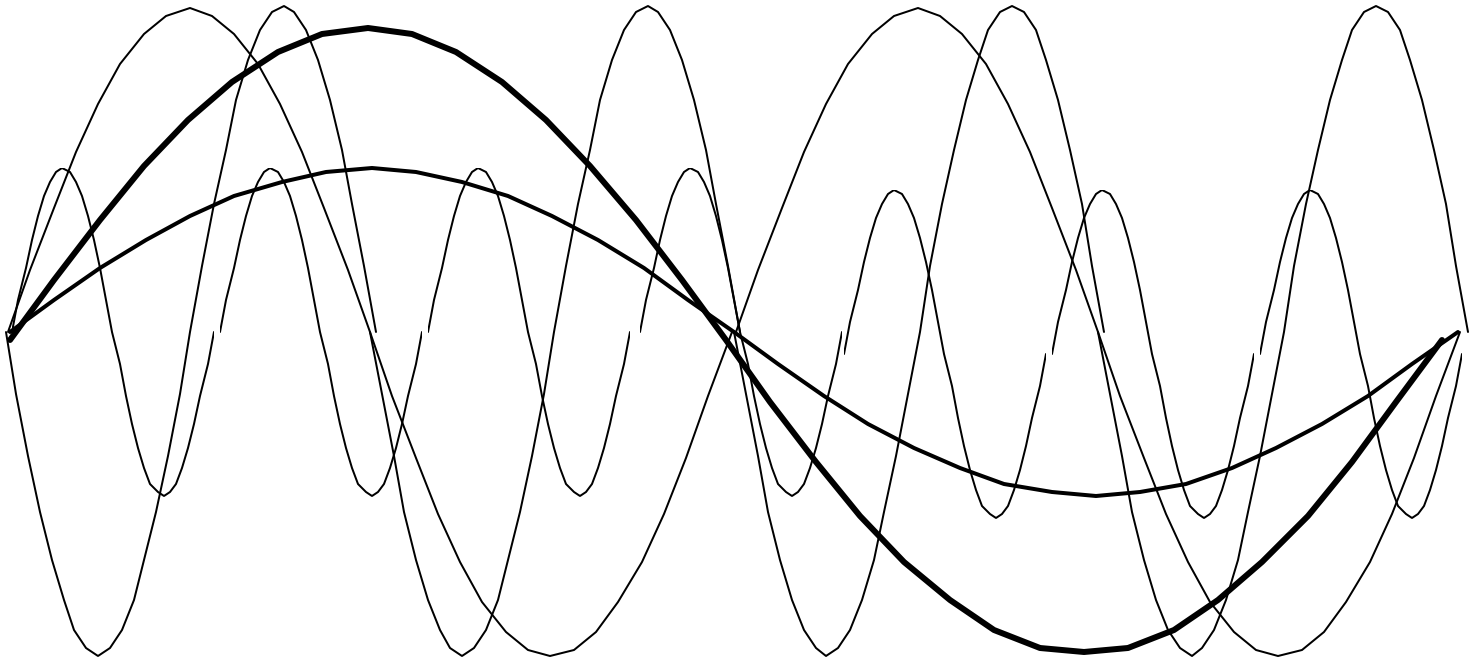
SINE WAVES



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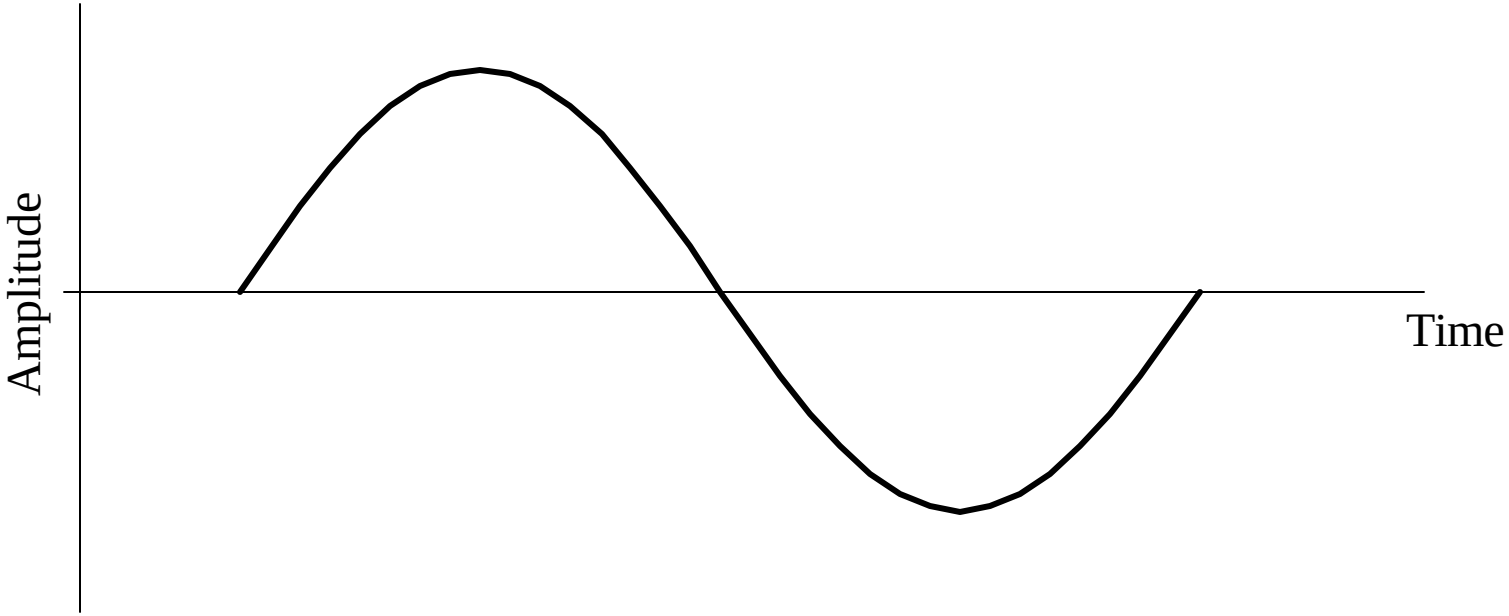
Analog to Digital Conversion Steps



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Nyquist Frequency

Sample Rate = 2 x Maximum Frequency

Voice: Maximum Frequency: 4,000 Hz
