UTM
UNIVERSITI TEKNOLOGI MALAYSIA

SKEE1223: Digital Electronics

2 – Number Systems

Binary Codes

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Number Systems

- Standard number systems
  - Decimal
  - Binary
  - Hexadecimal
  - Octal
- Binary Codes
  - BCD 8421
  - Gray Codes
  - ASCII
  - ECBDIC

Review

- Why binary numbers? Why not decimal?
  - Digital system understand binary numbers, not decimal numbers.

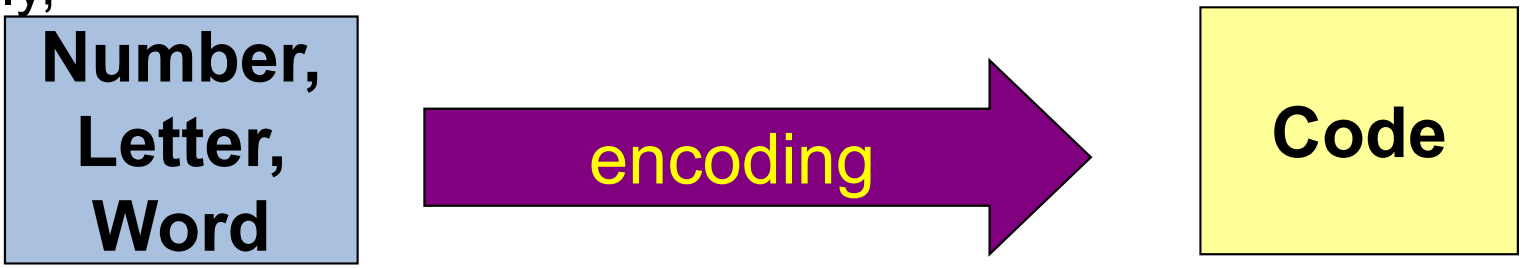
Review

- Why hexadecimal?
  - Shorthand of binary numbers
  - Easy to convert to and from binary
- Examples:
  - $1\ 1111\ 1000\ 0000\ 1010\ 1000\ 0001_2$
  - $1F80A81_{16}$

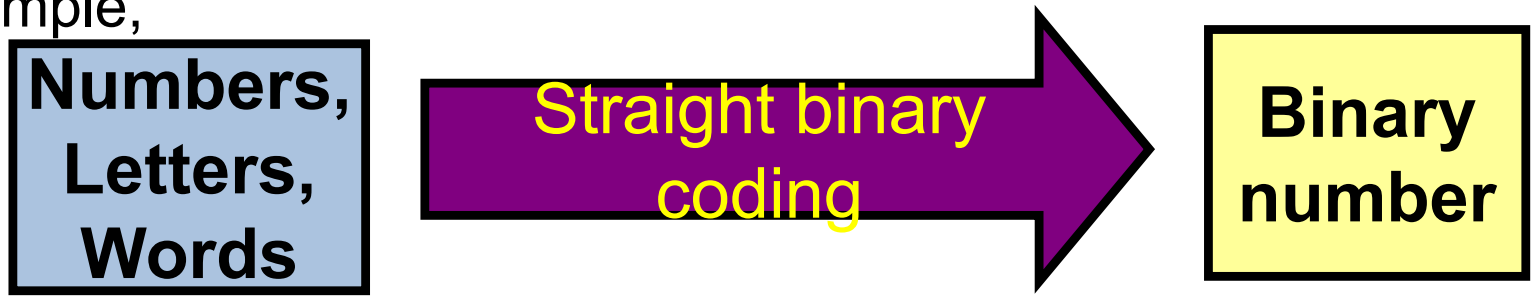
Code and Encoding

- Code-- Special group of symbols that is used to represent numbers, letters or words.
- Encoding– The process of converting a number/letter/word into a code.

Generally,



For example,



BCD Code

- **B**inary **C**oded **D**ecimal Code
- Binary Coded Decimal (BCD)—a way to represent each digit of a decimal number with its 4-bit binary number.

Example: 874_{10}

Decimal	8	7	4
	↓	↓	↓
BCD	1000	0111	0100

Therefore, the BCD code for 874_{10} is 1000 0111 0100

BCD Code

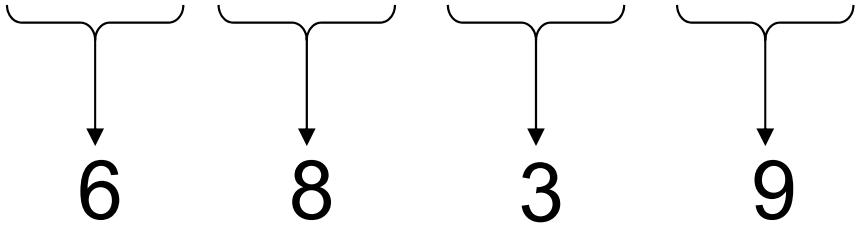
Do you know why?

