

Figure 2.7 The circuit diagram of the HEDS1000. The figure also includes the pinning.

The term 'moving beam'is attributed to the manner in which the device scans. In Figure 2.8, the laser emits a beam which is projected through special optics onto a rotating mirror with several angles (usually hexagonal). As the beam strikes the mirror surfaces, the beam is reflected through the scanner's window to the target area. What happens to the human eye a thin red line perhaps 3 to 4 feet high, is

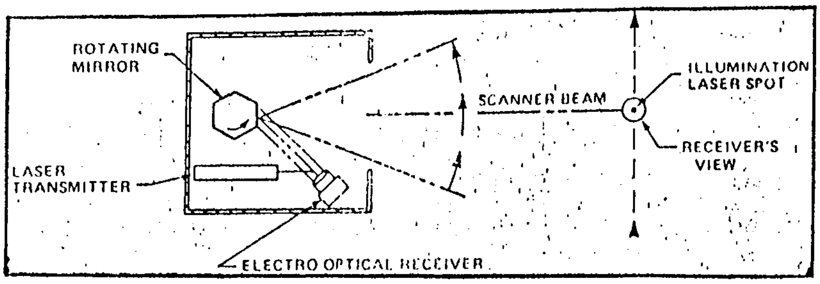

Figure 2.8 Moving beam laser scanner.

actually a laser spot moving so fast it resembles a line.

The laser spot transverses, from right to left, through each bar and space on the code. White areas reflect the laser light, black areas absorb it, to produce a well-defined impulse signal. The laser sources (i.e HeNe laser) are usually low powered.

A laser light source is superior to the non coherent light source used in pens and guns, because laser have a grater depth of field. The moving beam is superior to fixed beam because the speed of reading is not operator dependent, the number of 'reads' made with each push of the trigger ensures grater accuracy and the moving beam is much more likely to find the sweet spot in a marginally printed bar code. An advantage of all non contact scanners is that they don't mar or wear out the actual bar code.

At close distance, the incandescent light source works just as well as laser. Incandescent is also less expensive to bus and to repair.

Guns are most expensive than light pens. So, hand-held laser scanners are eventually going to replace pens in a lot of industrial applications.

2.3.1.3 Stationary Fixed Beam Scanners

A stationary fixed beam scanner reads a bar code (with a non coherent light source) as it passes through the scanner's field of view. To be read the code must be precisely oriented. It is often on a reflective label because it passes one time.

2.3.1.4 Stationary Moving Beam Scanners

A stationary moving beam scanner does not require bar code movement to scan codes. Moving beam scanners can read codes on items (at scan rates from 50 to 1200 reads per second) Moving past at speeds of up to 800 feet per minute [1]. These units also generally have a greater depth of field than fixed beam units, but they are more expensive. This scanner is operated as a stationary gun.

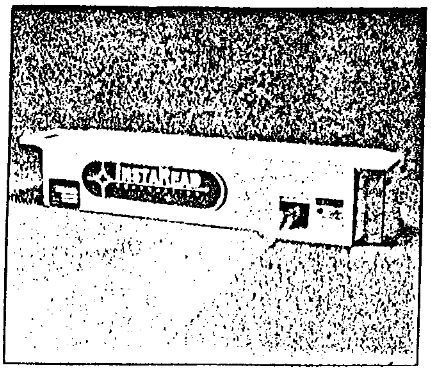

Figure 2,9 A stationary moving beam laser scanner manufactured by Instra Read Corp,

2.3.2 INTERFACE

This circuit converts the low level analog signals from the scanner module to a compatible logic level that can be easily interfaced to decoder. The output signal of scanner shown in Figure 2.10 will be too small to derive logic gates and it has to be

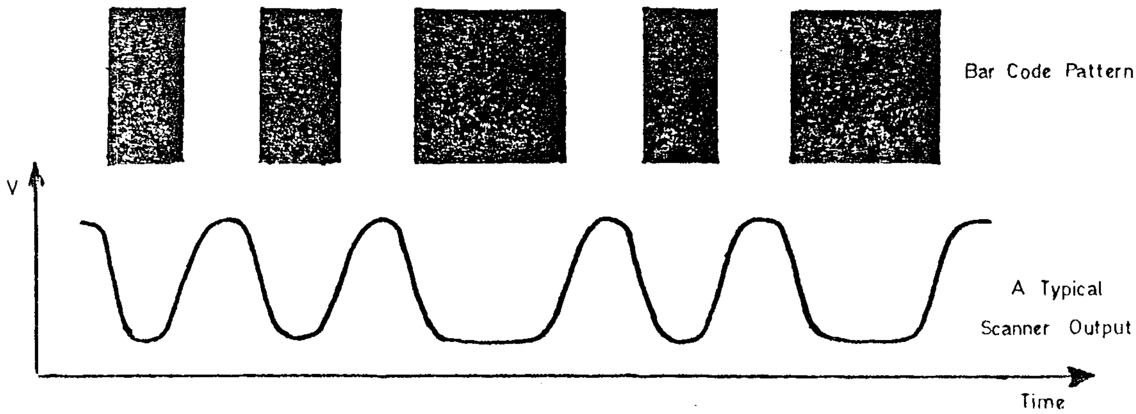

Figure 2,10 A typical bar code pattern and corresponding waveform resulting from a scan of the pattern,

amplified. In addition, something has to be done about cleaning up the output, for example, the original bars may be slightly ragged and not quite black. As for the spaces, they may well be smudged here and there. Even when there is an ideal, clear black-white transition, the output signal will rise gradually as the light spot is not infinitely small. The interface circuit block diagram is illustrated in Figure 2.11.

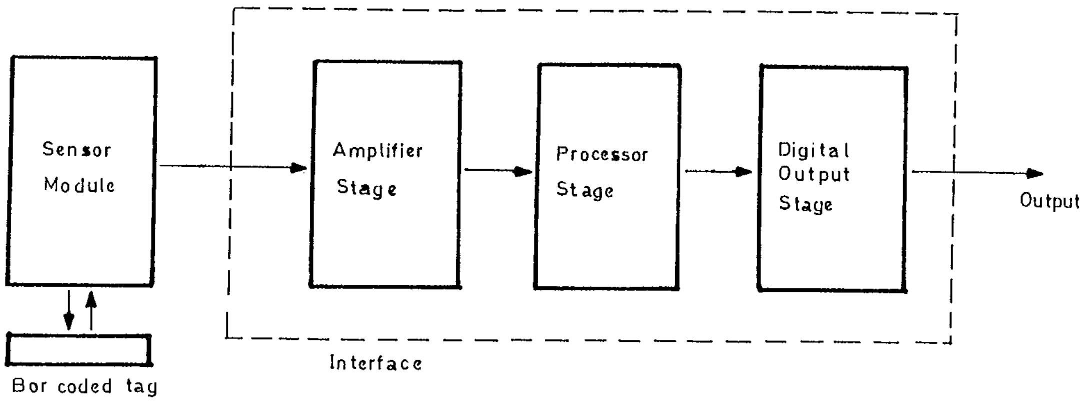

Figure 2.11 Block diagram of Interface circuit,

The amplifier is needed to increase the signal from the sensor up to a processable level by generally converting a current to a voltage. That amplifier has to have high transimpedance to accomplish current to voltage conversion.

The processing circuit is used for determining bars and spaces by using the signal from amplifier stage. There is a signal digitized on the output of that stage.

The digital output section provides a logic zero for the white spaces and logic one for the black bars and it is used to drive TTL or CMOS logic gates in decoder.

2.3.3 DECODER

Decoder will be a circuit that converts the electrical signals from the interface into serial binary data, apportions the serial binary data into bytes, stores the bytes for retrieving by using RAM, and interfaces with computer bus lines to transfer the data to the computer CPU.

All decoders use an oscillator to determine the widths of bars. The number of clock pulses of oscillator corresponding to a bar is the width of that bar for decoder.

Decoding is done according to used bar coding systems. As previously mentioned in Section 2.2, bar coding systems can be classified as two level and multilevel code.

The block diagram of decoding circuit for two level code is shown in Figure 2.12. It needs one reference value for decoding because there are two different bar widths, logic one and zero.

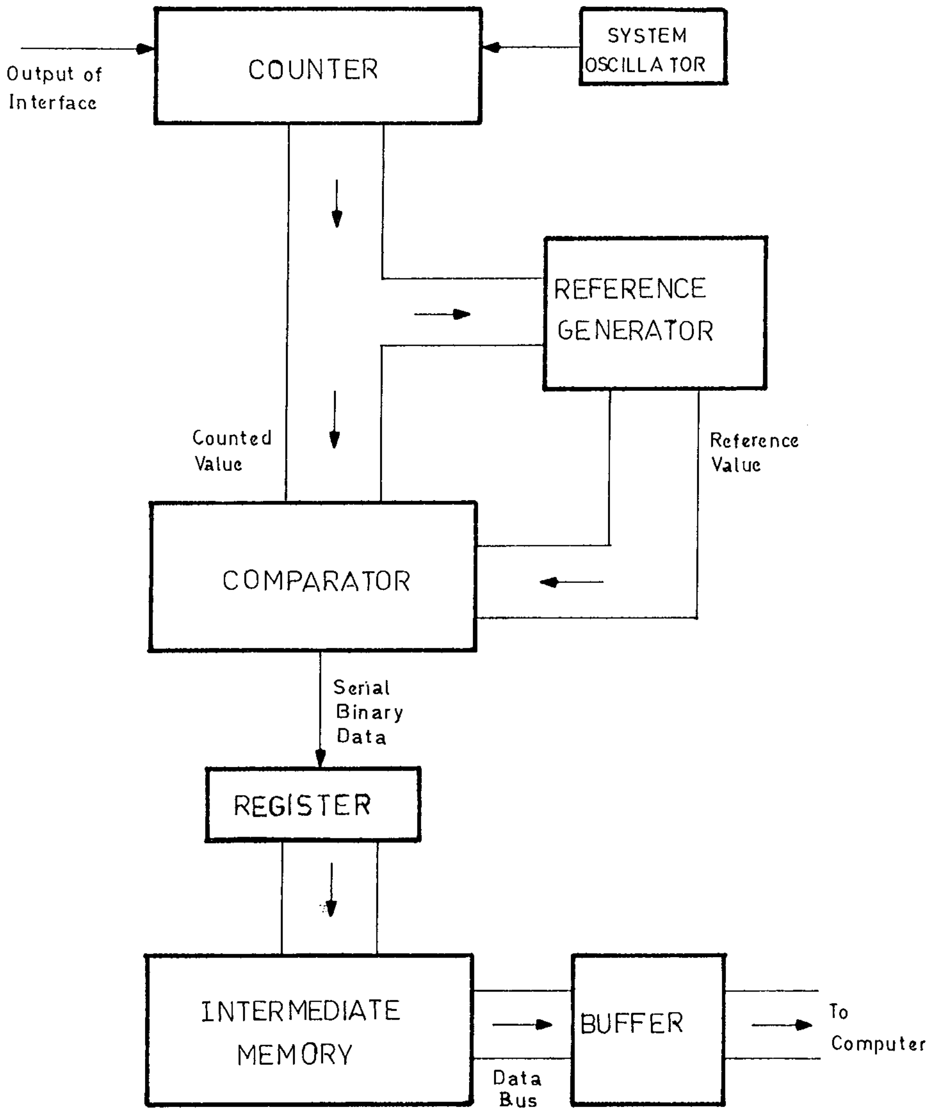

Figure 2,12 The block diagram of decoding circuit for two level code,

For a four level code, decoding circuit needs three reference to decode it. Each of them is positioned to between two neighbour levels. The block diagram of that decoding system is illustrated in Figure 2.13.

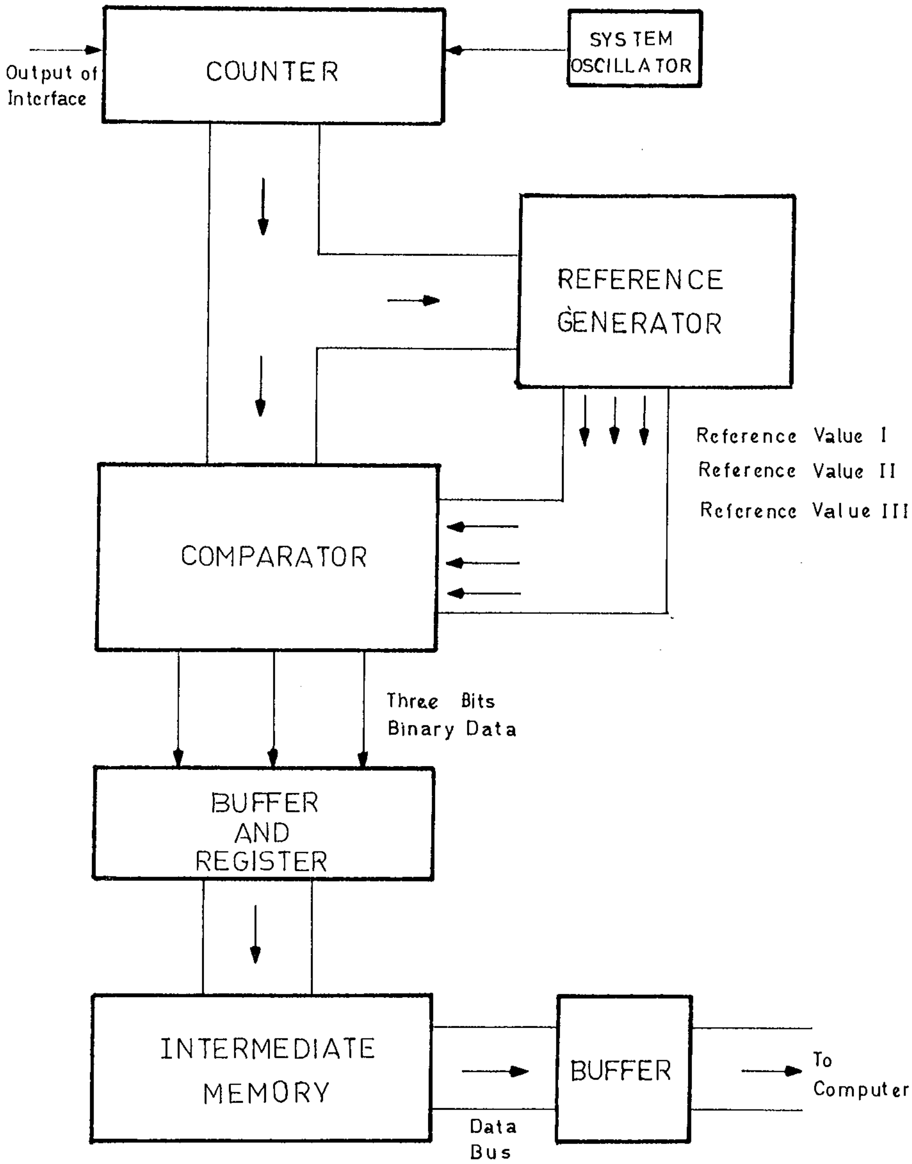

Figure 2.13 The block diagram of decoding circuit for four level code. Reference 1 is positioned between 1X and 2X width. Reference 2 is positioned between 2X and 3X width. Reference 3 is positioned between 3X and 4X width.

