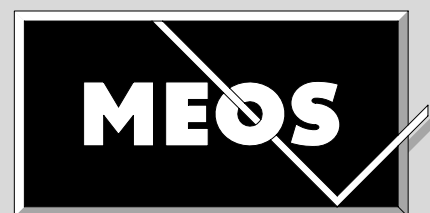
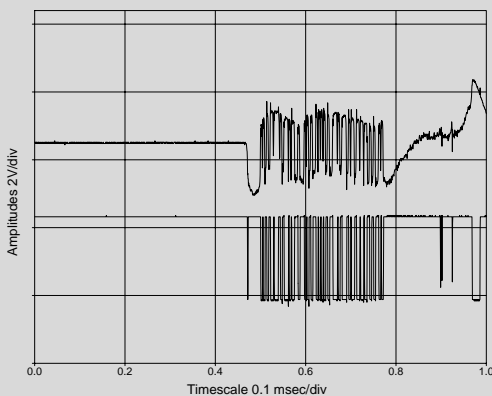
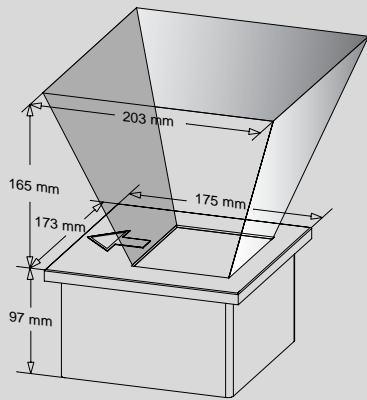
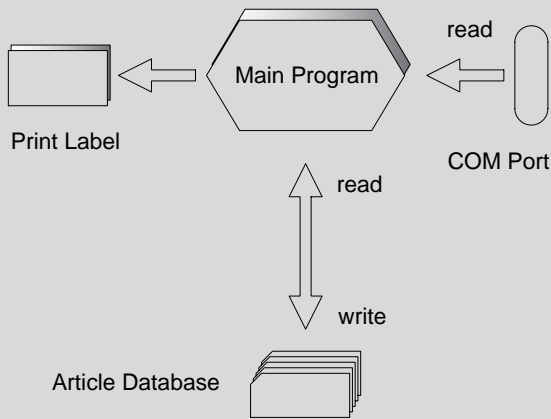


# EXPERIMENT 27

## Barcode Scanner



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## 1 Introduction

The invention and the application for identifying products of all kinds with the help of bar-code technology is one of the most important developments of our century. Those, who have had to wait for long hours at the cash counter of a super market, because the bar-code reading system has broken down, can imagine this. However, the impetus for developing this technique did not come from the desire to offer the customers a special service, but instead to make the supermarket more profitable. The existence of the supermarkets can be traced back to the colonisation of North America. Small business concerns during this time specialised in everything that was needed for a new start. It is, therefore, no wonder that the bar-code technique was invented and developed in this country. When the concept of the supermarkets was introduced in the big cities, naturally a competition arose, which aimed at attracting the customers with the best possible prices. This again required that the undertaking still remained profitable. The boss of the supermarket had to know exactly the goods that were leaving his company, to make arrangements for the supplies on the one hand and to avoid the dead stocks on the other. For this purpose, his market had to be closed down at least once a month for stock-taking. Long before the bar code was invented, the businessmen knew that such a thing was required urgently. The first step in this direction was taken in 1948, when Bernard Silver overheard by a chance a conversation between the President of a chain of grocery stores and the director of the Philadelphia's Drexel Institute of technology. In this conversation the President requested the Director to develop a technique, which made it possible to manage the goods traffic in supermarkets much easier than a monthly stock taking. However, the director turned down the request, probably because the subject was to mundane for him.

When B. Silver talked to his 27-year old friend Norman Joseph Woodland about this conversation, he became very enthusiastic about it. In one of the first experiments they used ink, which fluoresced very strongly under the influence of ultraviolet light. Although the process worked, the long-term stability of the ink was not satisfactory and the printing of the labels was too expensive. But Woodland was convinced of his idea. He resigned from his work at the Drexel Institute of Technology, gathered all his savings and shifted to the apartment of his grandfather in Florida, in order to think more about this problem there. He found the solution after a few months, and the linear bar code was born. Woodland made use of the technologies already available, namely the sound film and the Morse code. He simply transformed the dash-dot arrangement of the code into vertical bars:

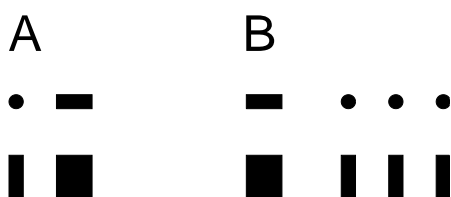


Fig. 1: Morse- and barcode

For reading the arrangement he made use of the idea of Lee de Forest's technique of the year 1920, in which the sound track of a film was recorded as a transmission on the border of the film strip as variations in the frequency of the sound. While playing the film, the changes of the transmission generated electrical currents with the help of an illumination and a photodetector, which after amplification, were passed on to the loudspeakers.

Woodland was, however, dependent on the reflection or scattering of the light for reading his printed bar code.

With this idea in mind, he went back to the Drexel Institute of Technology for formulating the patent together with his friend Silver, which they submitted on 20 October 1949. Silver modified the linear code to a concentric one for making the reading easier from all the directions.

In 1951 Woodland approached IBM with the hope of realising his ideas in a better way here. Together with Silver he made the first prototype in his New York apartment, which was about the size of a writing table. They used a 500-Watt light bulb as the source of light and as detector the photodetector 925 by RCA, which had been used in the sound film technology. An oscilloscope displayed the signal of the detector. Both the inventors could actually read a bar code. However, the same got damaged under the influence of strong light radiation. Moreover, they had to cover the whole apparatus with black cloth in order to suppress the outside light. However, they were able to demonstrate the basic functioning of their device and got the patent in 1952.

They were still very far from an actual application, because it was still not possible to process the signals further with the help of a computer. Woodland was able to convince IBM to depute an expert to estimate the potential of their invention. The expert recognised the potential and also the problem, that this technique was about five years before its time. IBM tried many times to buy the patent from Woodland for a meager sum, but could not do it. Woodland sold the patent to Philco in 1962, who later sold it to RCA.

Many more pushes were needed before the bar code technique could enter business and industry. A clear impetus came from the railway industry, which was being operated by a number of private owners in North America. The freight cars of different companies were running on the tracks and it could be easily understood that it was a very demanding task to determine and follow up the current status in such a big network.

Around 1960 the Sylvania Corporation was on the look out for applications for its newly developed computer. For this purpose it engaged David J. Collins, who had worked on this subject during his studies with the Pennsylvania Railroad. Collins developed a bar code comprising of elements reflecting orange and blue. When the rail cars marked with this bar code entered the station, they could be registered with the help of flashlights and photodetectors and the computer could do the rest. By 1967 Collins had advanced so much with his work, that he suggested the company to develop devices, which could read and evaluate the black-white bar code of Woodland, since he perceived a huge market here. Sylvania Corporation did not see this and Collins went and

established his own company, the *Computer Identics Corporation*.