1000 1111 is not a BCD

Invalid BCD Numbers
These binary numbers are not allowed in the BCD code:
1010, 1011, 1100, 1101, 1110, 1111

BCD Code / 8421 Code

- Convert a BCD code to its decimal equivalent.
  - Step 1: Break the BCD into 4-bit groups, starting from LSB
  - Step 2: Replace each 4-bit group with its equivalent decimal
- Example: 0110 1000 0011 1001



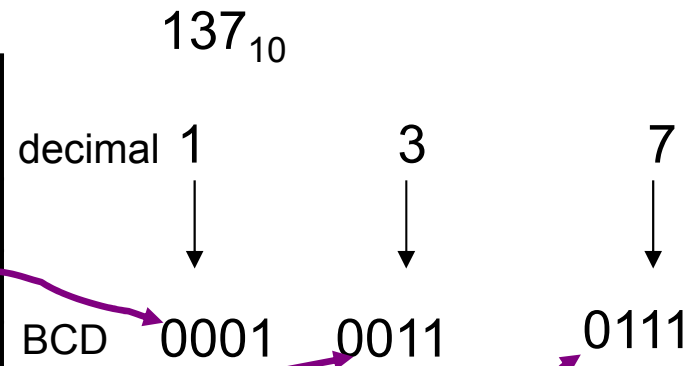
So, the decimal equivalent is 6839_{10}

BCD coding vs. Straight Binary Coding

- BCD coding is easier.

BCD coding

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



The BCD code is 0001 0011 0111

137_{10}

$\frac{137}{2}$	=68	1
$\frac{68}{2}$	=34	0
$\frac{34}{2}$	=17	0
$\frac{17}{2}$	=8	1
$\frac{8}{2}$	=4	0
$\frac{4}{2}$	=2	0
$\frac{2}{2}$	=1	0
$\frac{1}{2}$	=0	1

The straight binary code is 10001001_2

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BCD 8421 (Binary Coded Decimal)

- Each decimal digit (0 to 9) is represented by 4 bit binary

Binary		Decimal
0 0 0 0	=>	0
0 0 0 1	=>	1
0 0 1 0	=>	2
0 0 1 1	=>	3
0 1 0 0	=>	4
0 1 0 1	=>	5
0 1 1 0	=>	6
0 1 1 1	=>	7
1 0 0 0	=>	8
1 0 0 1	=>	9

How to represent 28?

=> $0010\ 1000_2$

What is 0011 0010 in BCD?

=> 32

What is 32 in binary?