The number of requiring reference value to an n level bar code to be decoded is (n - 1).

Counter determines the widths of bars and spaces by using system oscillator clock pulses.

Reference generator generates reference values for comparator so as to use to decide what width is of any bar.

Comparator provides logic outputs by comparing the widths of scanned bars or spaces and reference values.

Register saves logic outputs from comparator and orders them in digit form to sent memory.

Intermediate memory saves all digits or characters in a row of bar code until the end of scanning, and then information saved is loaded to computer by using reliable buffer stage.

CHAPTER 3

DETECTOR DESIGN AND CONSTRUCTION

At the block diagram of bar code detector system, there are three parts as shown in Figure 2.5. Each block of bar code detector, scanner, interface, decoder have been designed seperately to detect HP41C bar code. As it is previously mentionned HP41C bar code system uses bars only as information carriers. Spaces between two bars do not contain information, only are used to maintain reference. Narrow bars represent logic zero, wide bars logic one.

3.1 SCANNER

A light pen that mentioned in Section 2.3.1.1 has been used as a scanner. The emitter and receiver of optical sensor of light pen are

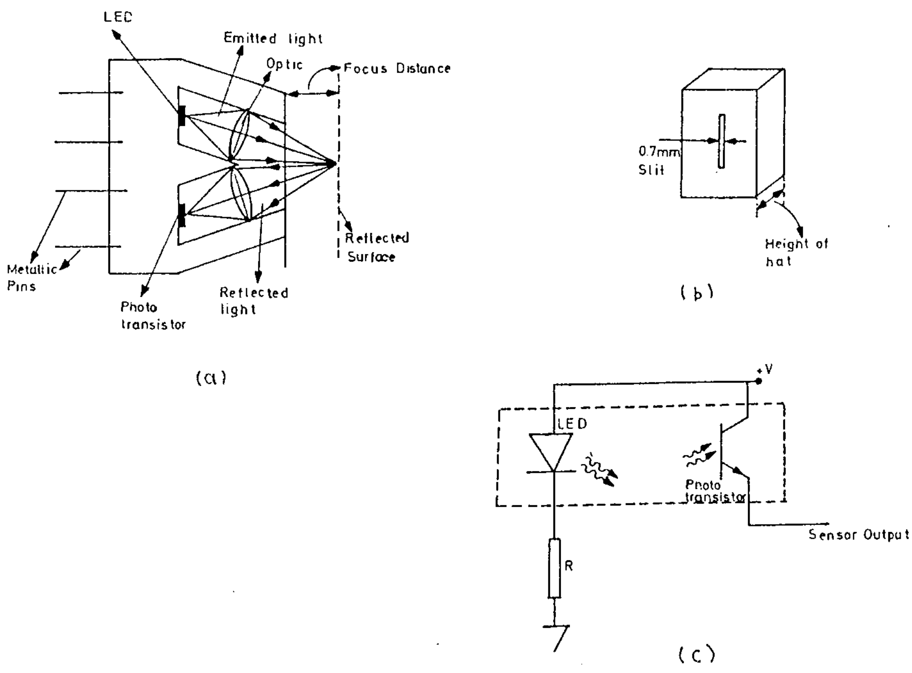

Figure 3.1 TIL139 infrared sensor and attached hat.

integrated in a single package manufactured by Texas Instrument (TIL139) and shown in Figure 3.1.a. 900 nm wavelength infrared light is emitted from emitter of TIL139. A hat that has slit width of 0.7 mm is attached on the top of sensor to improve the resolution of light pen as in Figure 3.1.b. The height of the hat is equal to focus distance of sensor which is 1.9 mm. So light pen can be closed on the bar code tag printed on the paper when the scanning is done. The light pen designed to read bar codes must be in perpendicular position to bar code pattern.

Maximum light is emitted from the emitter of sensor when it is powered from 5V dc power supply and 150 Ω current limiting resistor is used. The current passing through the LED is about (5 - 1.4)V / 150 Ω= 24 mA. The current maintained from the emitter of receiving transistor is between 5.3 μA and 6.8 μA depending on the reflectivity of the paper when the light pen is on the white space.

The resolution of the optical sensor is determined by the size of the slit width that allows reading of bar width as small as 0.7 mm, reliably. That width is equal to minimum X dimension which can be sensed by light pen. In present work, 1 mm X dimension will be used. Since, the widths of narrow bars and spaces are 1 mm then wide bars are 2 mm.

The maximum acceptable speed of light pen is set by the time required to decode a bar, to establish a new reference and to store eight bits in a buffer which corresponds to 1.7 ms (see Section 3.3.7.2). As mentioned before, the widths of narrow bars and spaces were 1 mm. So, from the formula v=s/t maximum scan speed will be 1 mm / 1.7 ms = 588 mm/s.

The maximum counting time for a bar must be less than 2^{12} oscillator clock cycles, because 12-bit decoder is used. Since the oscillator clock period is 5 μs, the maximum counting time will be about $(2^{12} - 1) * 5\ \mu s \simeq 20$ ms. Light pen should pass over a wide bar during 20 ms. So, minimum scan speed of light pen is 2 mm / 20 ms = 100 mm/s.

3.2 INTERFACE

This circuit will be designed to convert the analog signals coming from the scanner to a logic level which can be interfaced to decoder as previously mentioned in section 2.3.2.

There are various techniques which can help to generate logic level from scanner signal. The signal may be differentiated for instance, so that the high - low and low - high transitions are retrieved from the signal. However, this process has a number of serious disadvantages. In this technique, logic levels also depend on the departure of the light pen from the paper that bar codes are printed on. And this system is highly sensitive to interference (both printing errors and electrical interference).

Another possibility would be to amplify the signals considerably so that it starts to clip. This will only work if the signal is kept at a fairly constant level.

A potentially accurate technique is to detect the positive and negative signal's peaks and set a threshold halfway between the two peak values. This point corresponds to the sensor viewing area being positioned the boundary between bars and spaces. This works well if the signal level remains constant or the signal maxima increases and signal minima decreases. In a typical scan, this is not the case because the height above the bar code pattern and the light pen angle can vary considerably during the scan, which changes the dc level. If this technique is used, a means for resetting the peak detectors after each transition is needed to allow for case of changing the signal dc value. The solution of this problem is to use rapidly decaying peak detectors or using extensive digital circuits. The last technique will be used to design interface circuit.

Another problem with peak detection is how to handle static conditions when there are no transitions and reliable references as to what is black and what is white. Arbitrary logic default states and fixed black to white threshold could be used. The problem is that arbitrary states will not always be correct and fixed thresholds are subject to too many error sources, such as ambient light and supply voltage variations, sensor and amplifier circuit d rifts and component tolerances.

The final designed circuit is illustrated in Figure 3.2.

3.2.1 Current to Voltage Converter

The current to voltage converter converts the current from the scanner up to a processable voltage level. That converter is constructed by using an OPAMP (LM301). The peak to peak voltage swing of the output of the converter must be grater than $2V_x$ = 1.2 V to be sensed by D_1 and D_2 in the peak detector. The minimum current supplied from the sensor was 5.3μA when the light pen is on the white space. So,

$$R_1 \geq \frac{1.4\ V}{5.3 \mu A} = 226\ K\Omega\ ;\ R_1 = 270\ K\Omega,$$

since, peak to peak voltage on the output of converter is grater than 1.4 V.

3.2.2 Processor

The processing circuit uses peak detection to determine bars and spaces. A simple positive and negative peak detector (Figure 3.3) uses two diodes and a capacitor. As shown in Figure 3.4 b, maximum peak voltage minus a diode drop (0.7 V) is stored on C.The comparator circuit compares this value with the output of the converter. When the converter output signal goes through its negative peak value, D_2 starts conduction and the negative peak voltage minus a diode drop is stored on C. As the signal becomes more positive than the voltage on C, the comparator changes the state. Diode D_1 then conducts until the maximum peak voltage minus a diode drop is stored on C again. This process repeats itself.

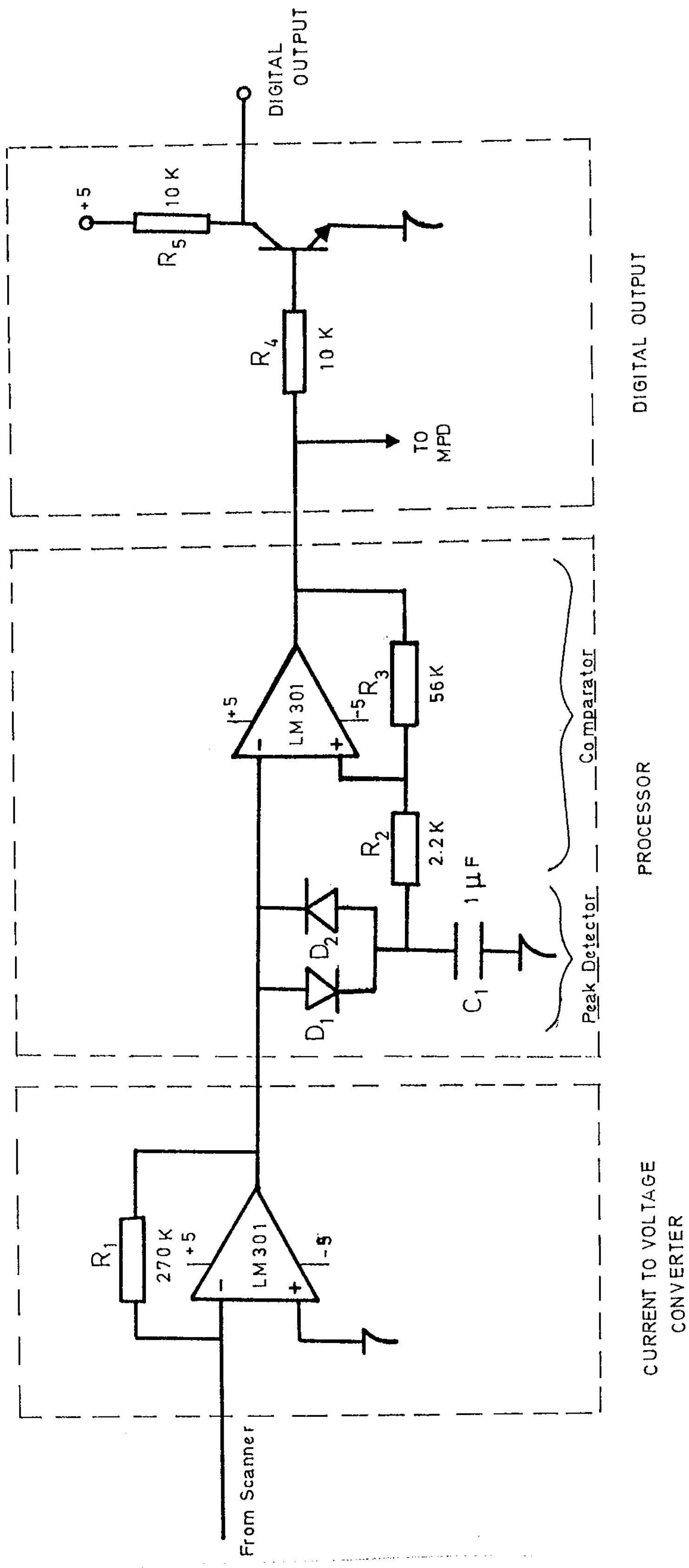

Figure 3,2 The interface circuit

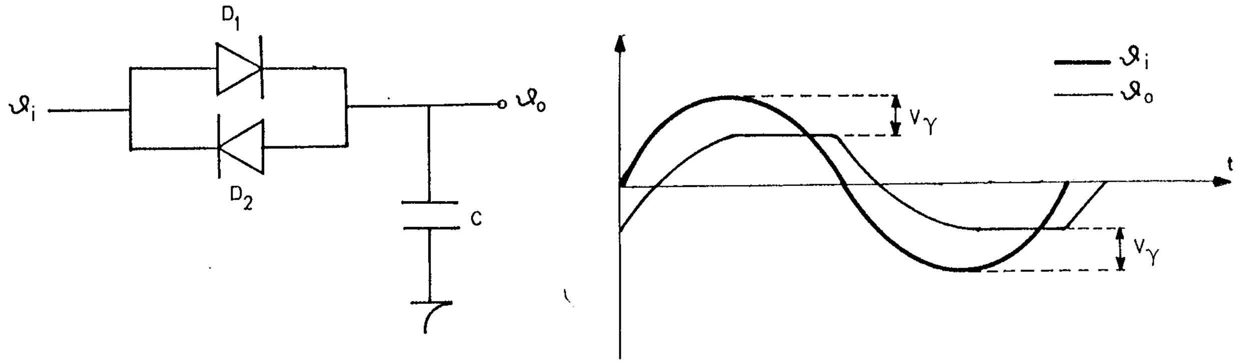

Figure 3.3 A simple positive and negative peak detector and resulting signal.