Nyquist Frequency: 8,000 samples/sec
Sampling Interval: 1/8000 or .000125 sec

Video: Maximum Frequency: 4 MHz (4,000,000 Hz)
Nyquist Frequency: ??
Sampling Interval: ??

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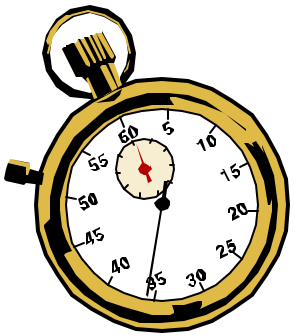
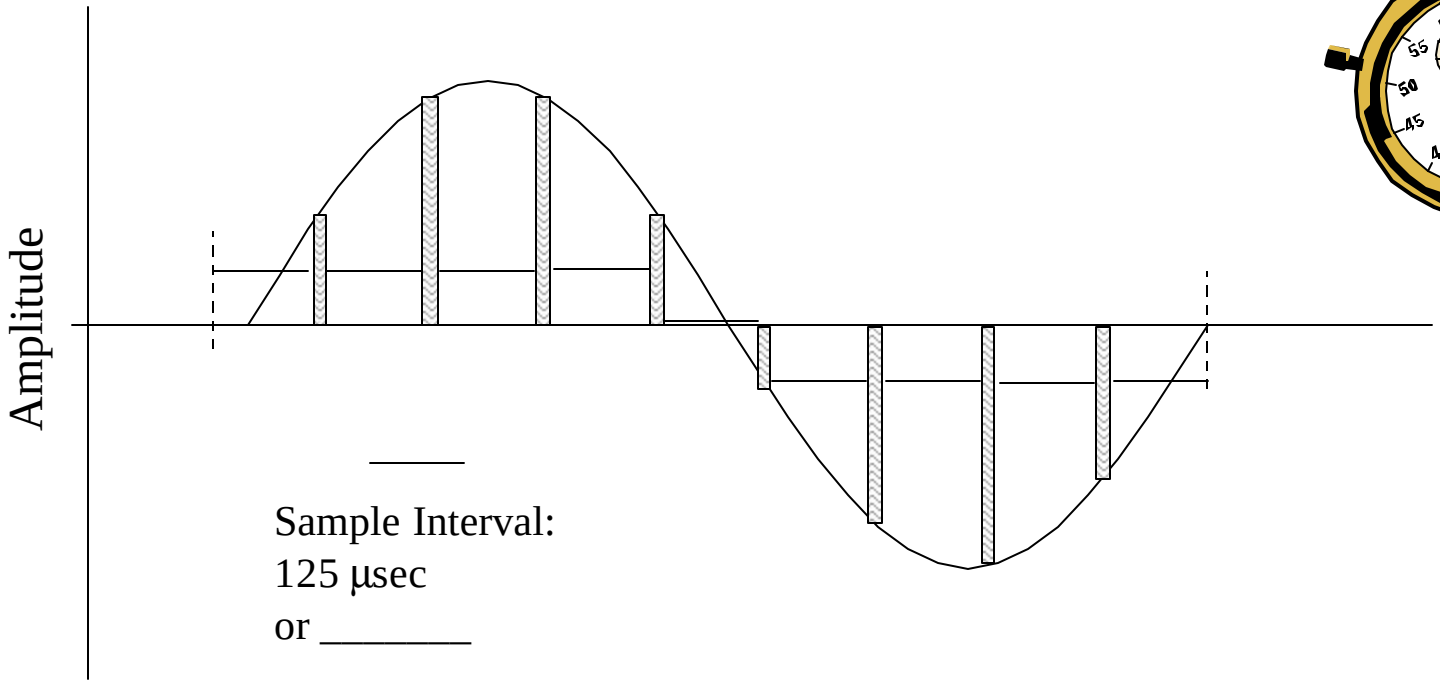
Sampling