=> 100000_2

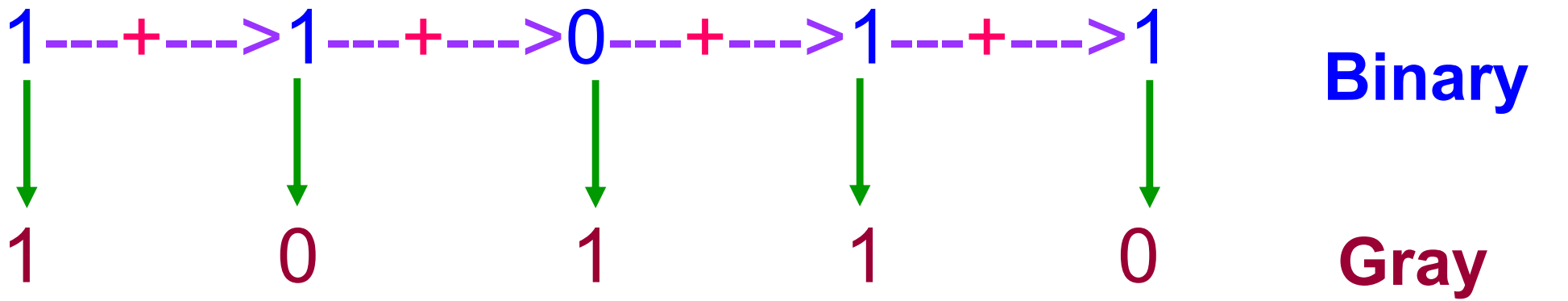
Gray Code

Binary		Decimal		Gray Code
0 0 0 0	=>	0	=>	0 0 0 0
0 0 0 1	=>	1	=>	0 0 0 1
0 0 1 0	=>	2	=>	0 0 1 1
0 0 1 1	=>	3	=>	0 0 1 0
0 1 0 0	=>	4	=>	0 1 1 0
0 1 0 1	=>	5	=>	0 1 1 1
0 1 1 0	=>	6	=>	0 1 0 1
0 1 1 1	=>	7	=>	0 1 0 0
1 0 0 0	=>	8	=>	1 1 0 0
1 0 0 1	=>	9	=>	1 1 0 1
1 0 1 0	=>	10	=>	1 1 1 1
1 0 1 1	=>	11	=>	1 1 1 0
1 1 0 0	=>	12	=>	1 0 1 0
1 1 0 1	=>	13	=>	1 0 1 1
1 1 1 0	=>	14	=>	1 0 0 1
1 1 1 1	=>	15	=>	1 0 0 0

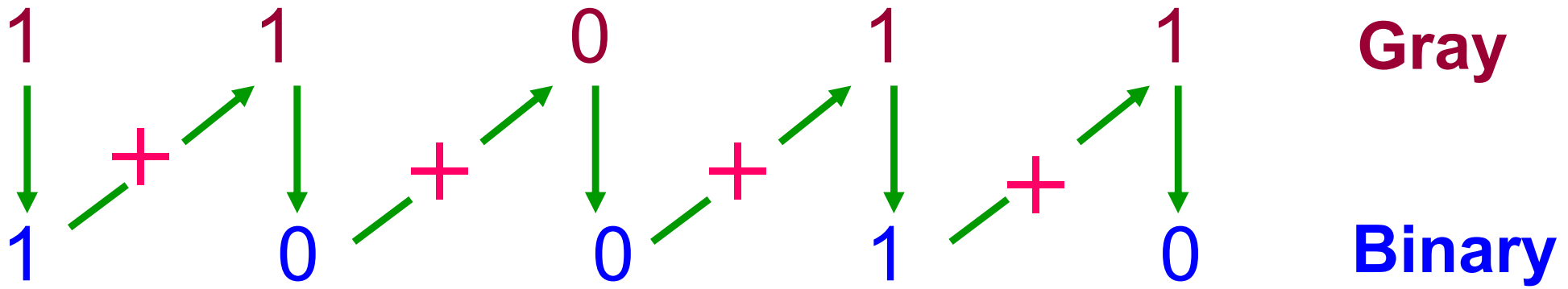
- Exhibits a single bit change from one code word to another