Comparator is a schmitt trigger circuit and provides two functions. First, it digitizes the signal by comparing the signal level from converter to the voltage on C. If the voltage on the output of converter changes between 0 and -2 volt while scanning is done, then

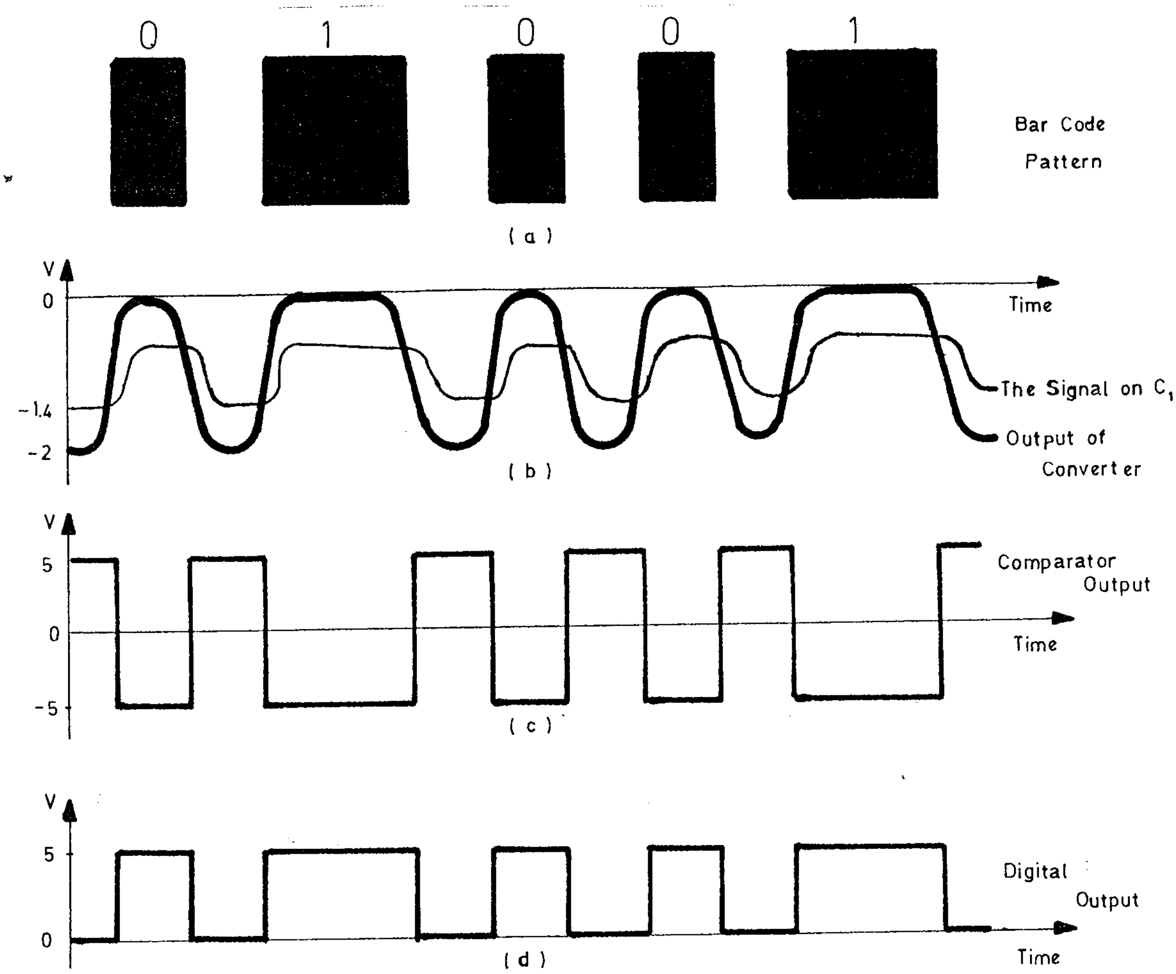

Figure 3.4 The signal waveforms of processor and digital output section.

capasitor voltage changes between -0.6 and -1.4 V. At schmitt trigger operation, V_c = -1.4 V then the output of comparator is +5 V, so the lower trigger point of that circuit is

$$V_{LT} = \frac{5 + 1.4}{R_2 + R_3} * R_2 - 1.4 = -1.16\ V.$$

If V_c = -0.6 V then output of comparator is -5 V, so the upper trigger point is

$$V_{UT} = \frac{-5 + 0.6}{R_2 + R_3} * R_2 - 0.6 = -0.77\ V.$$

Resistor R_2 and R_3 provide hysteresis for digitizing function to insure clean transition in the presence of a noisy signal. The hysteresis interval of that circuit is

$$V_{UT} - V_{LT} = 0.39\ V.$$

Figure 3.4-d shows the output of comparator circuit. Second, peak detector is decayed because C charges and discharges to output voltage of converter with time constant of $\tau = C * R_2$ = 2.2 ms when D_1 and D_2 are off state.

The shape of the waveform at (-) input of the comparator is approximately ramp function from -2 to 0 volt when the light pen departures from the paper, and the equivalent circuit and $V_1(t)$ are given in Figure 3.4.e.

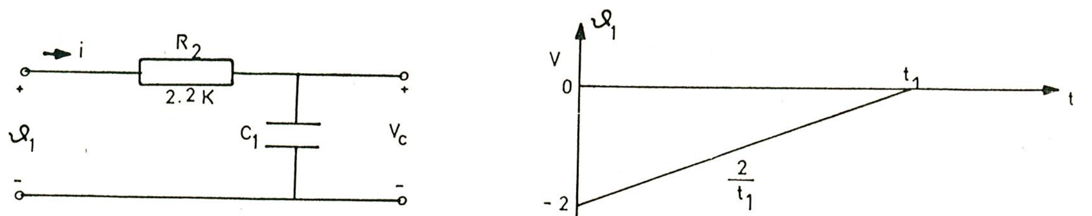

Figure 3.4.e The equivalent circuit of peak detector if both diodes are off state.

$$V_1 = iR_2 + 1/C\int idt \qquad (1)$$

$$\frac{dV_1}{dt} = \frac{di}{dt}R_2 + \frac{1}{C}i = a$$

a is the slope of ramp function and equal to $2/t_1$.

The solution of the differential equation for ramp input is given as,

$$i = A_o e^{-t/\tau} + aC \qquad (2)$$

Using initial condition at t = 0,

$$i(o) = -\frac{V_1(o) - V_c(o)}{R_2} = A_o + aC$$

for C = 1μF , R_2 = 2.2 KΩ

$$i(o) = -\frac{0.6}{2.2} = A_o + aC$$

$$A_o = -\frac{0.6}{2.2} - \frac{2}{t_1}10^{-6} \qquad (3)$$

Let's take t_1 which is the minimum rising time required of V_1 from -2 to 0 volt, not to change the state of comparator.

$$i(t_1) = \left[\frac{-0.6}{2.2} - \frac{2}{t_1}10^{-6}\right] e^{-t_1/\tau} + \frac{2}{t_1}10^{-6}$$

At t = t_1 time, (-) input of the comparator is 0 volt. There is no changing of the comparator state when (+) terminal is above 0 volt. To satisfy this condition;

$$\frac{5\ V}{56K} \geq \frac{V_c}{2.2K} \qquad \Rightarrow \qquad V_c \leq -0.2\ V$$

and,

$$V_c(t_1) = V_1(t_1) - V_{R2}(t_1) \qquad (4)$$

so, $\quad -0.2\ V = 0 - i(t_1)R_2$

$$i(t_1) = \frac{0.2\ V}{2.2\ K}$$

finally,

$$\frac{0.2\ V}{2.2K} = -\left[\frac{0.6}{2.2K} + \frac{2}{t_1}10^{-6}\right] e^{-t_1/\tau} + \frac{2}{t_1}10^{-6} \qquad (5)$$

From the solution of Equation 5, t_1 is found 22 ms. t_1 behaves a half period of $V_1(t)$. So, the limit frequency of $V_1(t)$ which does not affect output of comparator is $1/2t_1 \approx 23$ Hz(Hertz). That limit frequency was found 21 Hz experimentally.

An another experimental result is that; the maximum frequency of signal resulting handle static condition is 20 Hz, since that signal does not change the state of comparator. The state is changed only by bar code pattern.

3.2.3 Digital Output Section

The digital output section serves to buffer the output of comparator and provides logic compatible levels, a logic zero for the white spaces and logic one for the black bars as shown in Figure 3.4d.

3.3 DECODER

The decoder circuit has been designed according to block diagram in Figure 2.12. The shematic representation of this circuit is given in Figure 3.9. In that Figure, the blocks of decoder are shown by dash lines.

As seen before, the widths of narrow bars and spaces are equal to each other. A logic one is represented as a bar of twice that width. The output of interface circuit is high when light pen scans bars, and low when it passes across spaces.

The flow chart of the decoder circuit is given in Figure 3.10.

3.3.1 System Oscillator

System oscillator is used to determine the width of any bar for decoder. It is constructed by LM555 timer IC (Integrated circuit) and generates clock pulses for counter.

Its frequency is calculated by;

$$f = \frac{1}{T} = \frac{1}{0.7(R_1 + R_2)C} \simeq 200\ KHz.$$

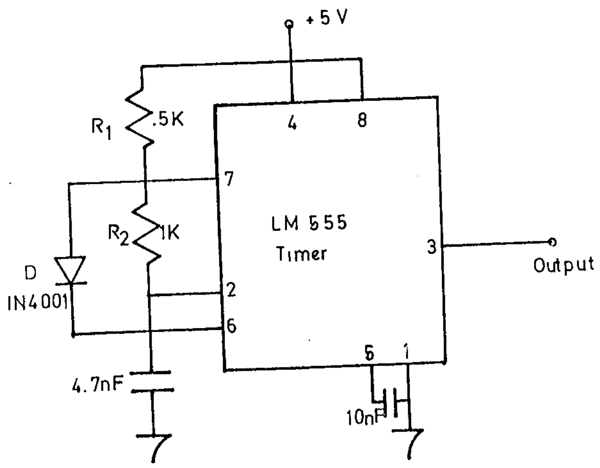

Figure 3.5 System oscillator.

3.3.2 Counter

Decoding is achieved by counting the system oscillator clock pulses [see Figure 3.9]. At the beginning of each counting period, counters will be cleared by L1 (Latch 1) and L2 (Latch 2)signal pulses come from control unit [see Figure 3.6]. Counted value for a low period is saved to use in reference generator until the end of next low period by latch ICs (CD4042). Counted value for a high period is saved to compare it with reference value by others latch ICs.

Counted value should not exceed from 2^{12} = 4096. This condition gets a limitation on the speed of light pen as previously discussed in Section 3.1.

3.3.3 Reference Generator

The number of requiring reference value to decode HP41C bar code is n - 1 = 2 - 1 = 1, because this bar code is two level code. That reference value can be calculated by

[The width of narrow bar + The width of next space]*(3/4)

The high level and the low level of digital output are counted by two 12-bit binary counters (CD4040) seperately. For example, the first bar is measured and found to be 1100 pulses. Next there is a space equivalent to 900 pulses. The reference value will therefore be 2000*(3/4) = 1500 pulses. The next bar turns out to be 1600 pulses; since this is more than 1500, it will be a logic one. Now a new space follows, 700 pulses. The 'unit width X' of the narrow bar corresponded to 800 pulses so, the new reference value will be [800 + 700]*(3/4) = 1125 pulses. In other words, the light pen picking up speed!

The updating of reference value prevents all errors come from acceleration of light pen.

The number of clock pulses corresponding to space is saved in latch ICs for adding by using L2 signal, at the end of each space. A bar width appears at the output of shift register by pass signal (Figure 3.6), at the end of each bar. If the bar is wide, then shift signal is generated. That signal shifts one bitto right the output bits of shift register. So, the width of wide bar have been divided by two to maintain narrow bar value. If the bar is narrow, then shift signal is not generated (Figure 3.6).

Example: Suppose that the width of wide bar is
01011010 = 90. If it is shifted to right one bit, it becomes
00101101 = 45. It has been divided by two.

The width of narrow bar (X dimension) with the following space are added by first full adder. The formula of reference can be rewritten as

[The width of narrow bar + the width of next space]*(1/2 + 1/4)

Second full adder is employed to generate reference value. The output of first full adder is connected to the second full adder shifting to the right one bit and two bits seperately to maintain 1/2 and 1/4 respectively.

The reference value for a bar depends on the previous space and previous bar.