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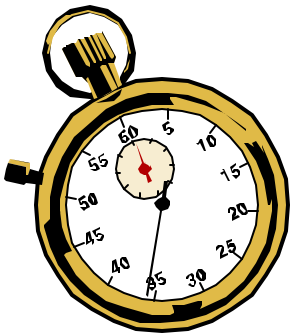
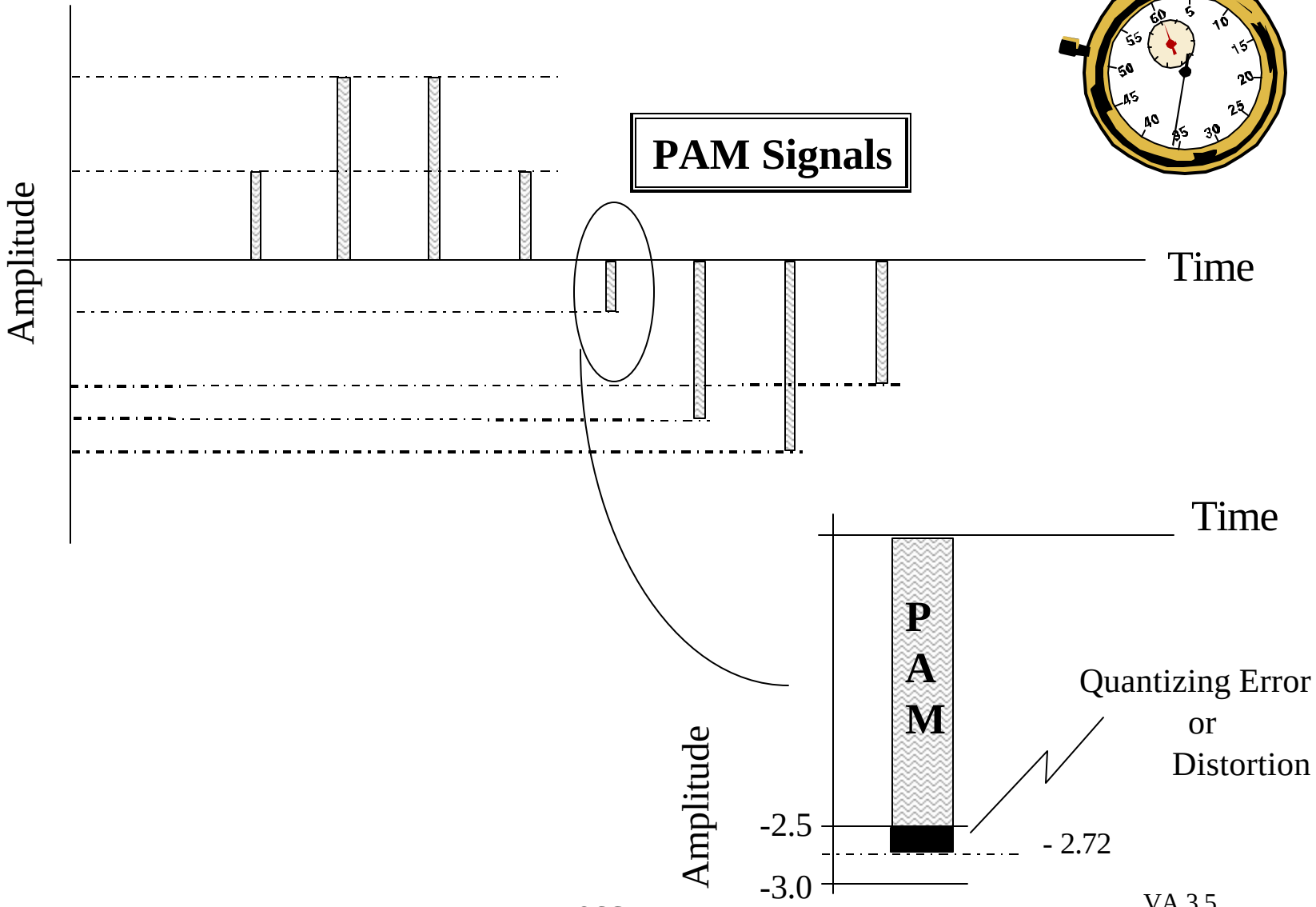
Quantizing the Sample