At this time the Helium Neon Laser were available at economical prices, with the help of which Collins developed his first bar code reading devices for the industry. A source of light was now available, whose thin beam could scan the bar code labels with the help of a rotating mirror.

However, the decisive push for a breakthrough came from the grocery industry, which formed a committee to study the technical introduction of the bar codes of Woodland and Collins and its standardisation. RCA, which possessed the patent of Woodland and Silver, propagated the concentric bar code pattern. IBM now perceived big business and remembered that Woodland was once in its employ. He was immediately re-called into a team, which worked on developing a better pattern. IBM decided on a linear pattern. An eighteen-month long field test was carried out. The linear pattern of IBM proved to be superior, since the concentric patterns normally got smeared during printing, which made a proper reading of the code impossible. The linear pattern could be arranged during printing in such a way, that the smear got directed in the direction of the code and hence did not influence the reading process.

The code suggested by IBM was officially introduced in USA as the Universal Product Code (UPC) on April 3, 1973. The huge investments related with this made even the Pentagon pale in the face. US\$ 5.200.000 alone was proposed for buying the new devices for the thousands of super markets. The annual printing costs of the bar code labels were estimated to be a whopping 200 Million. Apart from this, the chain of stores needed separate computing centres (which naturally pleased IBM). A gigantic volume of investments was not only planned, but also spent. According to initial estimates, the investments would pay off within 2-3 years.

The other regions of the world also showed interest in this system. A slightly modified UPC code was introduced in Europe in December 1976 called the European Article Numbering Code (EAN). It is difficult to imagine the huge investments done all over the world for introducing the bar code. Apart from the super markets, all the organizations concerned with the management and distribution of goods also started working with bar codes. This included the industry, the complete book industry with the ISBN code, the pharmaceutical industry, hospitals and libraries, just to name a few.

The next time when you now go to the departmental store and stand at the cash counter, you would view the strange device, which takes money out of your pocket with a beep, in a different way. Maybe you would also think what would happen, if all these devices broke down. However, once you have finished the project "EXP27 Barcode Reader", your trust in this exciting technology would make you forget the rare breakdowns. One thing remains: Each beep costs you money, when you are in the supermarket and it is your turn to pay.

## 2 Fundamentals

This chapter will discuss the symbols, the coding and the optical-electronic determination of the bar code.

### 2.1 Barcodes

Different kinds of bar codes have been developed during the course of time. They are different, corresponding to the requirements to the different user groups. The UPC code became established in the USA for trade and for the supermarkets. Based on this code, the EAN code was introduced in Europe. Both the types are meant to be used mainly in the supermarkets. The disadvantage of this code for other areas of economy is that firstly only numbers are permitted and secondly the length of the code is fixed. Hence, a special code was developed for libraries, which can also represent alphanumeric characters. At first the Codabar was developed for these codes, which initially recognised only the special characters. The quick development of microcomputers also permitted more complex codes. The code 39 already includes all the capital letters and the code 93, based on code 39, contains even the regular alphabet. However, the barcode labels should not become very long, as otherwise very special laser scanners are required. As a result, one is always searching for code forms, which not only have the highest possible character reserve, but also the highest possible density of information. The developments in this direction are the codes UPC 128 or EAN 128, which use control characters within the code for reducing the length of the bar code. These control characters send instructions to the processor of the bar code for converting the character set. There are also some relatively special codes, whose application area is relatively small. These exotic types will not be described here

### 2.2 UPC Standard

The Universal Product Code (UPC) was introduced in 1973 in USA and Canada and is even today the most important bar code in these countries. There are two sub-groups of this code – the UPC A and the UPC E. The latter is a shorter version and is used for products with smaller dimensions e.g. cigarette packets.

#### 2.2.1 UPC A

Each bar code has two properties. One is the symbol and the other the coding. The properties of the symbol refer to the geometric arrangement of the information and that of coding on the decoding of the information. The UPC A symbol is divided into two halves. A "centre guard" has been inserted in the middle of the symbol. A start and a stop character ('101') are present at the start and the end of the symbol respectively. 6 characters each are present on the right and the left side of the symbol. The actual information is present as the arrangement of two strips (black) and two blank strips (white) each within 7 modules (Table 1).

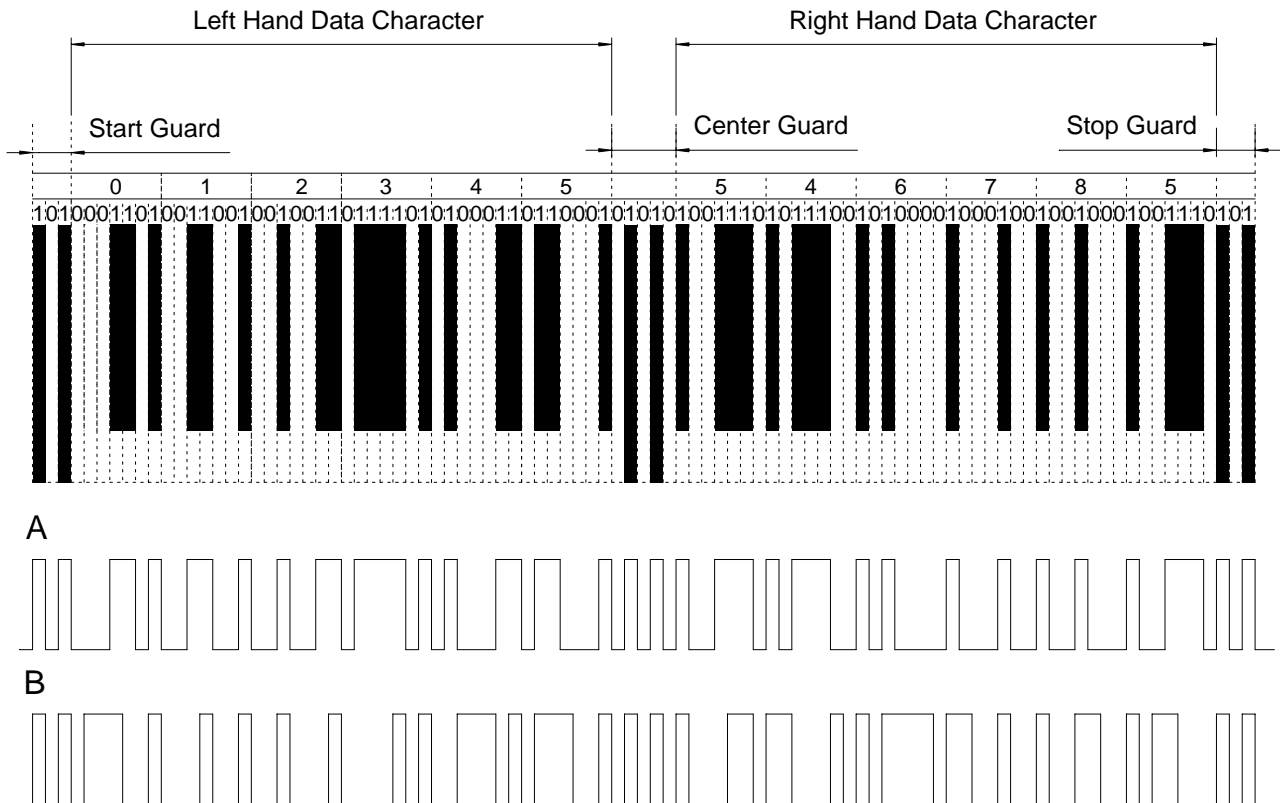


Fig. 2 : UPC-A Code Structur “01234554678”

