Lecture 9

Second Stage

Medical Physical Department

Digital Electronics

Lecture 9: Binary Codes

By

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Binary Codes

The electronic digital systems like computers, microprocessors etc., are required to process data which may include numbers, alphabets or special characters. The binary system of representation is the most extensively used one in digital systems i.e, digital data is represented, stored and processed as group of binary digits (bits). Hence the numerals, alphabets, special characters and control functions are to be converted into binary format. The process of conversion into binary format is known as binary coding. Several binary codes have developed over the years. Some of them are discussed in this section.

1. Binary coded decimal (BCD).
2. Gray code.
3. ASCII code

1- Binary Coded Decimal (BCD)

Internally, ***digital computers operate on binary numbers***. When interfacing to humans, digital processors, e.g. pocket calculators, communication is decimal-based.

Input is done in decimal then converted to binary for internal processing. For output, the result has to be converted from its internal binary representation to a decimal form.

One commonly used code is the *Binary Coded Decimal* (BCD) code which corresponds to the first 10 binary representations of the decimal digits 0-9. The BCD code requires 4 bits to represent the 10 decimal digits. Since 4 bits may have up to 16 different binary combinations, a total of 6 combinations will be unused

Table (1)

Decimal Digit	0	1	2	3	4	5	6	7	8	9
BCD Code	0000	0001	0010	0011	0100	0101	0110	0111	0100	1001

To illustrate the BCD code, take a decimal number such as 874. Each digit is changed to its binary equivalent as follows:

8 7 4 → **Decimal**

↓ ↓ ↓

0111 0100 30 → **BCD**

Example: Convert $(95)_{10}$ into BCD code .

Solution:

95

↙ ↘

1001 0101

2- Gray Code

The gray code is un-weighted and is not an arithmetic code; that is, there are no specific weights assigned to the bit positions. The important feature of the Gray code is that it exhibits only a single bit change from one code number to the next.

Table (2) is a listing of the four bit gray code for decimal numbers 0 through 15. Notice the single bit change between successive gray code numbers. For instance, in going from decimal 3 to decimal 4, the gray code changes from 0010 to 0110, while the binary code changes from 0011 to 0100, a change of three bits. The only bit change is in the third bit from the right in the gray code; the other remain the same.

Table (2)

Decimal	Binary	Gray	Decimal	Binary	Gray
0	0000	0000	8	1000	1100
1	0001	0001	9	1001	1101
2	0010	0011	10	1010	1111
3	0011	0010	11	1011	1110
4	0100	0110	12	1100	1010
5	0101	0111	13	1101	1011
6	0110	0101	14	1110	1001
7	0111	0100	15	1111	1000

2.1 Binary Number to Gray Code Conversion:

The procedures of conversion from binary to gray code are:

1. put down the MSB
2. start from the MSB, adding without carry each two adjacent bits

Example: convert the (10110)2 into gray code.

Solution:

1 — + → 0 — + → 1 — + → 1 — + → 0 Binary

↓ ↓ ↓ ↓ ↓

1 1 1 0 1 Gray

Example: convert the binary number 10110 to Gray code.

Step 1: the left-most Gray code digit is the same as the left-most binary code bit.

10110 (Binary)

↓

1 (Gray)

Step 2: add the left-most binary code bit to the adjacent one:

1 + 0 110 (Binary)

↓

1 1 (Gray)

Step 3: add the next adjacent pair:

1 **0 + 1** 10 (Binary)

↓

1 1 1 (Gray)

Step 4: add the next adjacent pair and discard the carry:

1 0 **1 + 1** 0 (Binary)

↓

1 1 1 0 (Gray)

Step 5: add the last adjacent pair:

1 0 1 **1 + 0** (Binary)

↓

1 1 1 0 1 (Gray)

Hence the Gray Code is 11101

2.2 Gray Code to Binary Number Conversion:

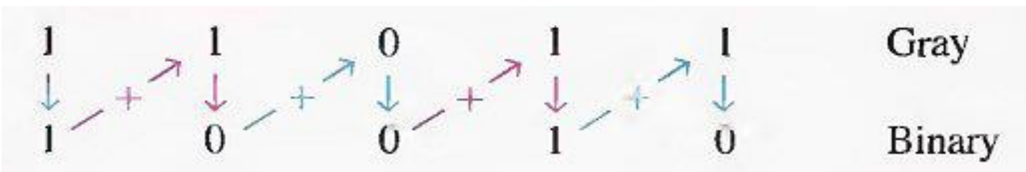
The procedure of conversion from gray code to binary are:

1- put down the MSB

2- start from the MSB adding without carry each result binary bit with the lower gray code bit

Example: convert the $(11011)_{gray}$ into binary.