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Converting a signal whose amplitude varies between - 4.00 mv and 0.00 mv, to a discrete binary number.

Millivolts	Discrete Points	Discrete Intervals	Binary Number for the Intervals
0	1		
-0.5	2	1	111
-1	3	2	110
-1.5	4	3	101
-2	5	4	100
-2.5	6	5	011
-3	7	6	010
-3.5	8	7	001
-4	9	8	000

Assign Discrete Binary Numbers to represent a voltage in an interval.

For the interval -4.00 to -3.50 mv, the binary number is 000.

For the interval -1.50 to -1.00 mv, the binary number is 101.

For 0.50 to 0.00 mv, the binary number is 111

For our value of -2.72 mv, we read the interval from -3.00 to -2.50 mv as 010

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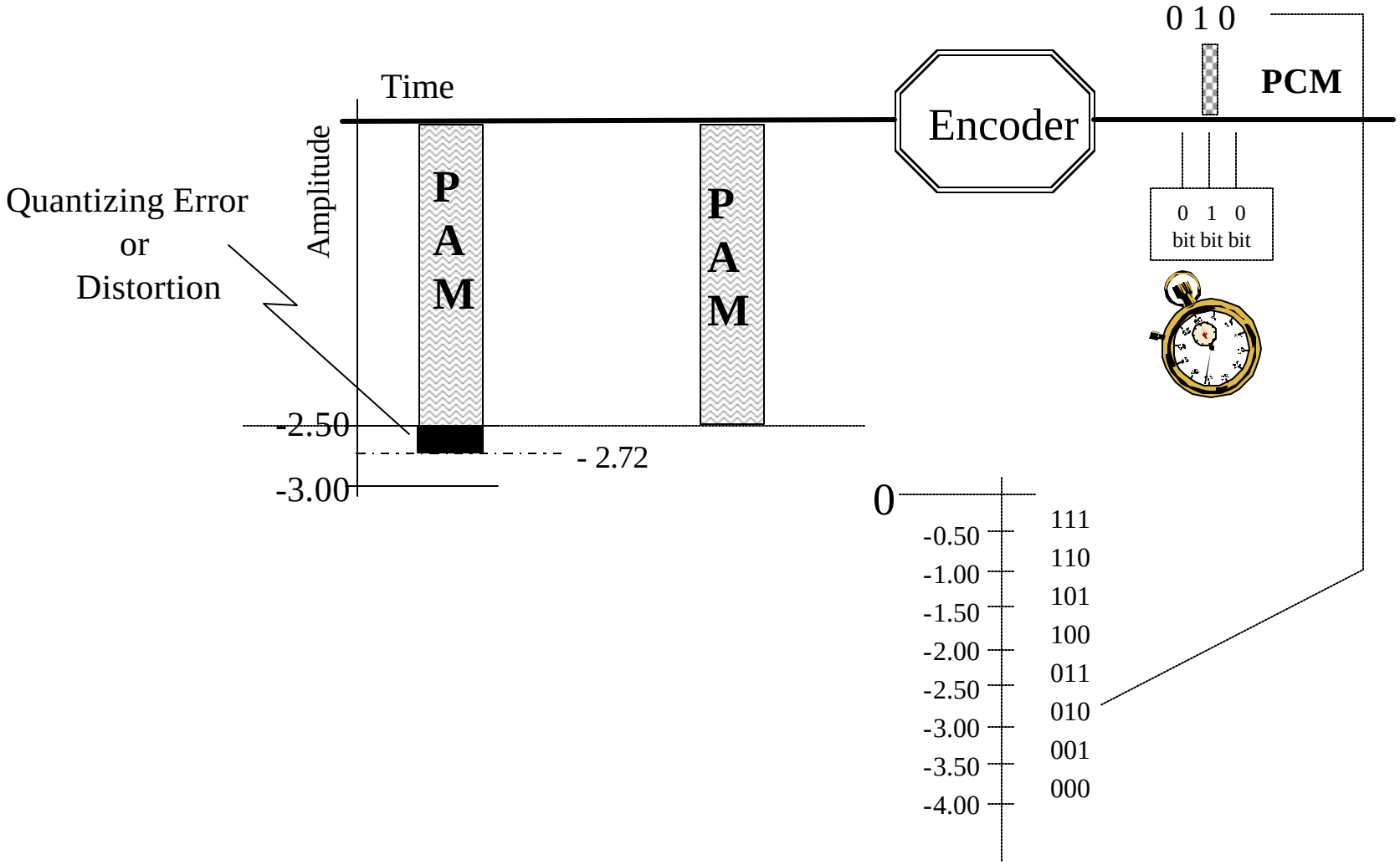
Encoding the PAM Signal