The start- and the stop characters are coded as 101, whereby a logical 1 is assigned to a dark strip and a logical 0 to a bright strip. The Centre Guard is coded as 01010. The actual information comprises of 12 x 7 bits. The complete symbol thus consists of 95 bits or strips.



Fig. 3 : UPC - UPC-A Code with the information “01234554678” of the size SC5 (see Table 8)

The character set A is used for the left side of the UPC-A symbol and the character set C for the right side (Table 1). In this way the scanner can determine the direction, in which the bar code was scanned. For this reason, the start- and the stop characters are identical.

The purpose of these characters is only to inform the scanner about the width of the strip. The remaining strips are evaluated according to this information. This increases the angular area, in which the bar code can be read.

The nominal width of a strip has been fixed at 13 mils. (1 mil corresponds to 1/1000 inch). For a strip number of 95 it amounts to a width of the complete symbol of 1.235 inch or 31.4 mm. Symbol widths of 25 to 62.8 mm are permissible for a permissible enlargement of 0.8 to 2.

	Character Set A	Character Set C
0	[Pattern]	[Pattern]
1	[Pattern]	[Pattern]
2	[Pattern]	[Pattern]
3	[Pattern]	[Pattern]
4	[Pattern]	[Pattern]
5	[Pattern]	[Pattern]
6	[Pattern]	[Pattern]
7	[Pattern]	[Pattern]
8	[Pattern]	[Pattern]
9	[Pattern]	[Pattern]

Table 1 : The character set A is used for the left half and the character set C for the right half of the UPC-A code

For a symbol to be decoded free of errors, the coded data set must contain a mechanism for a self-check. The check sum process, for example, represents such a process. For this purpose, a test number is calculated from the data set with a specific algorithm and is added to the symbol. A data set is uniquely valid only when the scanned data set and the newly calculated check number fit with each other. The 12<sup>th</sup> character in the UPC-A symbol contains this information. As a result, only 11 characters are available for the coding of the product.

1	2	3	4	5	6	7	8	9	10	11	
0	1	2	3	4	5	5	4	6	7	8	
0		6		12		15		18		24	75
	1		3		5		4		7		20
Sum =											95
Residual (95/10)											5
Check number =10-Residual											5

**Table 2: Check sum calculation for the number 01234554678**

One multiplies the characters present at odd places (1,3,5,7,9,11) with 3 and adds the results. One then determines the sum of the even places (0,2,4,6,8,10 without the check number at the 12<sup>th</sup> place!).

One then adds both these results and divides the number by ten. The difference of 10 – residual is then the check-sum:

$$10 - \text{residual}(95/10) = 5$$

In case any character is not read properly during scanning, the scanner then calculates a checksum, which does not conform to that at the twelfth place of the symbol. The result is thus not validated. Hence, the test number procedure cannot re-establish the original code. It can, in all probability, determine a reading error.

We now know, that the UPC-A symbol consists of 11 characters and a checksum. Each supplier and manufacturer, who have adopted the barcode procedure, has been assigned a unique number, so that no two manufacturers or suppliers issue duplicate data sets. The left data block (6 characters) contains the unique identification of the manufacturer of the product and the remaining 5 characters of the right side the unique product identification issued by the manufacturer. The first digit of the UPC-A code specifies the information encoded in the code:

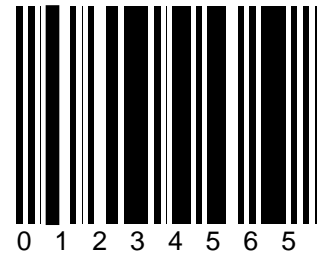
0	Normal regular UPC Code
1	Reserved (for later use)
2	Products, which are paid by weight. Barcode is made in house
3	National Drug Code (NDC) and National Health Related Items Code (HRI).
4	UPC Code, which can be used without format restrictions
5	Coupon
6	Normal regular UPC Code
7	Normal regular UPC Code
8	Normal regular UPC Code
9	Reserved (for later use)

**Table 3: Meaning of the first Characters**

### 2.2.2 UPC E Symbol

The UPC E symbol serves for identifying products with relatively small dimensions. The symbol comprises of eight characters, out of which the first is used for identifying the characters set used and the last for the check number. The start character consists of 2 and the stop

character consists of 3 bars. A “Centre Guard” is not present



**Fig. 4 : UPC E symbol with the information “123456” and the size SC5**

The character 0 is specified as the first character and implies that the first 3 characters are coded from the character set A and the remaining three of the data set from the character set B.

	Character Set A	Character Set B
0	[Barcode pattern for 0 in Set A]	[Barcode pattern for 0 in Set B]
1	[Barcode pattern for 1 in Set A]	[Barcode pattern for 1 in Set B]
2	[Barcode pattern for 2 in Set A]	[Barcode pattern for 2 in Set B]
3	[Barcode pattern for 3 in Set A]	[Barcode pattern for 3 in Set B]
4	[Barcode pattern for 4 in Set A]	[Barcode pattern for 4 in Set B]
5	[Barcode pattern for 5 in Set A]	[Barcode pattern for 5 in Set B]
6	[Barcode pattern for 6 in Set A]	[Barcode pattern for 6 in Set B]
7	[Barcode pattern for 7 in Set A]	[Barcode pattern for 7 in Set B]
8	[Barcode pattern for 8 in Set A]	[Barcode pattern for 8 in Set B]
9	[Barcode pattern for 9 in Set A]	[Barcode pattern for 9 in Set B]

**Table 4 : Coding table for the EAN E Symbol**

The check sum is calculated according to the same algorithm as in the case of UPC-A code.

### 2.3 EAN Standard

The “European Article Numbering” system is a further development of the UPC code for the European countries. It was introduced in 1978 and is at present the most widely used bar code system in the world. Apart from all the countries of the European Union, most of the other countries have also opted for this system.

