

Department of Electrical and Computer Engineering
The University of Texas at Austin

EE 306, Fall 2017

Yale Patt, Instructor

Stephen Pruett, Siavash Zangeneh, Aniket Deshmukh, Zachary Susskind, Meiling Tang, Jiahan Liu

Exam 1, October 18, 2017

Name: Solutions

Problem 1 (20 points): _____

Problem 2 (15 points): _____

Problem 3 (20 points): _____

Problem 4 (20 points): _____

Problem 5 (25 points): _____

Total (100 points): _____

Note: Please be sure that your answers to all questions (and all supporting work that is required) are contained in the space provided.

Note: Please be sure your name is recorded on each sheet of the exam.

I will not cheat on this exam.

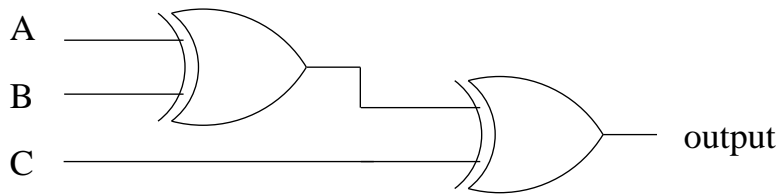
Signature

GOOD LUCK!

Name: Solutions

Problem 1. (20 points):

Part a. (5 points): The following logic circuits consists of two exclusive-OR gates. Construct the output truth table.



A	B	C	output
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

Part b. (5 points): After these two instructions execute:

x3030 0001 000 001 0 00 010

x3031 0000 011 000000111

the next instruction to execute will be the instruction at x3039 if:

R1+R2 is zero or positive

Please be specific, but NOT unnecessarily wordy.

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Part c. (5 points): We wish to know if R0 is being used as the Base Register for computing the address in an LDR instruction. Since the instruction is in memory, we can load it into R4. And, since the Base Register is identified in bits 8:6 of the instruction, we can Load R5 with 0000000111000000, and then execute AND R6,R5,R4. We would know that R0 is the base register if:

The result of AND is 0

Part d. (5 points): Three instructions all construct an address by sign-extending the low 9 bits of the instruction and adding it to the incremented PC.

The Conditional Branch	0000	111	xxxxxxxxxxx
The Load Effective Address	1110	111	xxxxxxxxxxx
The LD Instruction	0010	111	xxxxxxxxxxx

The xxxxxxxxx represents the 9-bit offset that is sign-extended.

Where does the LC-3 microarchitecture put the result of adding the 9-bit sign-extended offset to the incremented PC?

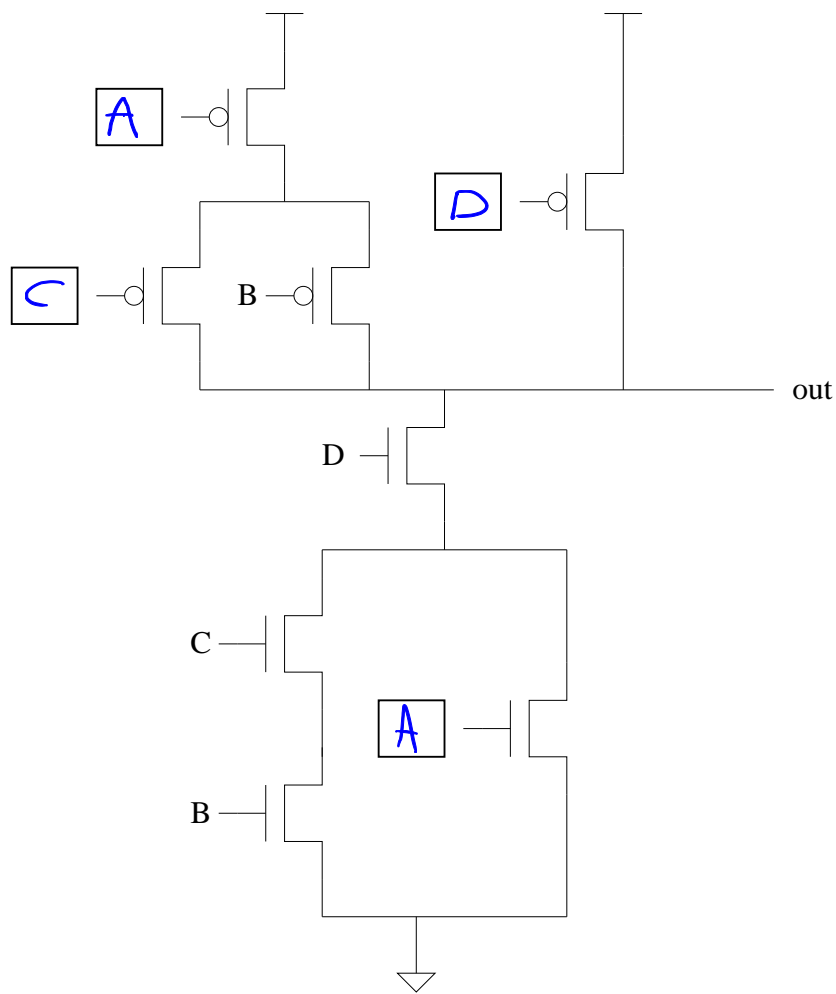
Conditional Branch PC LEA R7 LD MAR

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Problem 2. (15 points):

Shown below is a transistor circuit, having four inputs (A,B,C,D) and one output (out). Also shown is the truth table for this circuit. The gates of some of the transistors are not labeled, and the outputs of some of the input combinations in the truth table are not shown.