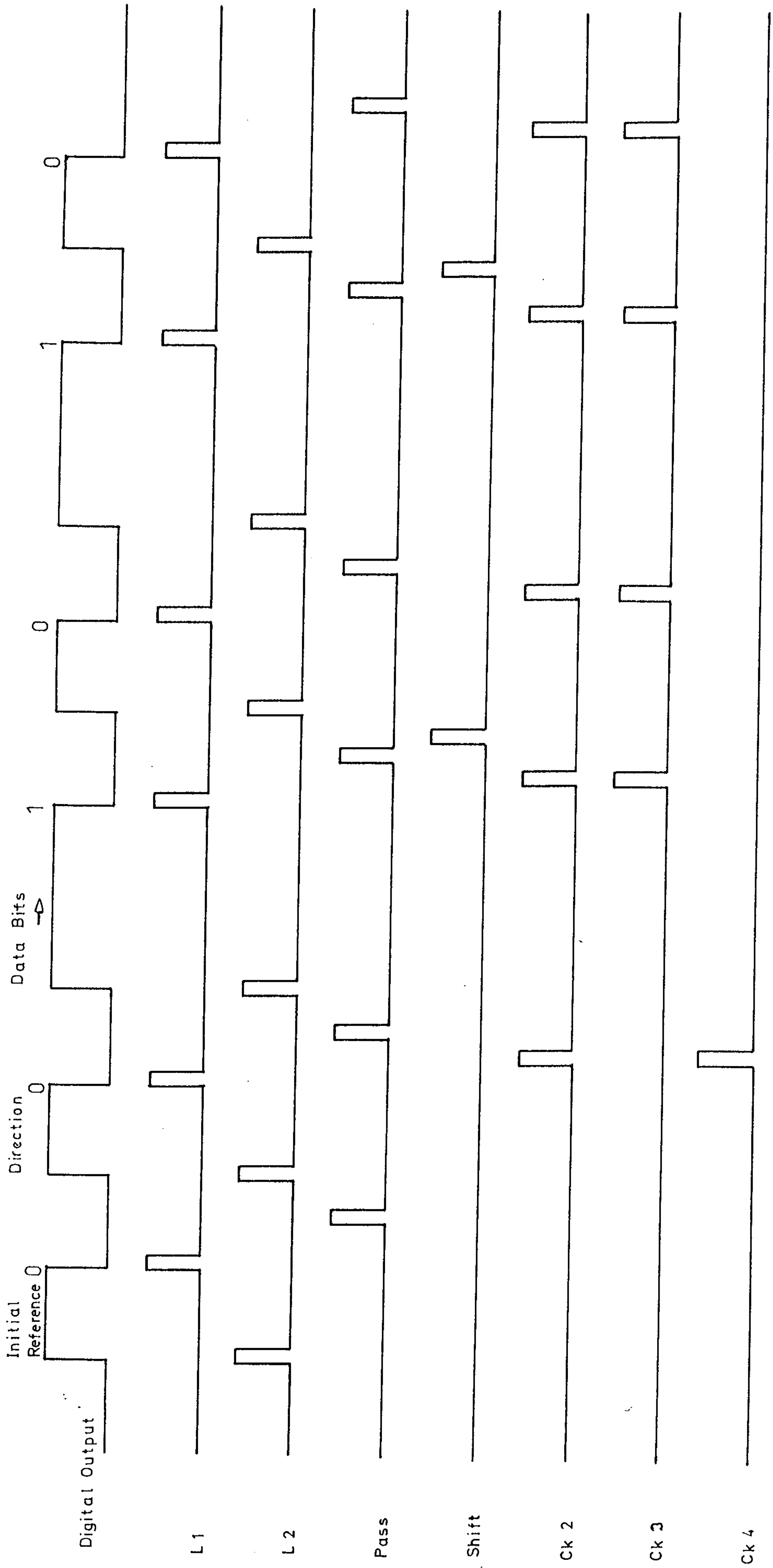

Figure 3.6 Digital output and corresponding control signals.

3.3.4 Comparator

The value of a bar (the number of oscillator clock pulses for that bar) and corresponding reference value are compared by comparator. If the bar width is grater than reference, output of comparator is logic one. If it is not, output is logic zero.

Output of comparator changes the state lasting, while the scanning is done, according to data bars. To get each data bit, corresponding clock pulses Ck3 (Figure 3.6) is generated by the control circuit.

First bit coming from comparator is direction bit. This bit is saved and seperated from other bits in the DFF1 (Data Flip Fiop 1).

All the time the previous data bit is saved in a DFF2 to decide the generation of shift pulse.

3.3.5 Register

Serial binary data from comparator stage is stored in the form of 8-bit (byte) in the SIPO (Serial Input Parelel Output) shift register IC by using Ck3 signal pulses. Each byte stored in this unit will be loaded to RAM (Random Access Memory).

3.3.6 Intermediate Memory

Any data which is encoded in the bar code is in the form of left to right direction and the first bit is taken as the MSB (Most Significant Bit). If the logic state of second bar obtained from comparator is zero, the system knows light pen is scanning the row of bar from left to right, a logic one state will indicate the opposite case. For both cases, decoded data have to be loaded to computer left to right direction. This process is accomplished by intermediate memory.

All bytes in a bar row are stored in RAM according to circumstances of scanning during up counting sequence of RAM address. First byte coming from register is placed in '0' address of RAM and so on.

As an example, let's take the character string of 'ADEM' which is encoded on a paper.

(i) If the scanning is done in left to right direction, the processing of memory is illustrated in Figure 3.7 by signals. Ck4 (Figure 3.6) clears the address counter and binary counter. Tristate buffer 1 is taken 'able mode' by low level of Dis 1 signal (Disable 1) to be passed each character of one byte from the output of shift register to RAM data line. When the Dis 1 signal is low level, one byte data on data line is written to addressed RAM array by low level of $\overline{W}$ signal (Writing signal). Address counter and binary counter are counted up sequence by the positive going edge of Dis 1 signal. Since, A, D, E, M are transferred in addrssed RAM arrays by 0, 1, 2, 3 respectively. As in the following;

0 ⇒ D , 'A' ⇒ B
write: (B) ⇒ <D>
1 ⇒ D , 'D' ⇒ B
write: (B) ⇒ <D>
2 ⇒ D , 'E' ⇒ B
write: (B) ⇒ <D>
3 ⇒ D . 'M' ⇒ B
write: (B) ⇒ <D>

At the end of scanning which is indicated by MPDO (Missing Pulse Detector Output), address counter is cleared and recounted from zero to up. Counting is done by positive going edge of Dis 3 signal which is produced by reading oscillator (see Section 3.3.7.1). Each byte is read from RAM and transferred to data line by low level of $\overline{G}$ signal (Reading signal). As in the following;

0 ⇒ D
read: (<D>) ⇒ B ⇒ data line
1 ⇒ D
read: (<D>) ⇒ B ⇒ data line
2 ⇒ D
read: (<D>) ⇒ B ⇒ data line
3 ⇒ D
read: (<D>) ⇒ B ⇒ data line

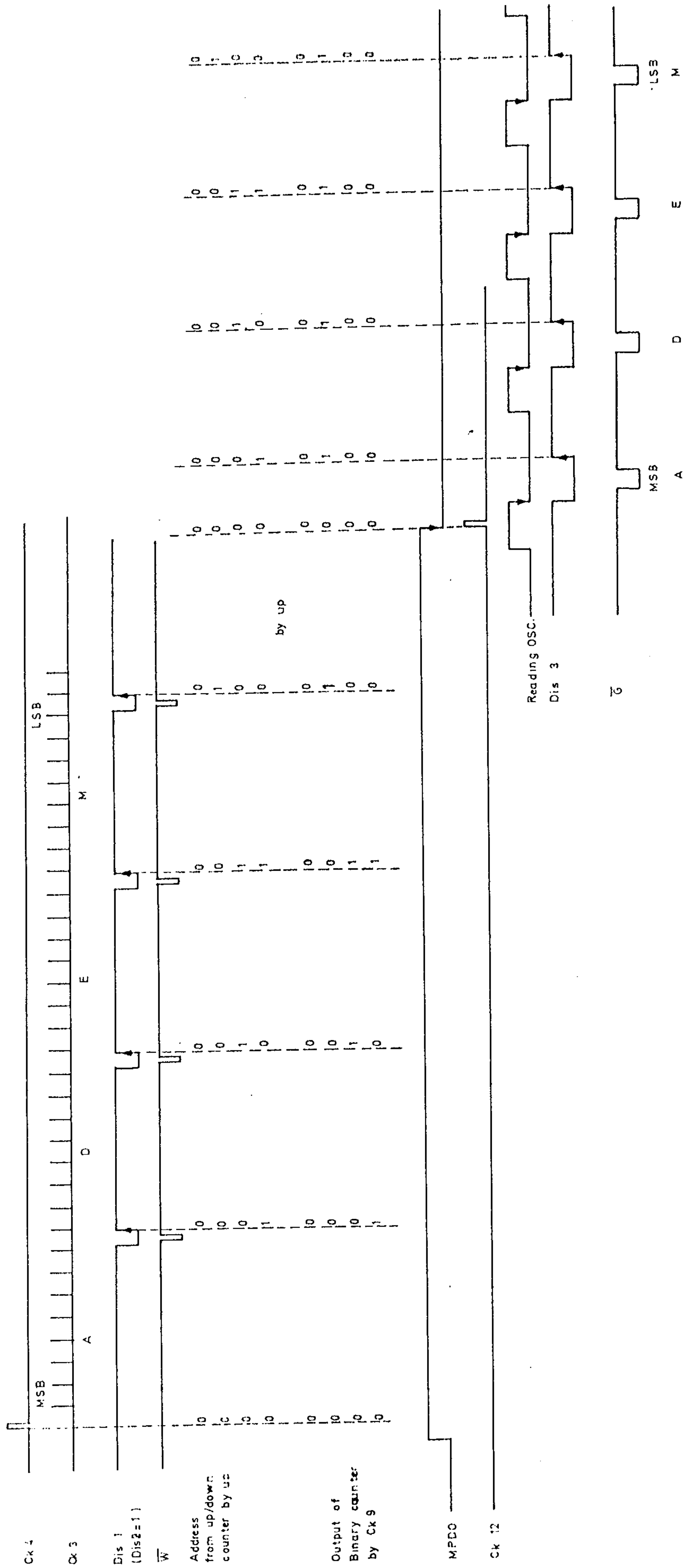

Figure 3,7 The writing and reading signals when the scanning is done from left to right.

Tristate buffer 3 is also taken to 'able mode' by the low level of Dis 3 signal and the data is transferred to the display unit.

Reading is completed when the output of address counter is equal to the output of binary counter. So, the character string of 'ADEM' is loaded to computer by one swift motion of light pen.

(ii) The operation of intermediate memory is given in Figure 3.8 by signals, when the scanning is done from right to left. In that case, character sequence from register are reversed and bit sequence of any character is reverse too. Bit sequence of any byte is corrected by tristate buffer 2 by changing the places of MSB (Most Significant Bit) and LSB (Least Significant Bit). So, the bits of each character appeared on the output of buffer or data line of RAM is at correct sequence.

Address counter and binary counter are cleared by Ck 4. Address counter is counted up direction by positive going edge of Dis 2 signal. Each character taken from register by low level of Dis 2 signal is written to addressed RAM array by low level of $\overline{W}$ signal. A, D, E, M are placed in addressed RAM arrays of 0, 1, 2, 3 respectively.

When the scanning is completed, address counter starts to count at down direction to provide correct reading by negative going edge of Dis 3 signal. Each character in RAM is read and transferred to data line by low level of $\overline{G}$ signal. Reading is stopped while the outputs of address and binary counters are equal. At the end of reading, all data have been loaded to computer.

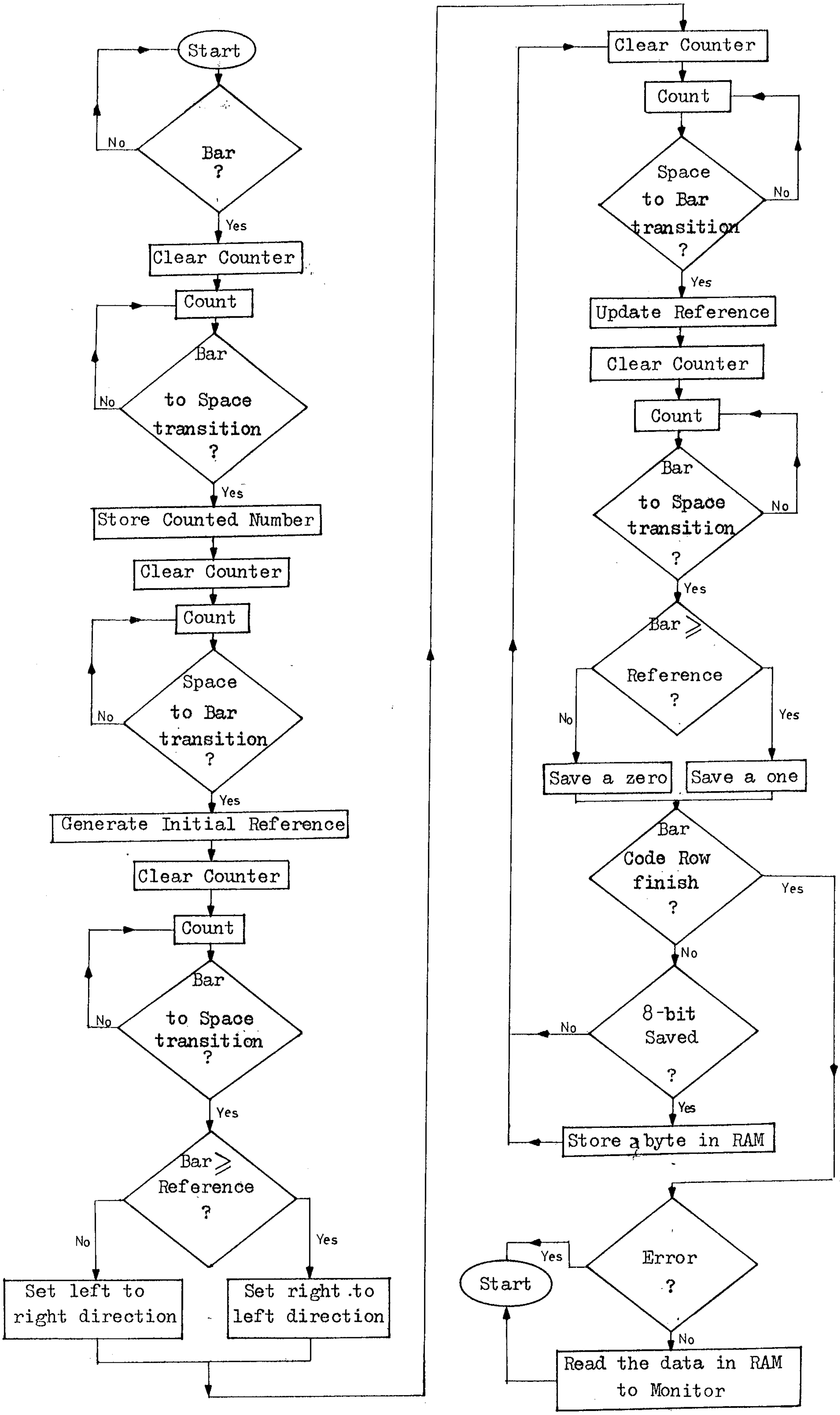

Figure 3.10 The flowchart of decoder

3.3.7 Control Circuit

The additional block not shown in Figure 3.5 is the control circuit. It ensures the synchronizing of all blocks in Figure 3.5. Other decoder blocks are cooperated by control circuit. Requiring signals are also generated in control circuit by using basic signals as input. Input and output signals of control circuit block are shown in Figure 3.11.