#### 2.3.1 EAN 13 Symbol

As the name already implies, the EAN-13 symbol comprises of 13 characters. The structure of the symbol is identical to that of the EAN-A. However, this symbol possesses one more character. The first 2-3 characters contain a country code (see Table 6). The next five identify the manufacturer of the product. Each country using the EAN code has a central issuing authority, which issues these characters. The next five characters are issued by the respective manufacturers and contain information

about the product. The last character is meant to be a check number.

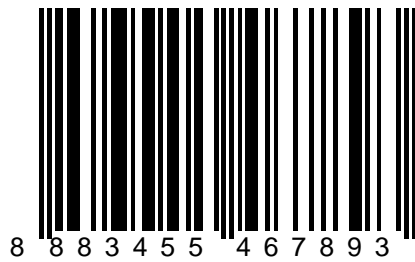


Fig. 5 : EAN-13 Symbol with the information “888345546789” in the size SC5

The above code identifies a product from Singapore (888) and has the check number 3. According to a convention, the positions of the characters are numbered from left to right. This means, that the check number is present at position 1. The numbers at even places are multiplied by 3 and added up, whereas the numbers at odd places are only added up.

13	12	11	10	9	8	7	6	5	4	3	2	1
8	8	8	3	4	5	5	4	6	7	8	9	*
8		8		4		5		6		8		39
	24		9		15		12		21		27	108
												147
Residual (147/10)												7
Check number=10-7												3

Table 5: Check number calculation for the EAN Code

As per the international agreements, the positions of the characters are numbered from right to left. For this reason, the check number is present at the first position (\*).

2.3.2 EAN 8

As in the case of the UPC symbols, there is a version that is suitable for smaller products. In contrast to the UPC-E symbol, this consists of only 8 characters.



Fig. 6 : EAN 8 Symbol of the size SC5

The first two or the first three characters identify the country of origin (Table 6), followed by four or five characters specifying the manufacturer and the product information. The first character (counted from right!) is the check number. The start- and the stop characters and the Centre Guard are present just as in the case of the EAN 13 Symbol. The check sum is calculated in the same way as for the EAN 13 Symbol.

Prefix	Country or use
00 - 13	U.S.A. & Canada (UCC)
20 - 29	In-store numbers
30 - 37	France (GENCOD EAN France)
380	Bulgaria (BCCI)
383	Slovenia (SANA)
385	Croatia (CRO EAN)
387	Bosnia Herzegovina (EAN BIH)
400 - 440	Germany (CCG)
45	Japan (Distribution Code Centre DCC)
460 - 469	Russian Federation (UNISCAN EAN Russia)
471	Taiwan (CAN)
474	EAN Estonia
475	EAN Latvia
477	EAN Lithuania
478	EAN Uzbekistan
479	EAN Sri Lanka
480	Philippines (PANC)
481	EAN Belarus
482	EAN Ukraine
484	EAN Moldova
485	EAN Armenia
486	EAN Georgia
487	EAN Kazakhstan
489	Hong Kong (HKANA)
49	Japan (Distribution Code Centre)
50	E Centre UK
520	Greece (HELLCAN EAN HELLAS)
528	EAN Lebanon
529	EAN Cyprus
531	FYR Macedonia (EAN MAC)
535	Malta (MANA)
539	EAN Ireland
54	Belgium & Luxembourg (ICODIF/EAN)
560	Portugal (CODIPOR)
569	EAN Iceland
57	EAN Denmark
590	EAN Poland
594	EAN Romania
599	Hungary (HAPMH)
600 – 601	EAN South Africa
609	EAN Mauritius
611	EAN Maroc
613	EAN Algeria
619	Tunisia (TUNICODE)
621	EAN Syria
622	EAN Egypt
625	EAN Jordan
626	EAN Iran
64	EAN Finland
690 – 693	China (Article Numbering Centre of China)
70	EAN Norge
729	EAN Israel
73	EAN Sweden
740	EAN Guatemala
741	EAN El Salvador
742	Honduras (ICCC)
743	EAN Nicaragua

744	EAN Costa Rica
745	EAN Panama
746	EAN Republica Dominica
750	Mexico (AMECE)
759	EAN Venezuela
76	EAN Schweiz, Suisse, Svizzera)
770	Colombia (IAC)
773	EAN Uruguay
775	EAN Peru
777	EAN Bolivia
779	EAN Argentina
780	EAN Chile
784	EAN Paraguay
786	Ecuador (ECOP)
789	EAN Brazil
80 - 83	Italy (INDICOD)
84	Spain (AECOC)
850	Cuba (CCRC)
858	EAN Slovakia
859	EAN Czech
860	Yugoslavia (EAN YU)
869	Turkey (UCCT)
87	EAN Nederland
880	South Korea (EAN Korea)
885	EAN Thailand
888	Singapore (SANC)
890	EAN India
893	EAN Vietnam
899	EAN Indonesia
90 - 91	EAN Austria
93	EAN Australia
94	EAN New Zealand
955	Malaysia (Malaysian Article Numbering Council)
977	Periodicals (ISSN)
978 to 979	Books (ISBN)
980	Refund receipts
981 - 982	Common Currency Coupons
99	Coupons

**Table 6: Country- and use-prefixes for the EAN Code**

In the following table you can see the sizes of the barcode labels agreed upon:

SC Type	Scale factor	Field dimensions B x H i. mm
SC0	0.82	30.58 x 21.53
SC1	0.91	33.93 x 23.90
SC2	1.00	37.29 x 26.26
SC3	1.10	41.02 x 28.88
SC4	1.21	45.12 x 31.78
SC5	1.36	50.71 x 35.17
SC6	1.52	56.68 x 39.91
SC7	1.67	62.27 x 43.85
SC8	1.82	67.87 x 47.79
SC9	1.97	73.46 x 51.73

**Table 7: Standard sizes for the EAN 13/UPC-A Barcode Labels**

The field dimension is the dimension of the labels including a left margin of 11 and a right margin of 7 bars each of 13 mils. These free areas are also called as “quiet zones”. These zones are necessary to prevent an abrupt transition from the printed area of the product and enhance the readability. The dimensions of the zones are valid for an enlargement factor of 1 or for the type SC2.

SC-Type	Scale factor	Field Dimensions B x H i. mm
SC0	0.82	21.92 x 17.74
SC1	0.91	24.32 x 19.69
SC2	1.00	26.73 x 21.64
SC3	1.10	29.40 x 23.80
SC4	1.21	32.34 x 26.19
SC5	1.36	36.35 x 29.43
SC6	1.52	40.63 x 32.89
SC7	1.67	44.64 x 36.14
SC8	1.82	48.65 x 39.38
SC9	1.97	52.66 x 42.63

**Table 8: Standard sizes of the EAN 8 Barcode Labels**

In these labels the free right and the left zone has 7 bars 13 mils for the SC2 type (scale factor 1).

### 2.3.3 ISBN Symbol

A special form of the EAN 13 symbol is the ISBN Code (ISBN stands for *I*nternational *S*tandard *B*ook *N*umbering System). The first three characters are fixed at 978 or 979 (see also Table 6).