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Powers of 2 or 2^n

Digit Position	1	2	3	4	5	6	7	8
Powers of 2	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
VALUE	128	64	32	16	8	4	2	1

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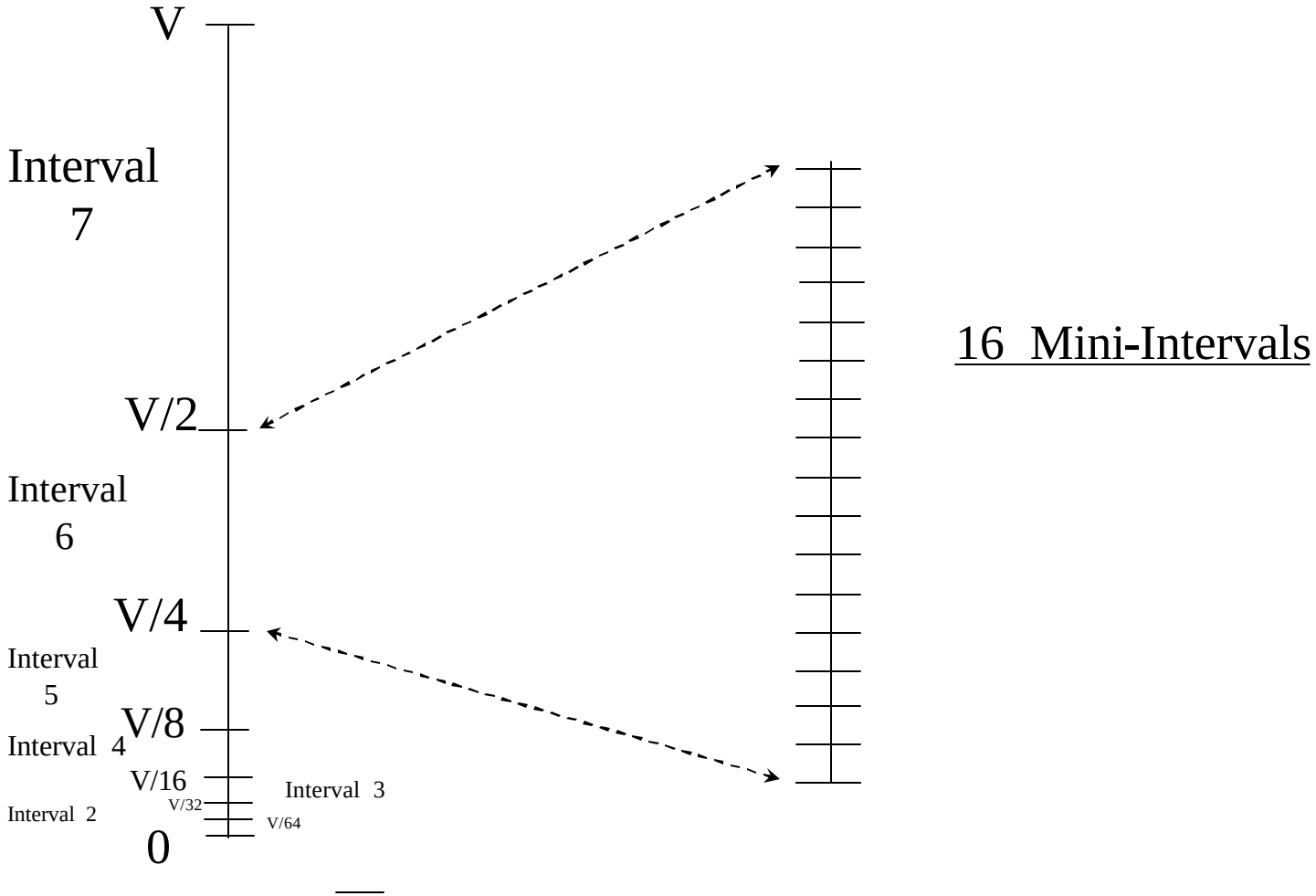
m-Law Encoding
North American Standard