Let's explain input and output signals of control circuit block one by one.

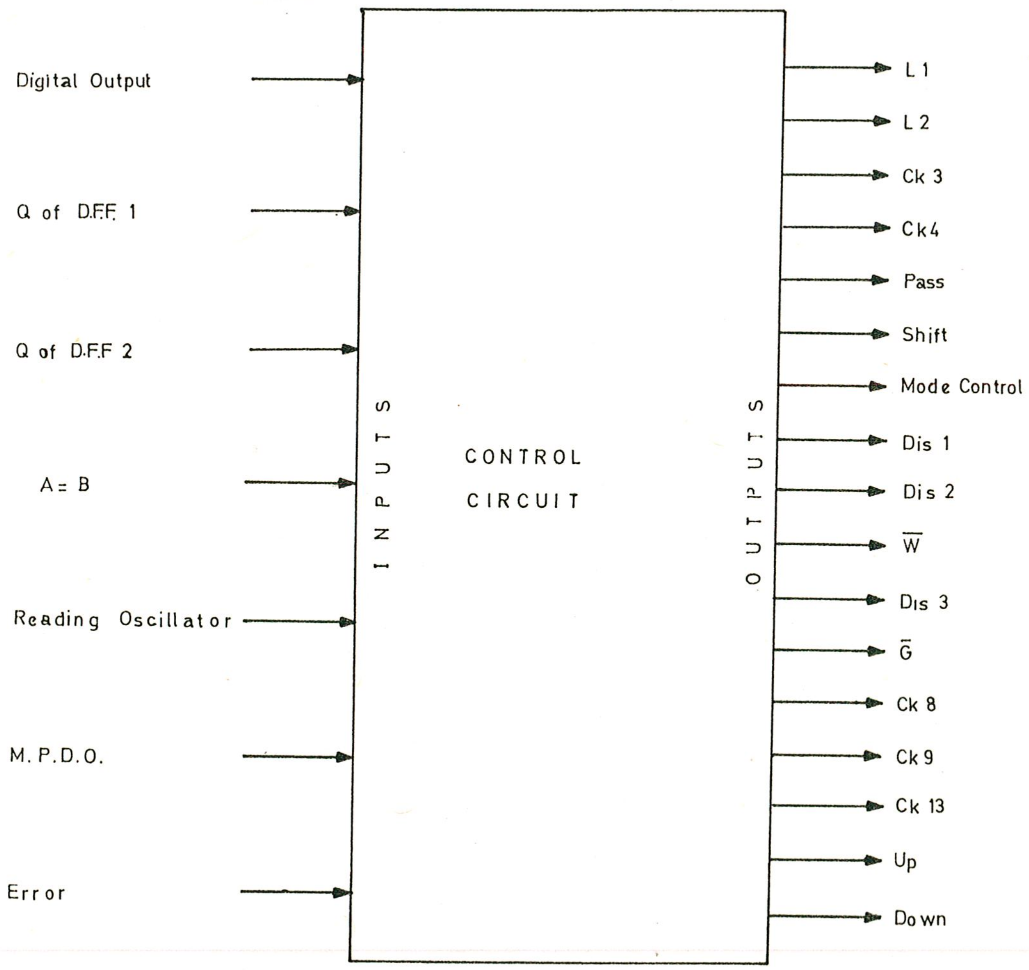

Figure 3.11 Inputs and outputs of control circuit.

3.3.7.1 Inputs of Control Circuit Block

(i) **Reading Oscillator** is constructed by LM555 timer IC as shown in Figure 3.12. Its frequency is calculated by;

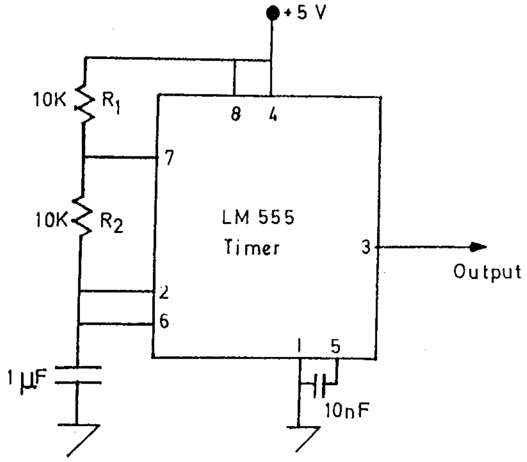

Figure 3.12 Reading oscillator.

$$f = \frac{1}{0,7(R_1 + 2R_2)C} = \frac{1}{0.7(10 + 20)*10^{3}*10^{-6}} = 47\ Hz.$$

This oscillator is used to read the data in the RAM at the end of scanning. The signals of reading period are generated by this oscillator.

(ii) **Digital output** is the output of interface circuit as explained before (see Section 3.2.3).

(iii) **DFF1** shown in Figure 3.5 is used to save the direction bit of a row of bar code. If the output of DFF1 is 'logic one', scanning is done from right to left. If it is 'logic zero', scanning is at left to right direction.

(iv) **DFF2** shown in Figure 3.5 is used to save previous data bit which determines whether the shift signal will be generated or not.

(v) **The output of A=B** comes from magnitude comparator in the intermediate memory block. That output senses the end of reading of data in RAM. The number of characters (byte) written in RAM is saved in binary counter or up/down counter. At the reading cycle, reading is stopped by control circuit when A=B.

(vi) **Missing pulse detector (MPD)** is used to sense the end of scanning. It is triggered by output of comparator in interface circuit to keep the MPDO (MPO Output) at high level. After the complition of scanning MPDO falls to low level with 0.11 ms delay and then reading starts, as shown in Figure 3.14. The delay time should be in the range of t_1 and t_2. t_1 ($\approx$ 0.02 s) is the period of digital output under minimum scan speed condition, t_2 ($\approx$ 1 s) is the time required to start next scanning. The calculation of delay time is

$$T = RC\ \ln \frac{V_f - V_i}{V_f - V_c}$$

$$= 10K\Omega * 10\mu F * \ln \frac{5 - 0}{5 - 10/3} = 0.11\ s,$$

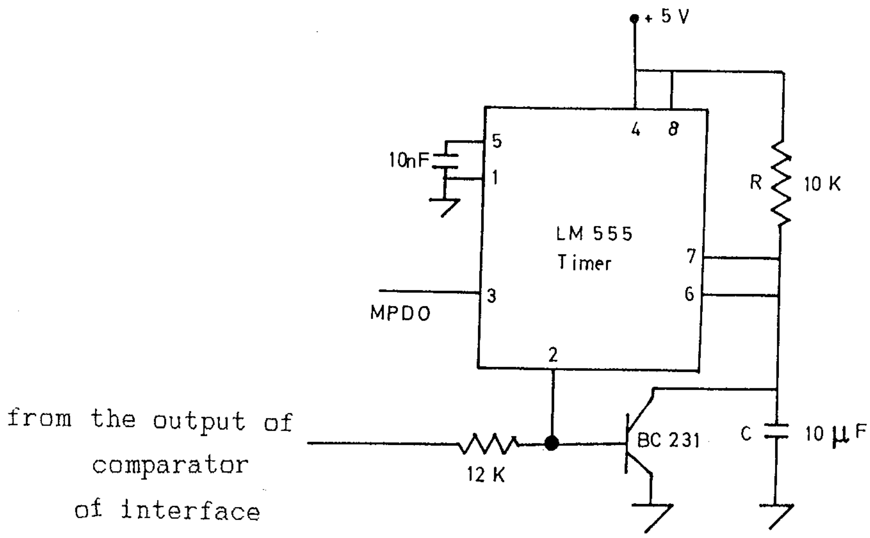

Figure 3.13 Missing pulse detector circuit.

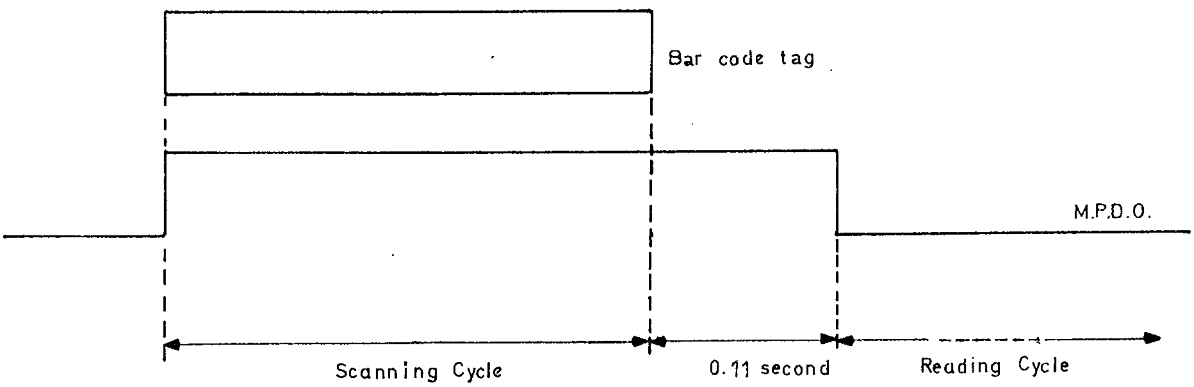

Figure 3.14 MPDO and scanning and reading cycle.

(vii) **Error detection circuit** checks parity bit of each byte. If it has even parity, there is no error for that byte. Otherwise, there is an error. When an error is sensed, scanning has to be repeated.

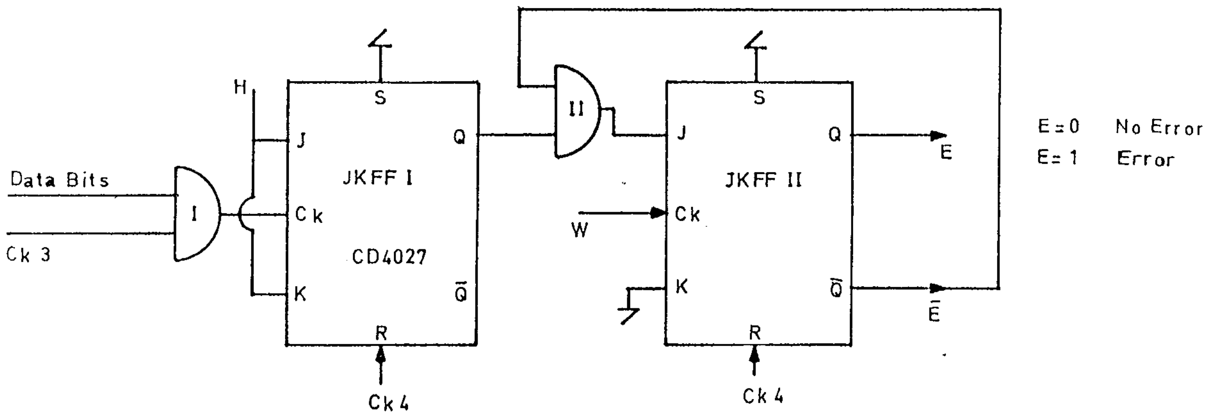

Figure 3.15 Error detection circuit.

As seen in Figure 3.15, at the beginning of scanning, each JKFF (JK Flip Flop) is cleared by Ck4. If data bit is logic one, AND-GATE I passes the corresponding pulse of Ck3, that pulse triggers the JKFF1 and that FF changes the state. At the end of one byte, W signal is generated for JKFF2 as a trigger pulse. If one byte has even number of 'logic one', at the end of that byte, output of AND - GATE II is 'zero' then Q (output) of JKFF2 becomes 'logic zero' after W pulse applied. If Q of JKFF2 is 'zero', there is no error for that byte. If any byte has odd number of 'logic one', then output of AND - GATE II is 'logic one' and Q of JKFF2 goes to 'logic one' state by W pulses. So, there is an error. When an error is sensed, error checking circuit is locked by AND-GATE II, because $\bar{Q}$ of JKFF2 is 'logic zero'. Scanning has to be repeated.

3.3.7.2 Output Signals of Control Circuit

(i) L1 and L2 (Latch 1 and Latch 2)

L2 signal is maintained from output of AND-GATE, if digital output and inverse of delayed digital output are applied to the AND-GATE as shown in Figure 3.17.

If delayed digital output and inverse of digital output are applied to an another AND-GATE, L1 signal is appeared at the output of that AND-GATE as shown in Figure 3.18.

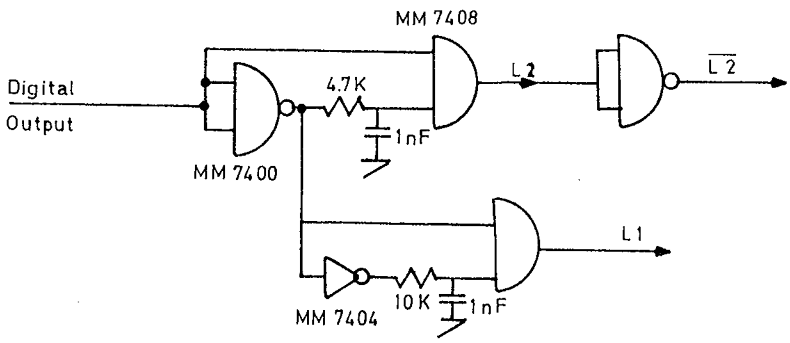

Figure 3.16 L1 and L2 signals circuit.

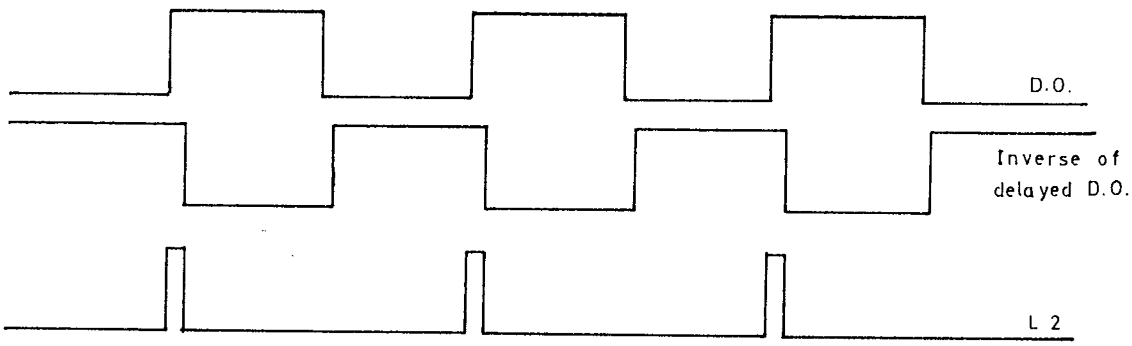

Figure 3.17 The generation of L2 signal.