**Fig. 7: ISBN Symbol with the information "091126109"**

The ISBN check number is calculated according to Table 9. For this, the characters are multiplied with the factors of row 2 and then added up without the three-digit prefix (978). One now supplements the result as described

above, so that it becomes divisible by 11 without any remainder. This supplement is then the ISBN check number. If the supplement is an even 10, an X must be set for the check number. The ISBN check number becomes 0 if the checksum is divisible by 11 without remainder.

1	0	9	1	1	2	6	1	0	9	
2	10	9	8	7	6	5	4	3	2	
3	0	81	8	7	12	30	4	0	18	163
$160/11 = 14.54.. \Rightarrow 15 \cdot 11 - 160 = 5$										
ISBN Check number										5

Table 9 : Calculating the ISBN check number

Since EAN 13 is the basis for the ISBN symbol, the check number comes out to be 7 in the above example according to its rules. Occasionally the UPC A and the EAN 13 Symbols are accompanied by the so-called "Add ON's". These are the symbols EAN 2 or EAN 5.



Fig. 8: EAN 2 und EAN 5 Symbols

These are, however, read by a reading device only together with a main symbol and contain, for example, information about the price.

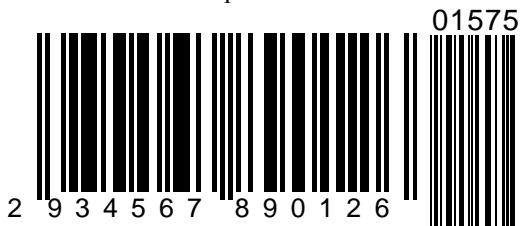


Fig. 9: EAN 13 Symbol with EAN 5 Add On

The example given in Fig. 9 shows a combination of an EAN 13 symbol that starts with the number 29. In Table 6 this number has been determined as the identification of an "In-Store" product. This can be a product from the supermarket, whose price depends upon its weight and is determined before its sale. The additional symbol then contains the price as 01575, which is interpreted as USD 15.75. The additional symbols do not have any checksum and can be read only together with a main symbol.

### 2.4 Codabar

This code was developed in 1972 and is mainly used today in libraries, for identifying the blood samples and by some parcel services.

Codabar can represent 16 different characters, the numbers from 0-9 as well as \$, :, /, ., and the + character. The alphabets ABC and D are used as the start and the stop characters, so that the total number of characters becomes 20. The total length of the code is variable as compared to UPC-A/E and EAN 13/8.



Fig. 10: Codabar with B as start and A as stop bit.

0	[Barcode]
1	[Barcode]
2	[Barcode]
3	[Barcode]
4	[Barcode]
5	[Barcode]
6	[Barcode]
7	[Barcode]
8	[Barcode]
9	[Barcode]
-	[Barcode]
\$	[Barcode]
:	[Barcode]
/	[Barcode]
.	[Barcode]
+	[Barcode]
A	[Barcode]
B	[Barcode]
C	[Barcode]
D	[Barcode]

Table 10: Encoding of Codabar Symbols

The letter ABC and D can be used as the start and the stop bits. Each individual Codabar character is made up of 4 bars and three empty spaces between them. It is a self-testing code and for this reason does not contain a checksum.

### 2.5 Code 39

The Code 39 was the first alphanumeric code developed for the Barcode applications. The character set includes the numbers from 0 – 9, the 26 capital letters from A – Z as well as the special characters -, ., \*, \$, /, + and %.



Fig. 11: Code 39 Symbol with the Information "CODE 39"

Each character comprises of 5 bars and 4 blanks. Three elements are broad and 6 are narrow. This aspect enables a self-check of the code 39. A gap is present as a separation between the individual characters. The advantage of this code is its big character set. The disadvantage is the low density of information as well as a low tolerance. The \* character is used as the start and the stop bit, which however, is not displayed always. The asterisks at the start and at the end of the text line are normally not printed. However, one sometimes finds the start/stop – asterisks in the text line. If, for example, \*1234\* is present in the text line, the useful information is only 1234, since the asterisks are an integral part of the Code 39 Symbol.

**2.6 Code 39 Extended**

This is an extended version of the Code 39 and can represent the ASCII – character set. The 26 small letters (a – z) as well as the special characters of the keyboard can also be represented with the help of the Code39 Extended.

**2.7 Code 93**

The Code 93 was introduced in 1982 as an extension of the code 39. The special thing about this code is its very high density. This also becomes clear in direct comparison with the Code 39 and Code 128.

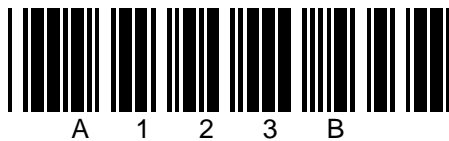


Fig. 12 : Code 39 Symbol



Fig. 13: Code 128



Fig. 14: Code 93

**2.8 Code 128 and UCC / EAN 128**

The Code 128 is an alphanumeric symbol and can represent the complete ASCII 128 character set with a very high information density. This code was introduced in 1981, but became popular for many applications only after 1990. Each character comprises of 11 bits that are arranged in such a way, that a sequence of three dark and three light bars arises for each character. The character set consists of 107 characters, four functional characters, 4 control characters for selecting the code set and three

different start characters. Depending upon the start character the character set A, B or C is used for decoding:

- Code 128A** The capital letters and the special characters are coded in this character set.
- Code 128B** The capital- and small letters are contained in this character set.
- Code 128C** This character set has been optimised for representing numbers

The internationally acceptable symbol UCC / EAN 128 was developed based on the Code 128. The coding essentially corresponds to that of the Code 128, but a double start character is used. The EAN 128 has acquired a significant position for the goods logistics and a worldwide introduction of this symbol is anticipated. The immense advances made in the microprocessor technology permit a higher and more comprehensive data processing than what was possible at the time of the introduction of EAN 13 or the UPC E symbols. The motivation for introducing the codes at that time rested on a desire to improve the logistics within a supermarket. But today, the complete way from the manufacturer to the supermarket or to any other sale point. Additional information must be appended to the symbol in this case, which is necessary for the logistics and product designation. On the other hand is the information for the controlling authorities, which check the quality or the risk degree of the product. The EAN 128 symbols offer here the best possible conditions, since the code is able to use the control characters. A control character instructs the reading process to do the following decoding for carrying out a specific interpretation. These control characters are also called as data identifiers (DI)

Excerpt from the list of the current data identifiers (DI)		
DB	Coded data content	Format*
00	Number of the dispatching unit	n2 + n18
01	EAN of the business unit	n2 + n14
10	Batch number	n2 + an20
11	Date of manufacturing (YYMMDD)	n2 + n6
13	Packing date (YYMMDD)	n2 + n6
15	Best before date (YYMMDD)	n2 + n6
17	Expiry date (YYMMDD)	n2 + n6
20	Product version	n2 + n2
21	Serial Number	n2 + an20
30	Quantity (No. of pieces contained)	n2 + an8
310(**)	Net weight in Kg	n4 + n6
314(**)	Area in square	n4 + n6
315(**)	Net volume in litres	n4 + n6
400	Order number of the	n3 + an30
410	“Delivered to”	n3 + n13
421	“Destination”, Pin code with 3-digit ISO country code	n3 + n13 + an9

(\*) Position 1 = Length of the following data identifier, following places = length of the actual information.  
 (\*\*) Position 4 = Indicator for the number of decimal places

n is used for numerical and an for alpha-numeric characters

A sample coding for a product with a net weight of 130.5 kg and a best-before date of 12.04.2002 will be:

3101130515020412

The characters in bold are the data identifiers.