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OTHER TECHNIQUES FOR CONVERTING ANALOG TO DIGITAL

ADPCM - Adaptive Differential Pulse Code Modulation Predicts the shape of voice signals by transmitting the difference between the measured amplitude of the actual pulse and the expected amplitude of the next pulse. Although ADPCM works well for voice and toll grade transmission, this method effectively cuts the data rate that can be sent via a telephony modem by one-half. This is because ADPCM sends only 4 bits of information rather than 8 for each sample.

DSI - Digital Speech Interpolation. Recognizes periods of silence on digital circuits, and does not transmit anything during those periods. This technique does not work well for data transmission, where there is continuous information on the line.

VQL - Variable Quantum Level Coding. Similar to PCM, except that the amplitude of the sample is recorded as a relative value, rather than the actual value. This method is used mostly for data transmission.

LPC - Linear Predictive Coding. A technique that uses compression. It involves creating a model of a voice tract. Typically, LPC is used to find intelligible sound, not necessarily recognizable voice. It has been used in another conversion technique, called vocoding, which is the oldest analog to digital conversion method.

Delta Modulation - A technique that transmits the difference between two successive samples as a 1 or 0. For samples that are higher amplitude than the previous sample, a 1 is transmitted. For lower samples, a 0 is transmitted.

SBC - Sub-Band Coding. SBC splits voice into two or more frequency bands and treats each band separately. This technique is usually combined with another, such as ADPCM.

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Morse Code

A • -	N - •	1 • - - - -
B - • • •	O - - -	2 • • - - -
C - • - •	P • - - •	3 • • • - -
D - • •	Q - - • -	4 • • • • -
E •	R • - •	5 • • • • •
F • • - •	S • • •	6 - • • • •
G - - •	T -	7 - - • • •
H • • • •	U • • -	8 - - - • •
I • •	V • • • -	9 - - - - •
J • - - -	W • - -	0 - - - - -
K - • -	X - • • -	. • - • - • -
L • - • •	Y - • - -	, - - • • - -
M - -	Z - - • •	? • • - - • •

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Baudot Code

Binary	Decimal	Letter	Figure	Binary	Decimal	Letter	Figure
00000	0	Blank	Blank	10000	16	E	3
00001	1	T	5	10001	17	Z	"
00010	2	CR	CR	10010	18	D	$
00011	3	O	9	10011	19	B	?
00100	4	Space	Space	10100	20	S	BEL
00101	5	H		10101	21	Y	6
00110	6	N	,	10110	22	F	!
00111	7	M	.	10111	23	X	/
01000	8	Line Feed	Line Feed	11000	24	A	-
01001	9	L	)	11001	25	W	2
01010	10	R	4	11010	26	J	'
01011	11	G	&	11011	27	Figure Shift	
01100	12	I	8	11100	28	U	7
01101	13	P	0	11101	29	Q	1
01110	14	C	:	11110	30	K	(
01111	15	V	;	11111	31	Letter Shift	

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Binary Coded Decimal Interchange Code
BCDIC

Bits	3	0	0	0	0	1	1	1	1
	2	0	0	1	1	0	0	1	1
	1	0	1	0	1	0	1	0	1
6 5 4									
0 0 0		SP	1	2	3	4	5	6	7
0 0 1		8	9	0	# =	@ '	:	>	√
0 1 0		SP	/	S	T	U	V	W	X
0 1 1		Y	Z	=	'	% (	γ	\	ⁿ
1 0 0		-	J	K	L	M	N	O	P
1 0 1		Q	R	!	$	.	]	;	
1 1 0		& +	A	B	C	D	E	F	G
1 1 1		H	I	?		¤)	[	<	‡