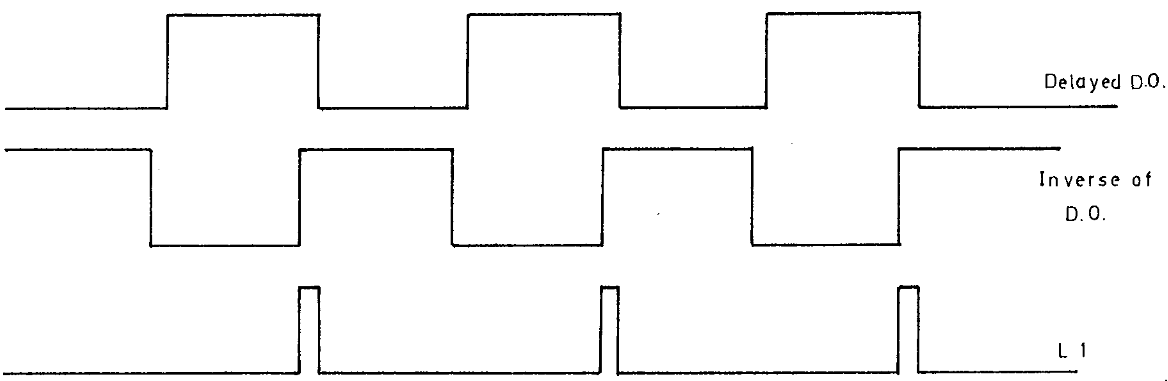

Figure 3.18 The generation of L1 signal.

(ii) **Ck3, Ck4, Pass, Shift and Mode Control signals**

As seen in Figure 3.19, the positive going edge of inverse of delayed L1 signal triggers monostable 1. That generates Ck1 pulses with a high level duration of RC (= 1K*2.7nF) =2.7μs. These pulses are

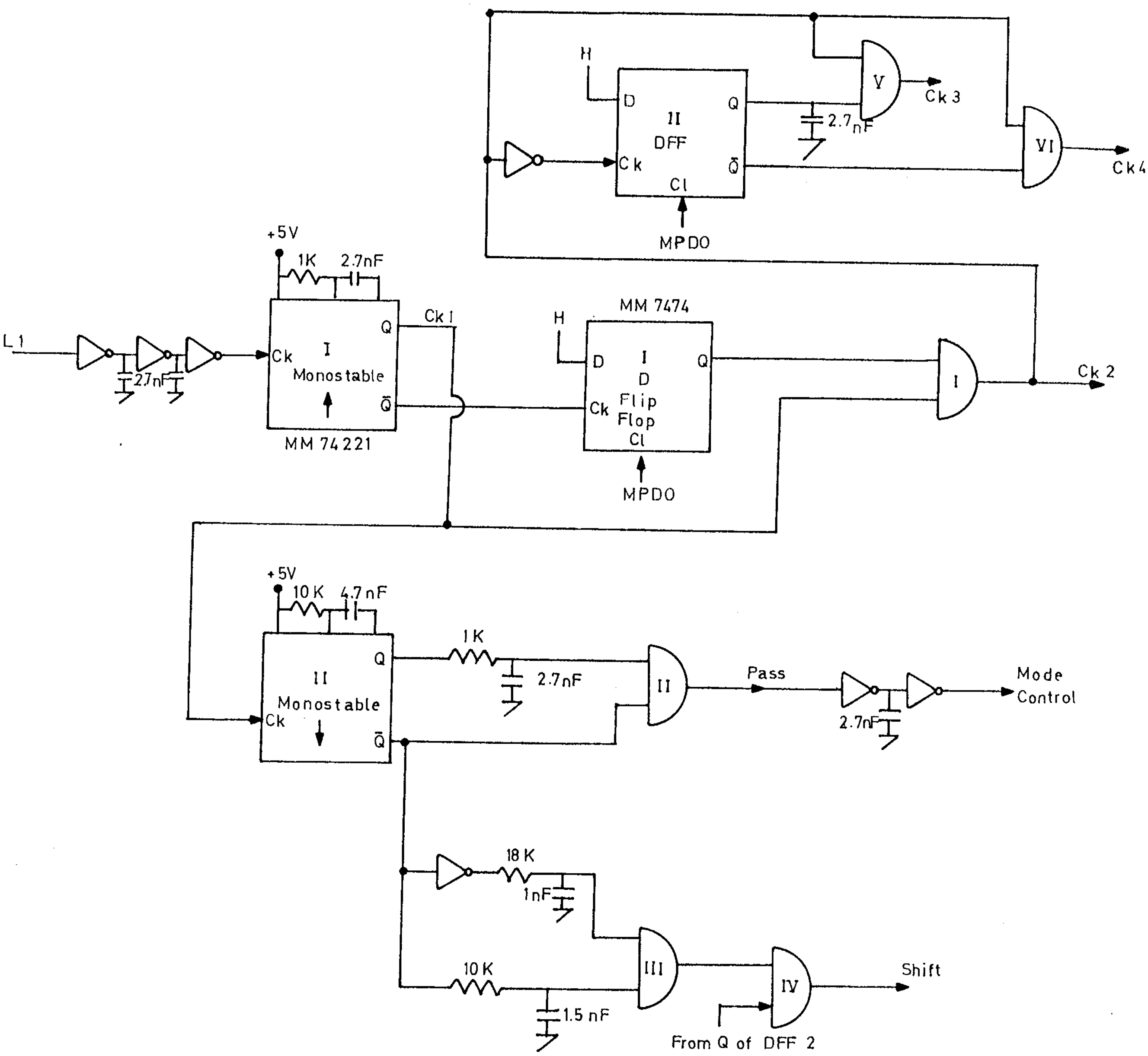

Figure 3.19 The circuit of Ck3, Ck4, Pass, Shift and Mode Control signals.

generated at the end of each bar. The first and second pulses of Ck1 are not corresponding to data bars. These two pulses blocked by AND-GATE I and V and DFF1 and 2 to produce Ck3 signal.

Ck4 is produced at the end of direction bar. It has single pulse for each row of bar code. It is generated by AND-GATE VI and DFF2.

Pass, Shift and Mode Control signals are generated with suitable delay from monostable 2 triggered by negative going edge of Ck1 pulse.

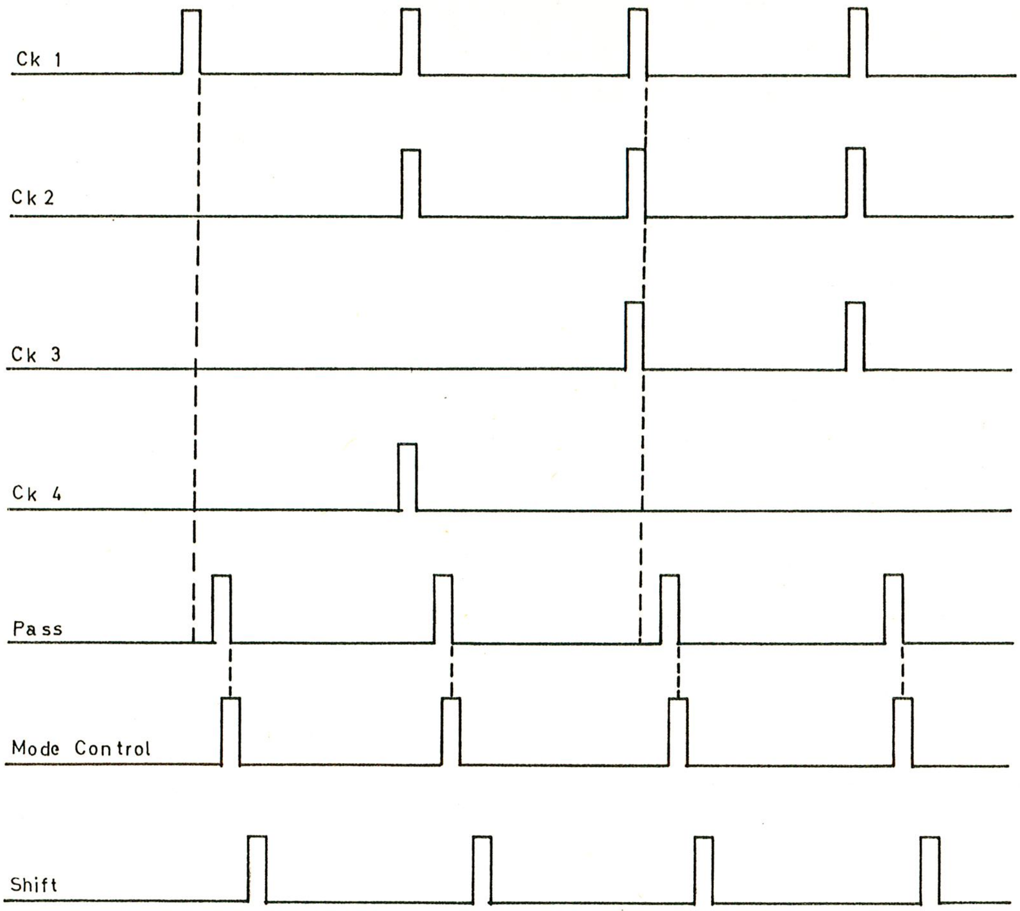

Figure 3.20 The position of Ck1, Ck2, Ck3, Ck4, Pass, Shift and Mode Control signals.

(iii) Dis1, Dis2, Dis3, $\overline{W}$ and $\overline{G}$ signals

As shown in Figure 3.21, three bits binary counter is cleared by Ck4 at the beginning of scanning. That counter is triggered by Ck3. For each 8-bit data string or each eight pulses of Ck3, a duration of $15K\Omega*15\mu F$ = 2.25 ms pulse is generated from the outputs of monostable 3 by using MSB output of that counter. By using these pulses, Dis1 or Dis2 signal is generated according to scanning direction (R-L signal). The duration of $12K\Omega*0.1\mu F$ = 1.2 ms $\overline{W}$ pulses are generated from $\overline{Q}$ of monostable 4 by using $\overline{Q}$ of monostable 3 and with a delay of 0.5 ms. Any Ck3 pulses should not be applied to the register until the end of $\overline{W}$ pulse. So, the minimum time between two Ck3 pulses should be 0.5 + 1.2 = 1.7 ms.

DFF3 and DFF4 are used to block the effect of reading oscillator when the scanning is done and while A=B output is high.

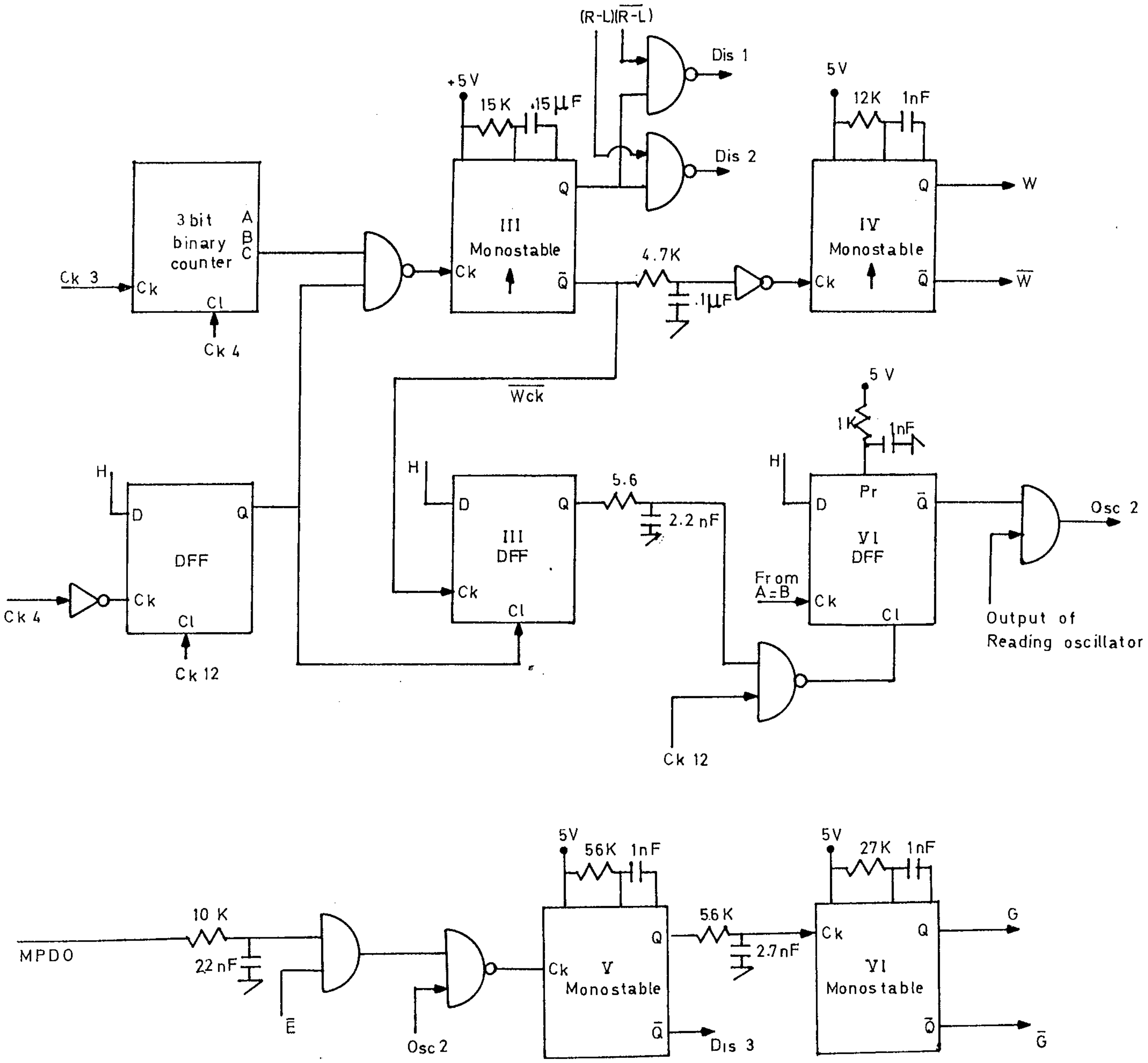

Figure 3,21 The circuit of Dis1, Dis2, Dis3, W and G signals,

Monostable 5 generates the Dis3 pulses following the complition of high level of MPDO by using reading oscillator. The duration of Dis3 pulses is 56KΩ*1nF = 56μs. $\overline{G}$ pulses are generated by using the $\overline{Q}$ of monostable 6 with a delay of 5.6KΩ*2.7nF. These signals are illustrated in Figure 3.9 and 3.10.