Fig. 15 UCC / EAN 128 Symbol

### 3 Detection of Barcodes

After discussing the barcode symbols and their coding in detail, we shall now move on to the optical-electronic reading of the symbols. The basic principle is shown in Fig. 16.

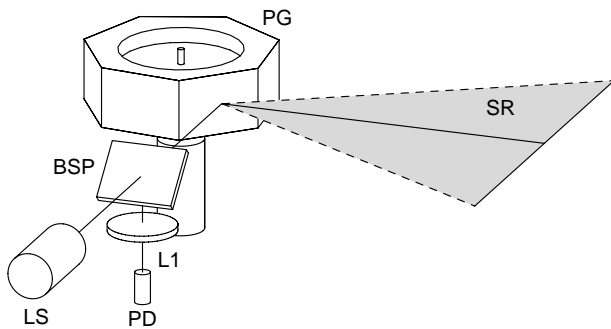


Fig. 16 : Principle of a barcode scanner

The laser beam is deflected periodically by a rotating polygon mirror (PG). When the deflected light strikes a barcode symbol, it gets scattered. The intensity of the scattering depends upon, whether the light has struck a dark or a light bar. The main direction of scattering is opposite to that of the laser beam. The scattered light is transferred to the photo-detector (PD) through a translucent mirror (BSP) and the lens (L1). Here the changes in the intensity are converted in electrical signals and are then processed by a microprocessor. In order to have a high and efficient reading speed, the laser beam, the photo-detector and the contrast of the barcode must fulfil certain conditions. The next chapter describes how these conditions can be fulfilled.

#### 3.1 Gaussian beams

Real parallel beams of light do not exist in reality and plain wave fronts are also present only at a specific point. The reason for the failure of the geometric optics is, that it arose at a time, when light was still not treated as an electromagnetic wave and that its behaviour could be described by Maxwell's equations:

$$\Delta \vec{E} - \frac{n^2}{c^2} \cdot \frac{\partial^2 \vec{E}}{\partial t^2} = 0$$

Without restrictions, light will propagate isotropically as a spherical wave in all the directions.

$$\vec{E} = \vec{E}(r) \text{ with } r^2 = x^2 + y^2 + z^2$$

However, for the case relevant to us, that the spherical wave propagates in a small solid angle in the direction z, so we have to define the boundary condition for the electrical field as:

$$\vec{E} = \vec{E}(r, z) \text{ whereby } r^2 = x^2 + y^2 + z^2$$

The solution of this modified wave equation gives electromagnetic fields, which have a Gaussian type distribution of intensity over the cross-section of the beam and are hence called Gaussian beams. Such beams, especially the Gaussian fundamental mode (TEM<sub>00</sub>) is generated preferably by lasers. However, the intensity of a pure mode is very small as compared to the total intensity of the light source. The situation is different in the case of lasers, where the complete light power can be generated in the base mode. Just like the monochromatic nature of the laser beam, this is one more outstanding difference to the conventional light sources. A Gaussian beam always possesses a "beam waist". The beam radius w (w stands for waist) gives the following from the solution of the above wave equation:

$$w(z) = w_0 \cdot \sqrt{1 + \left(\frac{z}{z_R}\right)^2}$$

Here the smallest beam radius is the waist  $w_0$  and  $z_R$  the Rayleigh length.

$$z_R = w_0^2 \frac{\pi}{\lambda}$$

Fig. 17 shows the course of the beam diameter of a beam, which is propagating in the direction z. The beam has the smallest radius at the point  $z = z_0$ .

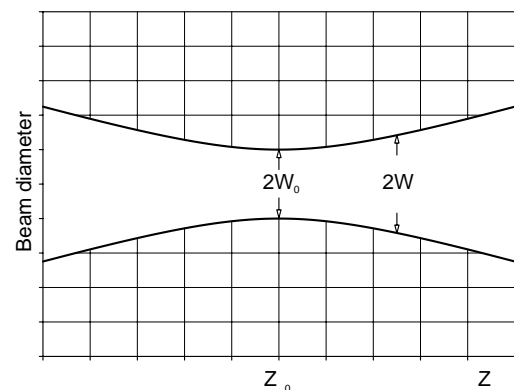
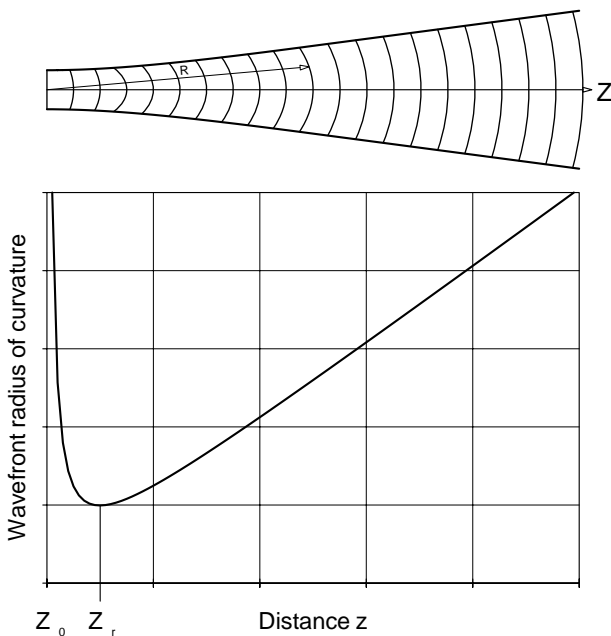


Fig. 17: Beam diameter of a Gaussian beam of fundamental mode TEM<sub>00</sub> as function of the location z

The beam radius increases linearly with increasing distance. Since Gaussian beams are spherical waves, a radius of curvature of the wave field can also be assigned to each point  $z$ . The radius of curvature can be calculated from the following formula:

$$R(z) = z + \frac{z_r^2}{z}$$

This situation has been displayed in Fig. 18. At  $z = z_R$  the radius of curvature is minimum. In the direction  $z \rightarrow 0$  the radius of curvature increases like a hyperbola. At  $z = 0$  the radius becomes infinite i.e. the wave front becomes plain here. Above the Rayleigh length  $z > z_R$  the radius increases again linear. This is a very important statement. According to it, the beam is parallel only in one point i.e. in its focus.