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EBCDIC CODE

	BITS 4321	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
BITS 8765																	
0000		NUL	SOH	STX	ETX	PF	HT	LC	DEL			SMM	VT	FF	CR	SO	SI
0001		DLE	DC1	DC2	TM	RES	NL	BS	IL	CAN	EM	CC	CU1	IFS	IGS	IRS	IUS
0010		DS	SOS	FS		BYP	LF	ETB	ESC			SMM	CU2		ENQ	ACK	BEL
0011				SYN		PN	RS	UC	EOT				CU3	DC4	NAK		SUB
0100		SP											.	<	(	+	
0101		&										!	$	*	)	;	
0110		-	/									|	,	%	_	>	?
0111												:	#	@		=	"
1000			a	b	c	d	e	f	g	h	i						
1001			j	k	l	n	n	o	p	q	r						
1010			~	s	t	u	v	w	x	y	z						
1011																	
1100		{	A	B	C	D	E	F	G	H	I						
1101		}	J	K	L	M	N	O	P	Q	R						
1110		\		S	T	U	V	W	X	Y	Z						
1111		0	1	2	3	4	5	6	7	8	9						

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ASCII CODE

	BITS 4321	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
BITS 765																	
000		NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	HT	LF	VT	FF	CR	SO	SI
001		DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS	RS	US
010		SP	!	"	#	$	%	&		(	)	*	+	,	-	.	/
011		0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
100		@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
101		P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
110			a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
111		p	q	r	s	t	u	v	w	x	y	z	{	|	}	~	DEL

Bit Position
765 4321

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ASCII

Control Character Set

NUL (NULL)	The all zeros character, used for time or media fill.
SYN (Synchronous idle)	Used for character synchronization in synchronous transmissions.
DEL (Delete)	Used to ease in paper tape punching.
SOH (Start of Header)	Use at the beginning of routing information.
STX (Start of Text)	Used at the end of the header or start of text.
ETX (End of Text) EOT (End of Transmission)	Used at end of text or start of trailer. Used at end of transmission, i.e., end of call.
SO (Shift Out)	Code characters that follow are not in the code set of the standard code in use. (Predefined as to which code you shift to.) Typically used to define graphic character extensions.
SI (Shift In)	Code characters that follow are in the code set of the standard code in use. (94 characters in ASCII.
DLE (Data Link Escape)	Used to change the meaning of a limited number of contiguously following characters. Use of DLE for additional controls is described in ANSI specification X3.28
ETB (End Of Transmission Block)	Used to indicate end of a block of data.
CAN (Cancel) EM (End of Medium)	Disregard the data sent with. End of wanted information recorded on a medium.
SS (Start of Special Sequence)	As named.
ESC (Escape)	Provided for an alternate set of control characters or a different code set. This is described in ANSI specification X3.64.
FS, GS, RS, US ENQ (Enquire)	(File, Group, Record, Unit Separators). Used as a request for response; “who are you”
ACK (Acknowledge)	Used as a request for response to a sender.
BEL (Bell) DC1, DC2, DC3, DC4 Nak (Negative Acknowledgement)	(Device Controls) Characters for the control of auxiliary devices; i.e., start, pause, stop. DC1=Xon and DC#=Xoff. Used as a negative response to a sender.