Solution:



Example: **convert the Gray code number 11011 to binary.**

Step 1: the left-most bits are the same.

11011 (Gray)

↓

1 (Binary)

Step 2: add the last binary code bit just generated to the gray code bit in the next position. Discard the carry.

1	**1**	011	(Gray)
+	↓		
1	0		(Binary)

Step 3: add the last binary code bit generated to the next Gray code bit.

1	1	**0**	11	(Gray)
	+	↓		
1	**0**	0		(Binary)

Step 4: add the last binary code bit generated to the next Gray code bit.

1	1	0	**1**	1	(Gray)
		+	↓		
1	0	**0**	1		(Binary)

Step 5: add the last binary code bit generated to the next Gray code bit. discard carry.

1	1	0	1	**1**	(Gray)
			+	↓	
1	0	0	**1**	0	(Binary)

Hence the final binary number is 10010

Example: **(a)** Convert the binary number 11000110 to Gray-code.
(b) Convert the Gray-code 10101111 to binary**.**

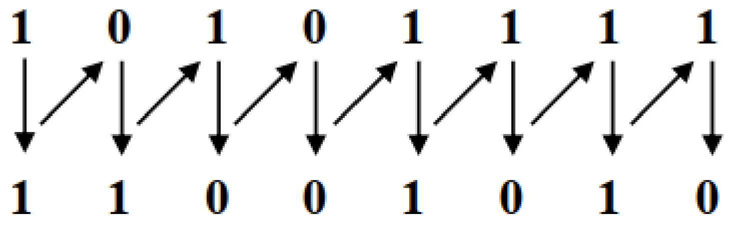
(a) Binary to Gray code:-

1 + 1 + 0 + 0 + 0 + 1 + 1 + 0

↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓

1 0 1 0 0 1 0 1

(b) Gray code to Binary:-



3. ASCII Code (Alphanumeric Code)

In order to be very useful, a computer must be capable of handling nonnumeric information. In other words, a computer must be able to recognize codes that represent numbers, letters, and special characters. These codes are classified as alphanumeric codes. The most common alphanumeric code, known as the American Standard Code for Information Interchange (ASCII), is used by most minicomputer and microcomputer manufacturers.

The ASCII is a seven-bit code in which the decimal digits are represented by the 8421 BCD code preceded by 011. The letters of the alphabet and other symbols and instructions are represented by other code combinations, shown in Table (4).

For instance, the letter **A** is represented by 1000001 (41_{16}), the **comma** by 0101100 ($2C_{16}$) and the **ETX** (end of text) by 0000011 (03_{16}).

Table (3)

LSBs	**MSBs**							
	000 (0)	001 (1)	010 (2)	011 (3)	100 (4)	101 (5)	110 (6)	111 (7)
0000	NUL	DLE	SP	0	@	P	`	p
0001	SOH	DC1	!	1	A	Q	a	q
0010	STX	DC2	“	2	B	R	b	r
0011	ETX	DC3	#	3	C	S	c	s
0100	EOT	DC4	$	4	D	T	d	t
0101	ENQ	NAK	%	5	E	U	e	u
0110	ACK	SYN	&	6	F	V	f	v
0111	BEL	ETB	‘	7	G	W	g	w
1000	BS	CAN	(	8	H	X	h	x
1001	HT	EM	)	9	I	Y	i	y
1010	LF	SUB	*	:	J	Z	j	z
1011	VT	EXC	+	;	K	[	k	{
1100	FF	FS	,	<	L	\	l	|