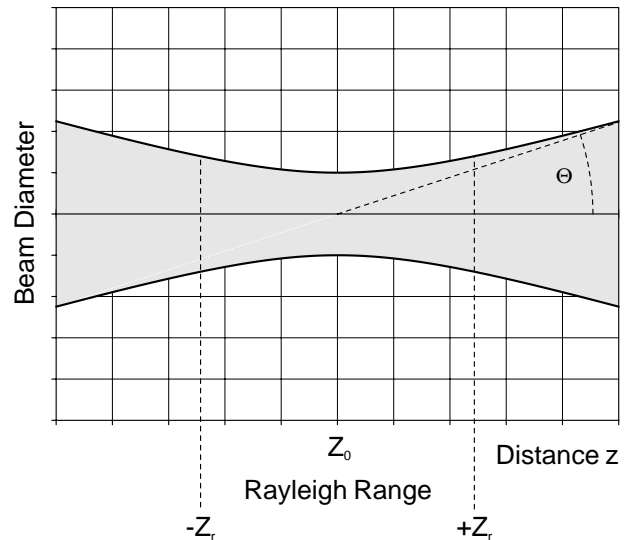


**Fig. 18: Course of the radius of curvature of the wave front as a function of the distance of the beam waist at  $z = 0$**

In the range for

$$-z_r \leq z \leq z_r$$

a beam can be considered approximately to be parallel. The Rayleigh range has been shown in Fig. 19 as well as the divergence  $\Theta$  in the far field ( $z \gg z_0$ ). The graphic representation shows, that the most excellent feature of the laser beam, namely its low divergence, cannot be represented in this way.



**Fig. 19: Rayleigh range  $z_R$  and the far field divergence  $\Theta$**

However, the reason for this is that the ratio of the beam diameter to  $z$  is not 1:1. As an example we take a HeNe-Laser (632 nm) with a beam waist  $w_0 = 1\text{ mm}$  at the point of exit of the laser, we get the following value for the entire Rayleigh range

$$2 \cdot z_R = 2 \cdot w_0^2 \frac{\pi}{\lambda} = 2 \cdot 10^{-6} \frac{3.14}{623 \cdot 10^{-9}} = 9,9 \text{ m}$$

We can consider the laser beam to be parallel within this length. After this the beam diameter increases corresponding to its divergence, which is determined by the divergence angle  $\Theta$ . We can determine this angle from Fig. 19:

$$\tan \Theta = \frac{w_0}{z_r}$$

We are making use of the approximation here, that the laser beam can be treated as parallel in the Rayleigh range. If we use

$$z_R = w_0^2 \frac{\pi}{\lambda}$$

we finally get :

$$\tan \Theta = \frac{\lambda}{\pi \cdot w_0}$$

A commercial HeNe-Laser has a beam waist of approx.:

$$w_0 \approx 0.8 \text{ mm}$$

With the wavelength of 633 nm we calculate its divergence angle as:

$$\tan \Theta = \frac{633 \cdot 10^{-8}}{\pi \cdot 0.8 \cdot 10^{-3}} = 2.5 \cdot 10^{-3} \hat{=} 2.5 \text{ mrad}$$

We have seen in chapter 2.2.1 that the nominal width of a bar of a symbol is 13 mils. The minimum permitted scaling factor is 0.8, so that the minimum width of a bar should be 10.4 mils or 0.026 mm. In order for the laser beam of the scanner to be able to differentiate between the bars, its diameter should not be higher than this value. In practice this means that the laser beam must not exceed this value within a specific distance from the scanner. The manufacturer of the scanner must manipulate the laser beam in such a way, that this condition is fulfilled. As already mentioned, a commercial HeNe-Laser has a beam diameter of 0.8 mm ( $2w_0$ ) at the point of exit. The manufacturer must now with the help of a precisely calculated lens or lens system see to it, that the laser beam does not show a diameter greater than 0.02 mm ( $2w$ ) over a distance  $b$  of, say, 50 cm.

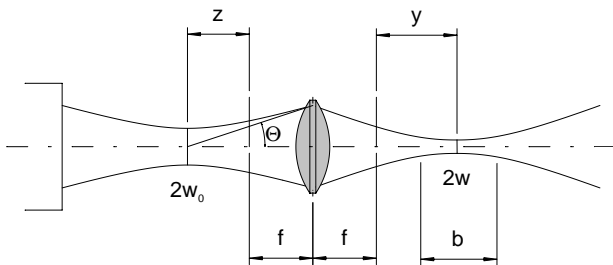


Fig. 20: For calculating the imaging optics

Beam waist radius: 
$$w = \frac{w_0 \cdot f \cdot \Theta}{\sqrt{w_0^2 + \Theta^2 \cdot z^2}}$$

Location of beam waist 
$$y = \frac{z \cdot f^2}{z^2 + \left(\frac{w_0}{\Theta}\right)^2}$$

With the help of the equations given above, the necessary focal length  $f$  and the distance  $z + f$  for the lens can be calculated. Hereby the range  $b$  must lie within the Rayleigh range.

### 3.2 Light scattering

When a laser beam strikes an optical surface, it gives rise to a scattering of light, which propagates in different directions of space depending upon the texture of the surface.

First, however, a description of the light scattered back by a destination object. There is no doubt that the intensity of the light scattered back depends on the texture of the destination object.

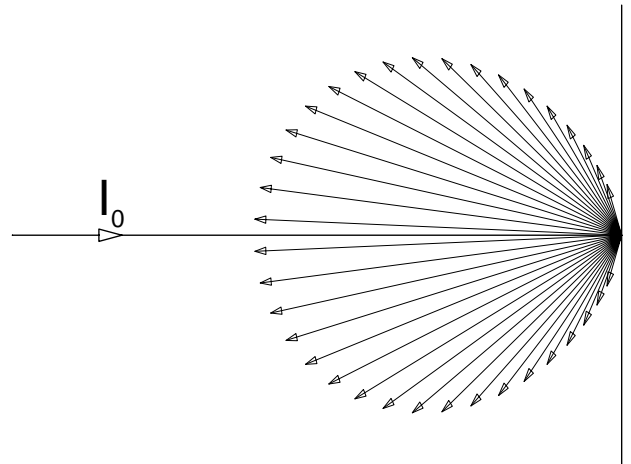


Fig. 21: Scattering of light at a surface

However, the scattering behaviour of many objects can be compared with that of the Lambert's bodies. Such a body emits received light as per the cosine distribution and it can also be called as a cosine radiator (Fig. 22).