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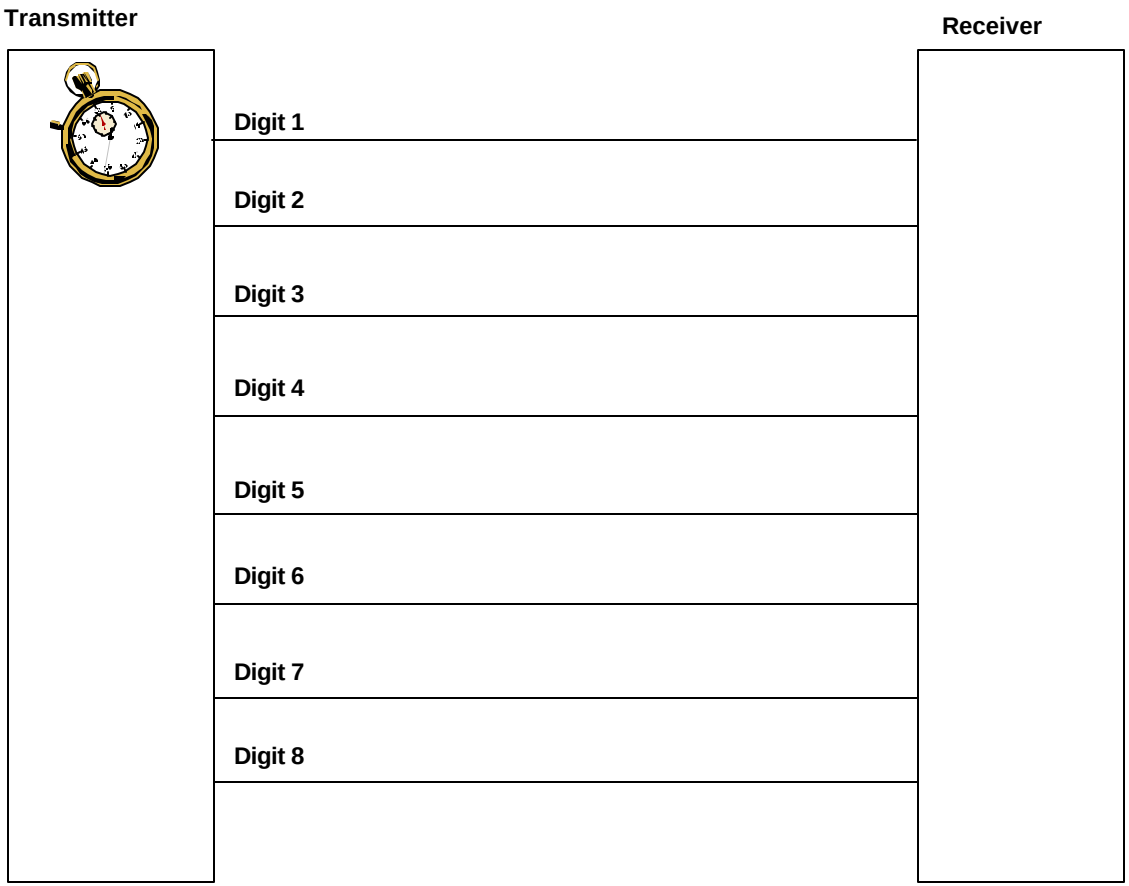
Parallel Transmission



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Asynchronous Transmission

Start Bit **8 Bit Word** **Stop Bit**

10 bits total: 8 bit word plus 2 bits for start and stop
Overhead = 2/10 = 20%

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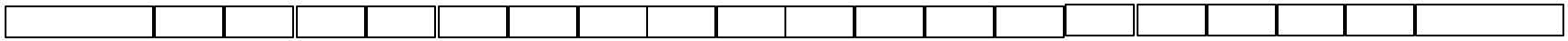
Synchronous Transmission

Bit Oriented



Control Character

Bit Stream within a Frame (May be a Mix of Words, Graphics, and Individual Bits)

Control Character

Byte Oriented

Control Character

Multiple Words Within a Frame

Control Character

Percent Overhead is Variable, based on the Frame Length

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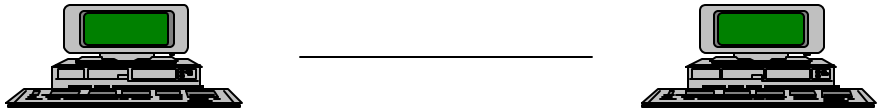
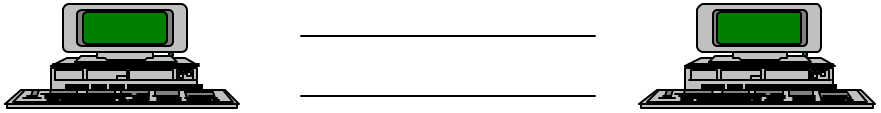
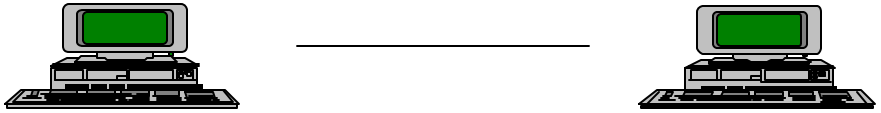
Modes of Transmission



Simplex: Transmission in One Direction Only



Half Duplex: Transmission in Both Directions, but Only One Direction at a Time



Full Duplex: Transmission in Both Directions Simultaneously

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