(iv) Ck8, Ck9, Ck13, Up and Down signals

As shown in Figure 3.22, Ck8 signal generated for each character is as a ready pulse for computer. It is generated by using G signal when the reading of any character is completed. Reading is done in the duration of G pulse, so, Ck8 must be generated while that duration is continuing. G, $\overline{G}$ and Ck8 pulses are presented in Figure 3.23.

Ck9 is counting pulses of binary counter in the address generator. It must be generated when the scanning is done from left to right using W_{Ck} signal generated for each byte. Its circuit is in Figure 3.24

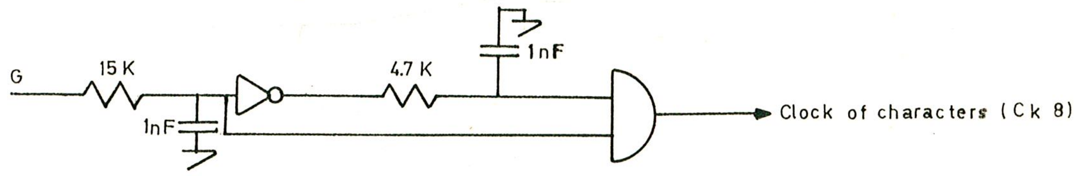

Figure 3,22 The circuit of Ck8,

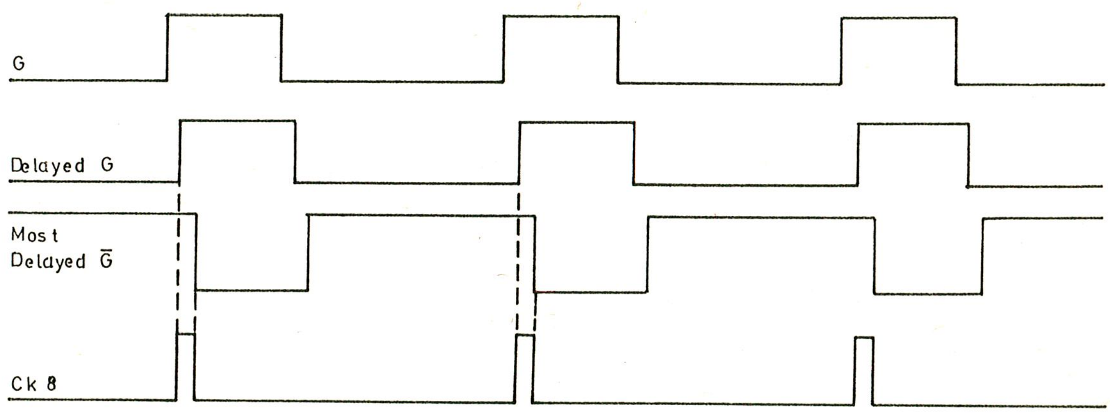

Figure 3,23 G, G signals and Ck8 pulses,

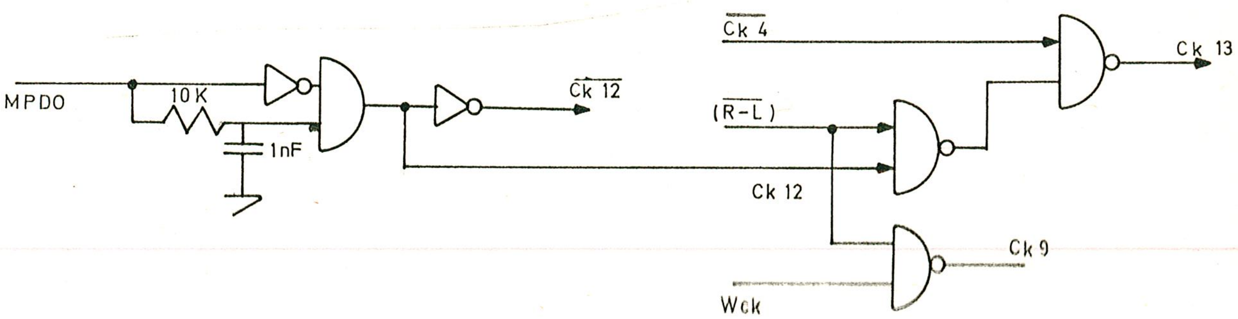

Figure 3,24 The circuit of Ck9 and Ck13, Ck13 is the clear pulse of up/down counter in the address generator block. It is generated at the beginning of each scanning by using Ck4. If the scanning was done from left to right direction, Ck13 pulse is generated also by Ck12 from negative going edge of MPDO at the end of scanning. These signals are illustrated in Figure 3.0.

Up/down counter counts up sequence by using Up signal. When MPDO is high, up counting is done by $\overline{W}_{ck}$ and when MPDO is low and R-L state is low, up counting is also done by Dis3 signal. The logic expression of this case can be found by 'carnough map'.

R-L, $\overline{W}_{ck}$ \ MPDO, Dis 3	00	01	11	10
00	0	1	0	0
01	0	1	1	1
11	1	1	1	1
10	1	1	0	0

$$Up = \overline{MPDO}.Dis3 + Dis3.\overline{W}_{ck} + MPDO.\overline{W}_{ck} + \overline{MPDO}.(R-L)$$

This expression can be constructed by NAND-GATEs as in Figure 3.25.

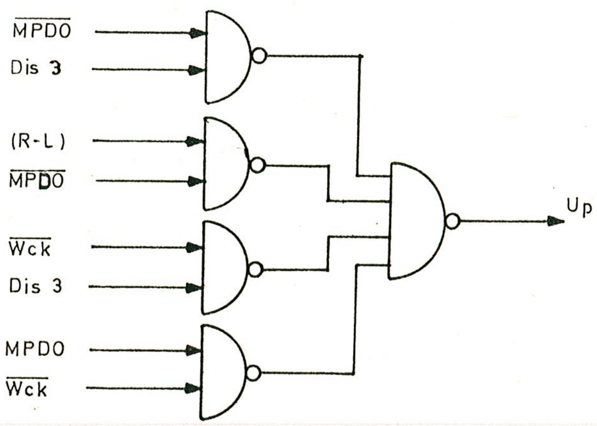

Figure 3.25 The circuit of Up signal.

Up/down counter counts down by Down signal. When MPDO is low and R-L is high, down counting is done by $\overline{Dis3}$ signal. The circuit of this case is designed by 'carnough map' as in Figure 3.26.

Dis 3 \ MPDO, R_L	00	01	11	10
0	1	1	1	1
1	1	0	1	1

Down = MPDO + $\overline{Dis3}$ + $\overline{R-L}$

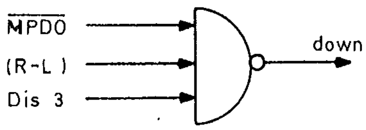

Figure 3.26 The Down signal's circuit.

3.4 GENERAL OPERATION

To run the bar code detector device is very simple as an alternative to keyboard. The work done is only to place the light pen on the quite zone which is white areas at both sides of bar code row and to sweep on the bar code tag. The light pen should be held at perpendicular position on the paper which involves bar code data. The slit on the top of light pen should be parallel to the bars in the bar code row and at the same time it must be softly closed on the paper. The speed of swift motion of light pen must be between 98 mm/s and 588 mm/s. One swift motion is generally enough to decode the information in bar code row on the monitor screen of computer. Sometimes, the information can not be seen on the monitor, although bar code tag was sweeped by the pen. So, an error which is indicated by a LED has been sensed by the device. Scanning of the same bar code row has to be repeated when the error is detected.

The scanning in both direction, from left to right or from right to left, is possible. In both cases, the information will be appeared on the monitor screen.

CHAPTER 4

RESULTS DISCUSSIONS AND CONCLUSIONS

4.1 BAR CODE

There are different possible coding schemes for bar codes as mentioned before. They have generally different application areas.

Code 39 is usually used for government applications. UPC is for supermarket applications. 2 out of 5 code is for library operations. Code 93 and Code 128 are convenient for industrial applications. To encode software programs, HP41C bar code system is generally employed. Computer software in bar code form can be produced inexpensively. This coding scheme is also reliable in other applications mentioned above. So, HP41C bar code detector has been designed and constructed in this thesis.

The main difficulty of bar code system is preparing the bar coded labels which are attached on merchandise in factory or goods in supermarket or books in library. The solution of this problem is to use bar code printers which are manufactured by some firms. For instance; Printronix Co., Matthews International Co., Welch Allyn Industrial Product Div., Comptype Inc.. These firms also produce bar code detectors.

Bar code printers can also be developped by some researchers who are interested in bar code.

4.2 LIGHT PEN

The resolution of the system is determined by the light pen according to the size of the light spot. The light spot of the optical sensor TIL139 used was ratherly large and not reliable for scanning the bar coded data. To improve the resolution to 0.7mm, as mentioned before, a hat which has 0.7mm slit width is attached on the top of TIL139. To improve the resolution further, the slit width could be less than 0.7mm. But, this case would reduce the sensivity of the optical system. If the light spot could be optained by an excellent optical order, the system resolution would be better than 0.7mm. For instance, if HEDS3000 light pen manufactured by Hewlett Packard was used, the resolution of the system would be 0.05mm.

The present system uses 1mm X dimension. So, the requiring average width for one character is 20mm, because, there are 8 spaces (8mm), 4 wide bars (8mm) and 4 narrow bars (4mm) in one character. Approximately, 10 characters can be encoded on one row of an A4 paper. So, if the height of the row is assigned as 2cm, then 150 characters can be encoded on an A4 paper. If the light pen which has 0.05mm resolution was used, the average width of one character would be 1mm. So, 200 characters could be encoded on one row, and then 3000 characters could be encoded on a paper. Approximately, 3000 alphabet characters can also be placed on A4 paper.

4.3 INTERFACE CIRCUIT

One of the main problems of scanning is the noise which results from touching the pen on the paper or departure of the pen from the paper. As mentioned before, the frequency of the noise signals are less than 20Hz. The noise signals below 21Hz are filtered out by the present interface circuit.

The block diagram of interface circuit is a general scheme which is usually present in any bar code detector.

4.4 DECODER

In this thesis, basic principles of any bar code decoder have been put forward by using MSIs (Medium Scale Integrated circuits) and discreate electronic components. This case increases the volume of device but, the flow chart and the circuit diagram of decoder given are appropriate to construct it by using microprocessor and its circumference units to set up a small size decoder. In that case, system can also detect a few type of bar code versions.

In the present decoder, there is a parity bit checking for each character to insure the decoded data be valid before it is sent to computer. Then second type of error checking is to use checksum digit corresponding to the number of characters in the bar code row, attached at the end of it. This type of checking can be accomplished by a small software program after the data loaded the computer, to verify the decoded data to be the same as the encoded data.

In one swift motion, the decoder can store maximum 16 characters (bytes) to order them. But, this range can be increased up to 2048 characters by increasing the bits of address counter. It is possible to enter the information to computer monitor either using bar code detector or keyboard as shown in Figure 3.5.

4.5 MONITOR

The present detector system can always detect the bar codes prepared with respect to 8-bit codes (ASCII, EBCDIC). Intellegent instrument used have to understand these codes. So, the alphanumeric character code selected to encode bar code labels must be the same as the computer system's code.

A model 550 monitor produced by Perkin Elmer Co. is used to display alphanumeric characters. Model 550 monitor is operated according to ASCII code. So, bar code labels are prepared with respect to that code. If the intellegent instrument was operated in EBCDIC code, then the bar code labels would be prepared according to that code.

FEATURE PROPOSAL

A bar code printer, a detector and a microprocessor based system are needed to use of bar code in library for the automation of book circulation. For this application, the author recommends the HP41C or 2 out of 5 bar code and HEDS1000 light pen as a scanner.