Conversions

BINARY TO GRAY CONVERSION

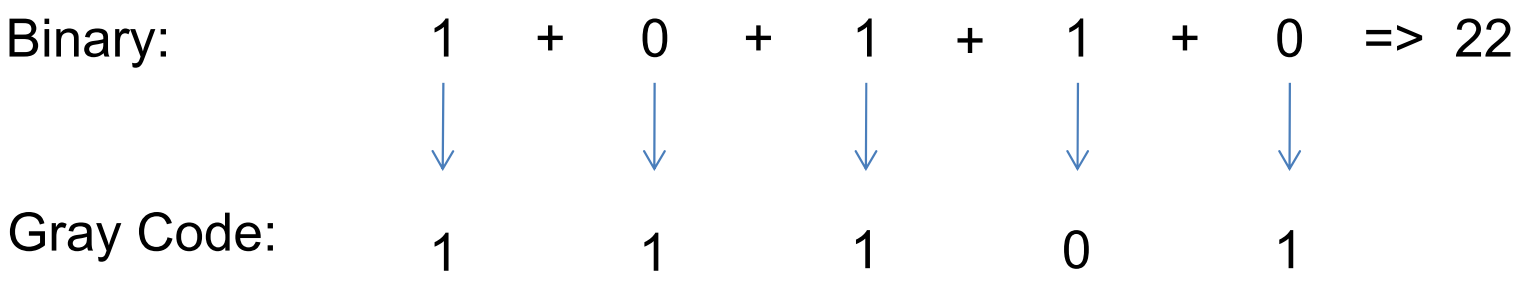


GRAY TO BINARY CONVERSION



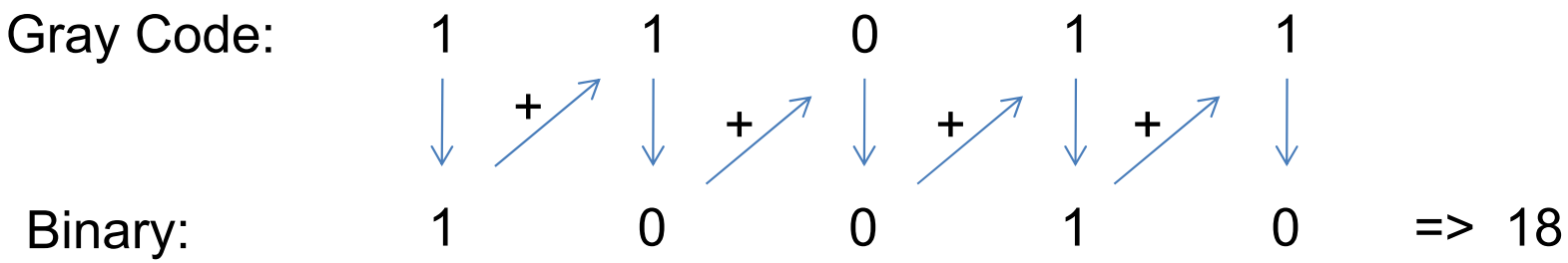
Binary-Gray Code Conversions

- MSB of Gray Code is the same MSB in binary
- From left to right, add each adjacent pair of binary code, discard carry



Gray Code-Binary Conversions

- MSB of binary is the same MSB in Gray Code
- From left to right, add each generated binary code with adjacent Gray Code, discard carry



Alphanumeric codes

- Codes that represent numbers and alphabetic characters (letters).
- At minimum, the code must represent 10 decimal digits (0-9) and 26 letters (A-Z).
- 6 bits are needed in the code that represent the numbers and letters.
- ASCII is the most common alphanumeric code.

ASCII

- American Standard Code for Information Interchange
- 128 characters, represented by 8-bit binary code with MSB ‘0’
- The 8-bit code runs from 00_{16} to $7F_{16}$
- The first 32 ASCII characters used for controls such as ESC, new line, space, start of text, etc
- Other characters include letters (upper and lower case), decimal digits, and symbols

ASCII Table

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

Extended ASCII Table

128	Ç	144	É	160	á	176	▒	192	└	208	╨	224	α	240	≡
129	ü	145	æ	161	í	177	▒	193	┴	209	╤	225	ß	241	±
130	é	146	Æ	162	ó	178	▓	194	┬	210	╥	226	Γ	242	≥
131	â	147	ô	163	ú	179	│	195	├	211	╙	227	π	243	≤
132	ä	148	ö	164	ñ	180	┤	196	─	212	╘	228	Σ	244	⌠
133	à	149	ò	165	Ñ	181	╡	197	┼	213	╒	229	σ	245	⌡
134	å	150	û	166	ª	182	╢	198	╞	214	╓	230	µ	246	÷
135	ç	151	ù	167	º	183	╖	199	╟	215	╫	231	τ	247	≈
136	ê	152	ÿ	168	¿	184	╕	200	╚	216	╪	232	Φ	248	°
137	ë	153	Ö	169	⌐	185	╣	201	╔	217	┘	233	Θ	249	∙
138	è	154	Ü	170	¬	186	║	202	╩	218	┌	234	Ω	250	·
139	ï	155	¢	171	½	187	╗	203	╦	219	█	235	δ	251	√
140	î	156	£	172	¼	188	╝	204	╠	220	▄	236	∞	252	ⁿ
141	ì	157	¥	173	¡	189	╜	205	═	221	▌	237	φ	253	²
142	Ä	158	₧	174	«	190	╛	206	╬	222	▐	238	ε	254	■
143	Å	159	ƒ	175	»	191	┐	207	╧	223	▀	239	∩	255	

Source: www.LookupTables.com

EBCDIC

- Extended Binary Coded Decimal Interchange Code
- Alternative to ASCII
- Developed by IBM in 1960's, mainly for mainframe computers
- Widely unsuccessful due to many incompatible versions
- ASCII remains the standard today

UNICODE

- The extended version of the ASCII character set is not enough for international use. The Unicode character set uses 16 bits per character. Therefore, the Unicode character set can represent 216, or over 65 thousand, characters.

UNICODE

- Unicode was designed to be a superset of ASCII. That is, the first 256 characters in the Unicode character set correspond exactly to the extended ASCII character set.

UNICODE

- Version 2.1
  - 1998
  - Improves on version 2.0
  - Includes the Euro sign (20AC16 =)
  - From the standard:
    …contains 38,887 distinct coded characters derived from the supported scripts. These characters cover the principal written languages of the Americas, Europe, the Middle East, Africa, India, Asia, and Pacifica.