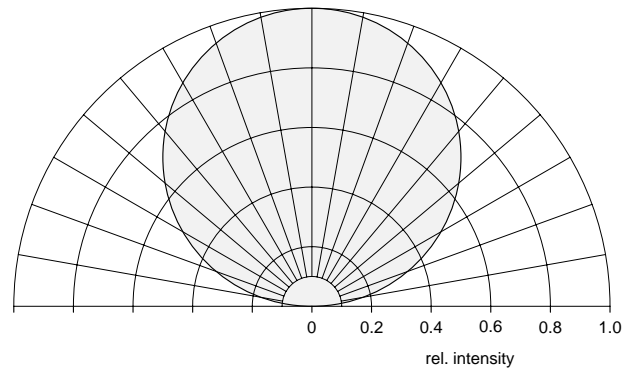


Fig. 22: Lambert's Cosinus radiator

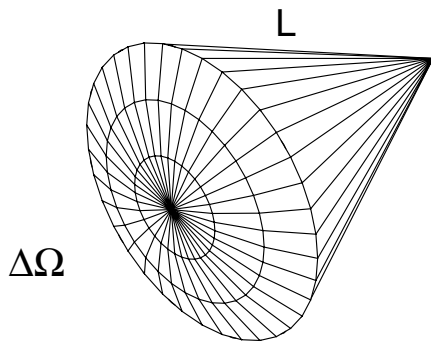
The main beam direction lies in the normal surface of the object. In reality the object distance  $L$  will be greater than the aperture diameter of the receiving optics. In this sense, the radiator can be considered as a spherical source, whose intensity decreases with the square of the distance and depends on the cosine distribution. The light power, which finally reaches the photo detector, is the power that enters through the cross section of the receiving optics. In exact words this means that:

$$P = \beta \cdot P_0 \cdot \int_{d\Omega} \cos(\vartheta) \cdot d\Omega$$

The constant  $\beta$  characterizes the reflectivity of the object. In case of a sufficiently large distance, the lens gets only the light from the scattering object, which comes from an angular range of  $\cos \vartheta \approx 1$ . This simplifies the equation to:

$$P = \beta \cdot P_0 \cdot \int_{d\Omega} d\Omega = \beta \cdot P_0 \cdot \Delta\Omega$$

The size of the solid angle is given by the aperture angle of the receiving optics.



**Fig. 23: Solid angle of receiver optics**

The radiator (destination object) emits radiation only in a hemisphere, since it does not radiate backwards. The ratio of the spherical segment of the receiving optics to the surface of the hemisphere is directly proportional to the ratio of the power received to the power radiated:

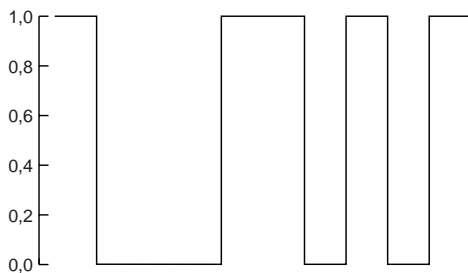
$$\frac{2 \cdot \Delta\Omega}{\Omega} = \frac{F_{\text{Optic}}}{2 \cdot \pi \cdot L^2} = \frac{P}{\beta \cdot P_0}$$

or

$$P = \beta \cdot P_0 \cdot \frac{F_{\text{Optic}}}{2 \cdot \pi \cdot L^2} = \gamma \cdot P_0 \cdot \frac{r^2}{L^2} \text{ with } \gamma = \beta/2.$$

The power received P reduces with the square of the distance L of the destination object and increases with increasing diameter r of the receiving optics. The distance L of the Barcode Symbol cannot be made small to any value, but instead only as per the requirements of the user. However, the effective diameter of the receiving optics can be optimised.

Ideally, the back-scattering coefficient for dark strips is 0 and is 1 for light strips.

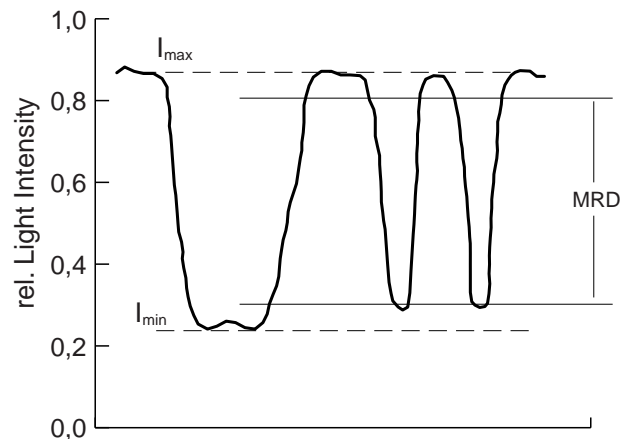


**Fig. 24: Ideal back scattering**

It is clear that this is not the case in reality. The decisive thing is that a sufficient contrast is present, so that the evaluating device can differentiate between dark and light bands. If we designate the light power received for a light bar with  $P_L$  and that for a dark bar with  $P_D$ , the contrast K becomes

$$K = \frac{P_L - P_D}{P_L} = \frac{\beta_L - \beta_D}{\beta_L}$$

Here  $\beta_L$  the back-scattering coefficient is for the light surface of the barcode symbol and  $\beta_D$  is for the dark surface.

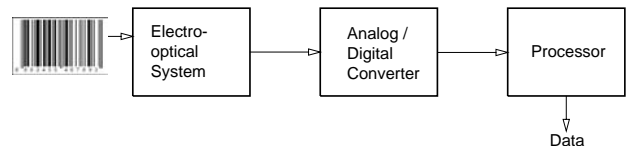


**Fig. 25: Real back-scattering intensity**

To have a uniform definition for the contrast and hence the minimum demands on the Barcode scanner, the term MRD (Minimum Reflectance Difference) was introduced. According to this, the MRD is 80% of the range of  $I_{\text{max}} - I_{\text{min}}$  (Fig. 25). The minimum MRD area should be 37.5% for Barcode symbols with a single bandwidth smaller than 40 mils and 20% for bandwidths equal to or greater than 40 mils. The manufacturers of the printers for barcode labels must adhere to this regulation. On this basis also the manufacturers of barcode scanners must design the signal evaluation electronics.

### 3.3 Signal evaluation

The signal evaluation of the Barcode Scanner can be broadly classified into three areas (Fig. 26).



**Fig. 26 : Block diagram of signal evaluation**

The electro-optical system converts the bright and dark transitions of the barcode signals into analogue voltages. In the subsequent Analogue-Digital converter these signals are converted in a digital form, which are then processed further by the processor. Basically the processor has to carry out the following steps:

1. Locating the start signal. The digital data are stored at first in a buffer. The processor checks, whether the first characters correspond to a known start code.
2. Determining the width of each bar. If the start code is recognized, the processor can then calculate the width of the remaining bars.
3. The code can now be determined from the width of the data elements. The code 39 makes use of two different widths and EAN four different widths.
4. It must now be checked, whether all the data is consistent with the determined code. If this is the case, the data is then compared with a stored table and decoded.
5. The direction of evaluation must be reversed, if necessary.