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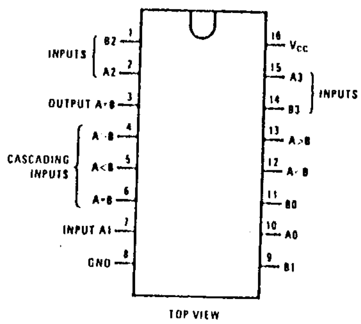
APPENDIX

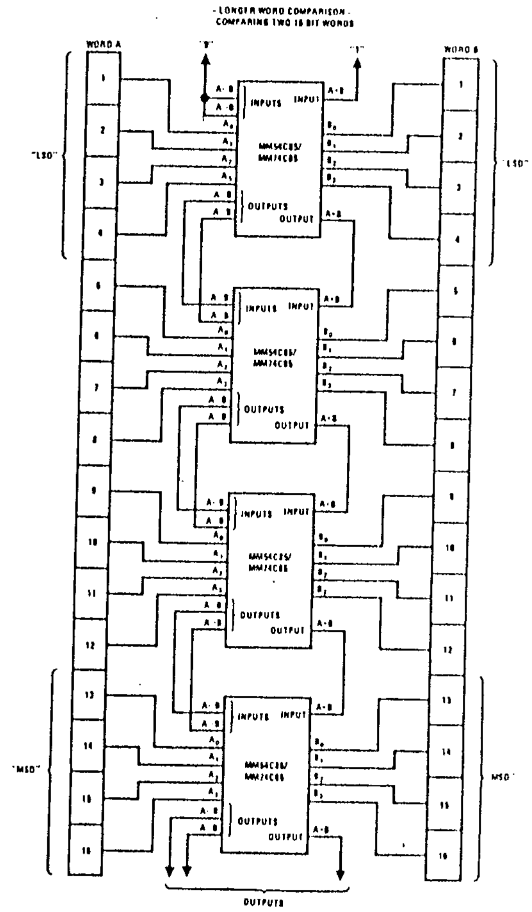
MM7485 4-bit Magnitude Comparator

connection diagram



typical application

Four Digit Comparator



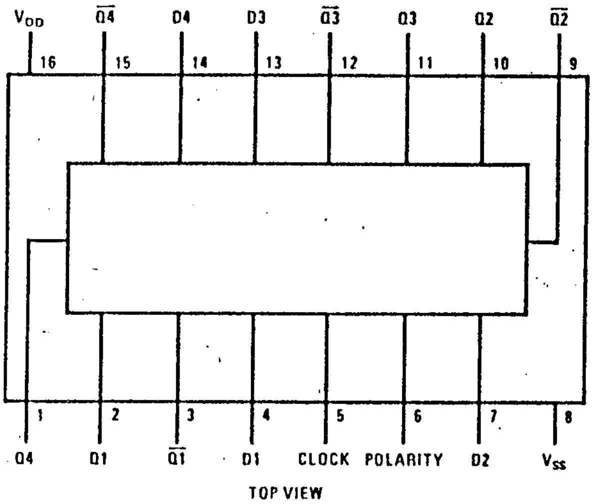
truth table

COMPARING INPUTS				CASCADING INPUTS			OUTPUTS		
A3, B3	A2, B2	A1, B1	A0, B0	A > B	A < B	A = B	A > B	A < B	A = B
A3 > B3	X	X	X	X	X	X	H	L	L
A3 < B3	X	X	X	X	X	X	L	H	L
A3 = B3	A2 > B2	X	X	X	X	X	H	L	L
A3 = B3	A2 < B2	X	X	X	X	X	L	H	L
A3 = B3	A2 = B2	A1 > B1	X	X	X	X	H	L	L
A3 = B3	A2 = B2	A1 < B1	X	X	X	X	L	H	L
A3 = B3	A2 = B2	A1 = B1	A0 > B0	X	X	X	H	L	L
A3 = B3	A2 = B2	A1 = B1	A0 < B0	X	X	X	L	H	L
A3 = B3	A2 = B2	A1 = B1	A0 = B0	H	L	L	H	L	L
A3 = B3	A2 = B2	A1 = B1	A0 = B0	L	H	L	L	H	L
A3 = B3	A2 = B2	A1 = B1	A0 = B0	L	L	H	L	L	H
A3 = B3	A2 = B2	A1 = B1	A0 = B0	L	H	H	L	H	H
A3 = B3	A2 = B2	A1 = B1	A0 = B0	H	L	H	H	L	H
A3 = B3	A2 = B2	A1 = B1	A0 = B0	H	H	H	H	H	H
A3 = B3	A2 = B2	A1 = B1	A0 = B0	H	H	L	H	H	L
A3 = B3	A2 = B2	A1 = B1	A0 = B0	L	L	L	L	L	L

H = high level, L = low level, X = irrelevant

CD4042 Quad Clocked D Latch

connection diagram

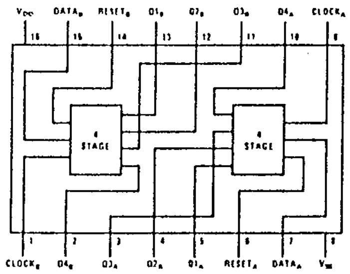


truth table

CLOCK	POLARITY	Q
0	0	D
↑	0	Latch
1	1	D
↓	1	Latch

CD4015 Dual 4-bit Static Register

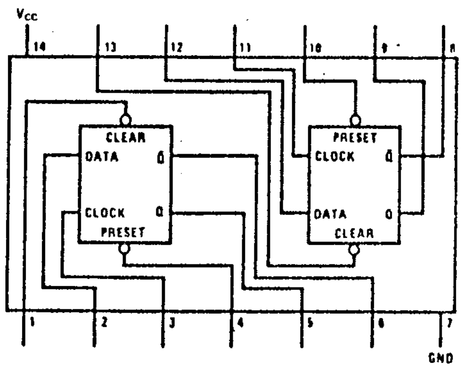
connection diagram and truth table



CL▲	D	R	Q1	Q_n	
↑	0	0	0	Q_{n-1}	
↑	1	0	1	Q_{n-1}	
↓	X	0	Q1	Q_n	(No change)
X	X	1	0	0	

▲ Level change.
X Don't care case.

MM7474 Dual D Flip-Flop

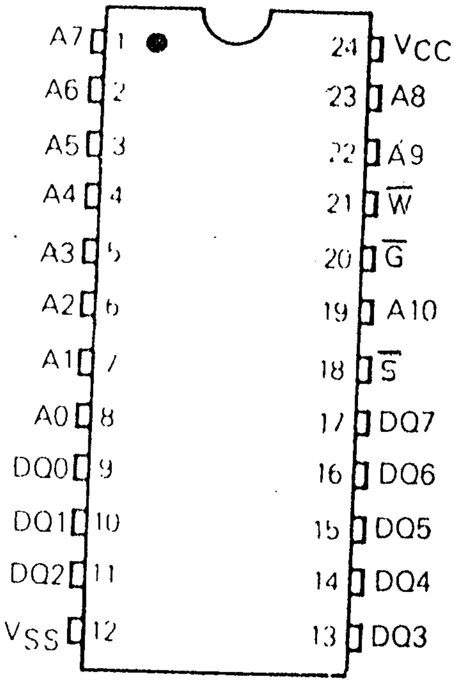


TOP VIEW

Note: A logic "0" on clear sets Q to logic "0."
A logic "0" on preset sets Q to logic "1."

HM6116 2048x8-bit Static RAM

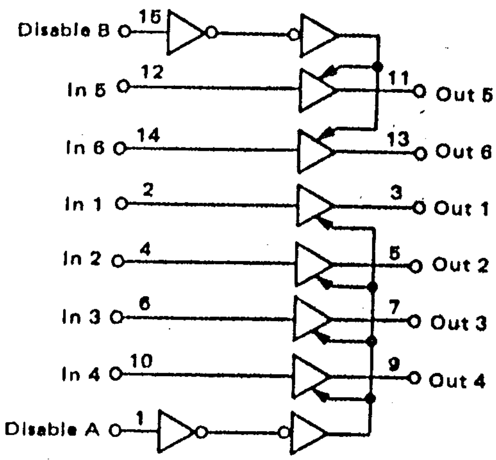
PIN ASSIGNMENT



*Pin Names	
A	Address
DQ	Data Input/Output
$\overline{G}$	Output Enable
$\overline{W}$	Write Enable
$\overline{S}$	Chip Select

CD4503 Hex Non-Inverting 3-State Buffer

LOGIC DIAGRAM



V_{DD} = Pin 16
V_{SS} = Pin 8

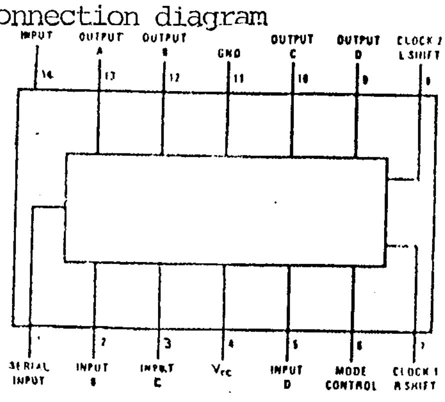
TRUTH TABLE

In_n	Appropriate Disable Input	Out_n
0	0	0
1	0	1
X	1	High Impedance

X = Don't Care

MM7495 4-bit Shift Register

connection diagram



TOP VIEW

function table

INPUTS								OUTPUTS			
MODE CONTROL	CLOCKS		SERIAL	PARALLEL				Q_A	Q_B	Q_C	Q_D
	2 (L)	1 (R)		A	B	C	D				
H	H	X	X	X	X	X	X	Q_{A0}	Q_{B0}	Q_{C0}	Q_{D0}
H	↓	X	X	a	b	c	d	a	b	c	d
H	↓	X	X	Q_B†	Q_C†	Q_D†	d	Q_{Bn}	Q_{Cn}	Q_{Dn}	d
L	L	H	X	X	X	X	X	Q_{A0}	Q_{B0}	Q_{C0}	Q_{D0}
L	X	↓	H	X	X	X	X	H	Q_{An}	Q_{Bn}	Q_{Cn}
L	X	↓	L	X	X	X	X	L	Q_{An}	Q_{Bn}	Q_{Cn}
↑	L	L	X	X	X	X	X	Q_{A0}	Q_{B0}	Q_{C0}	Q_{D0}
↓	L	L	X	X	X	X	X	Q_{A0}	Q_{B0}	Q_{C0}	Q_{D0}
↓	L	H	X	X	X	X	X	Q_{A0}	Q_{B0}	Q_{C0}	Q_{D0}
↑	H	L	X	X	X	X	X	Q_{A0}	Q_{B0}	Q_{C0}	Q_{D0}
↑	H	H	X	X	X	X	X	Q_{A0}	Q_{B0}	Q_{C0}	Q_{D0}
↑	L	H	X	X	X	X	X	Undefined			
↓	H	L	X	X	X	X	X	Operating Conditions			

†Shifting left requires external connection of Q_B to A, Q_C to B, and Q_D to C. Serial data is entered at input D.

H = high level (steady state), L = low level (steady state), X = irrelevant (any input, including transitions)

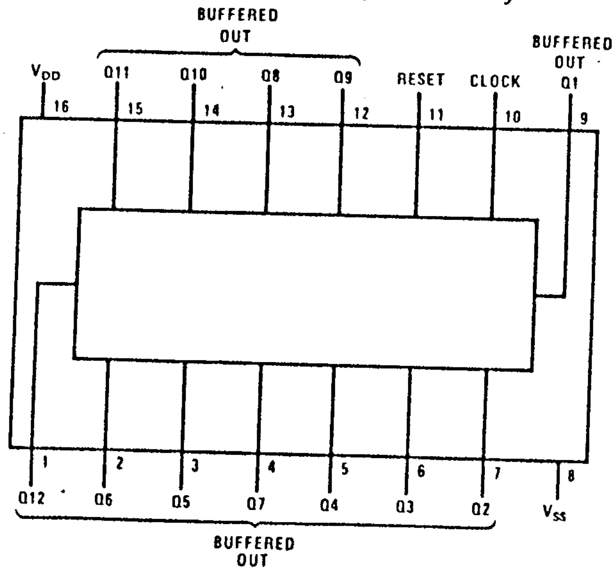
↓ = transition from high to low level, ↑ = transition from low to high level

a, b, c, d = the level of steady-state input at inputs A, B, C or D, respectively.

Q_{A0}, Q_{B0}, Q_{C0}, Q_{D0} = the level of Q_A, Q_B, Q_C, or Q_D, respectively, before the indicated steady-state input conditions were established.

Q_{An}, Q_{Bn}, Q_{Cn}, Q_{Dn} = the level of Q_A, Q_B, Q_C, or Q_D, respectively, before the most-recent ↓ transition of the clock.

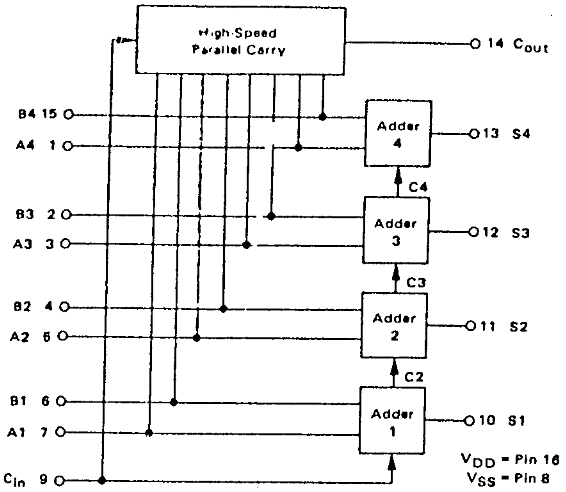
CD4040 12-Stage Ripple-Carry Binary Counter



TOP VIEW

CD4008 4-bit Full Adder

BLOCK DIAGRAM

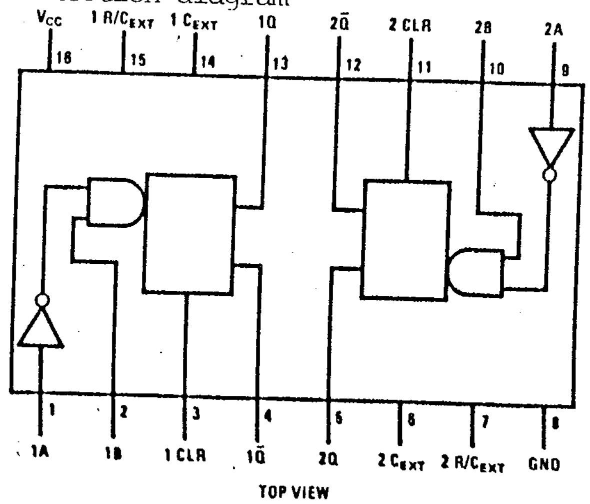


TRUTH TABLE
(One Stage)

C_{in}	B	A	C_{out}	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

MM74221 Dual Monostable Multivibrator

connection diagram



truth table

INPUTS			OUTPUTS	
CLEAR	A	B	Q	Q̄
L	X	X	L	H
X	H	X	L	H
X	X	L	L	H
H	L	↑	⊓	⊔
H	↓	H	⊓	⊔

H = High level
L = Low level
↑ = Transition from low to high
↓ = Transition from high to low
⊓ = One high level pulse
⊔ = One low level pulse
X = Irrelevant