Your job: Complete the transistor diagram by labeling the missing inputs to the gates, and by adding the missing outputs to the truth table. Every input combination produces an output of either 0 or 1. The result will be a transistor diagram and the truth table describing its behavior.



A	B	C	D	out
0	0	0	0	1
0	0	0	1	1
0	0	1	0	1
0	0	1	1	1
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	0
1	0	0	0	1
1	0	0	1	0
1	0	1	0	1
1	0	1	1	0
1	1	0	0	1
1	1	0	1	0
1	1	1	0	1
1	1	1	1	0

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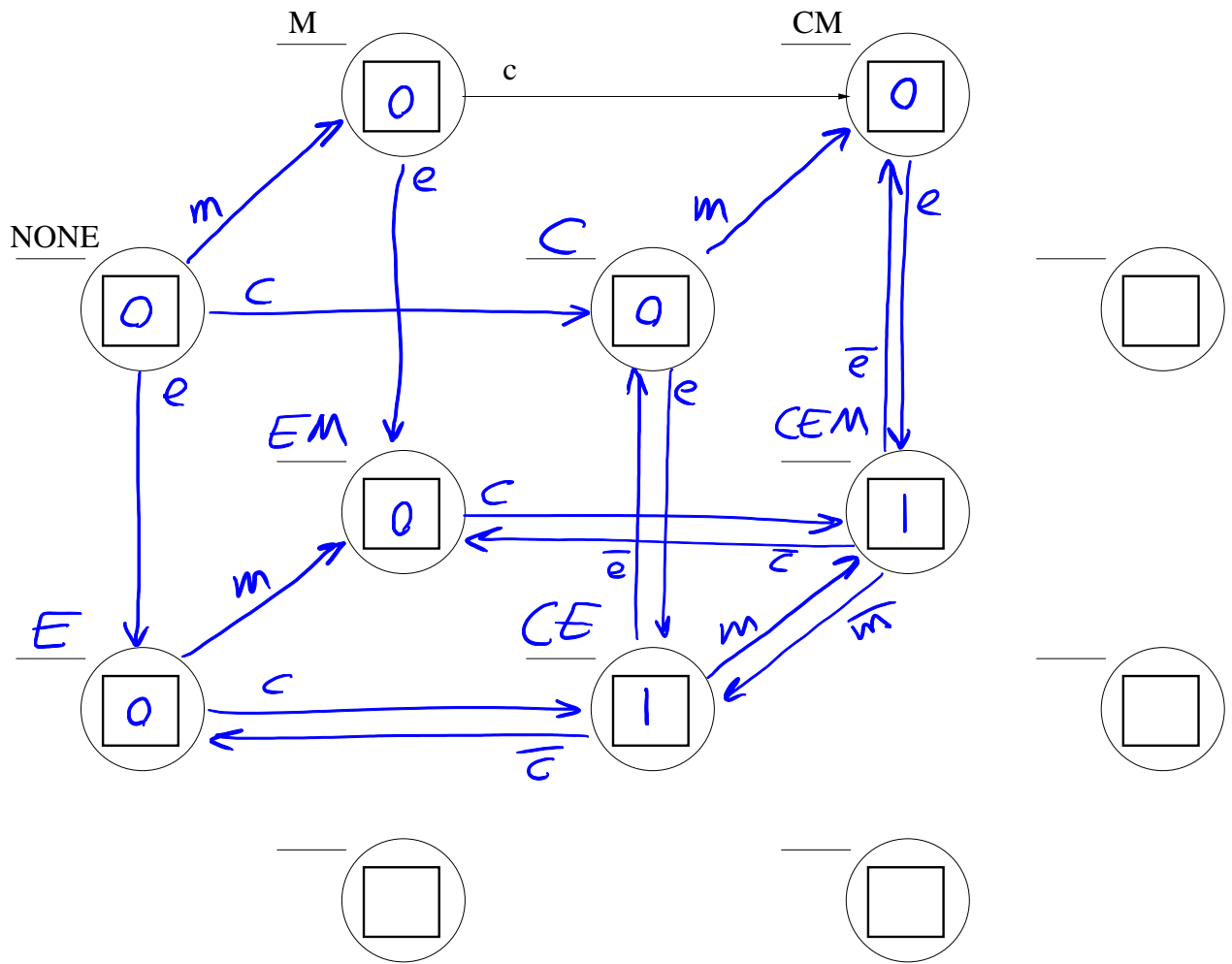
Problem 3. (20 points): You are taking three courses, one each in computing (C), engineering (E), and math (M). In each course, you periodically receive assignments. You never receive more than one assignment at a time. You also never receive another assignment in a course if you currently have an assignment in that course that has not been completed. You must procrastinate (i.e., do nothing) unless you have unfinished assignments in both computing and engineering.

Design a finite state machine to describe the state of the work you have to do and whether you are working or procrastinating.

Part a. (5 points): Label each state with the unfinished assignments (with letters C,E,M) for when you are in that state. There are far more states provided than you actually need. Use only what you need.

Part b. (10 points): There are six inputs: $c, e, m, \bar{c}, \bar{e}, \bar{m}$. c, e, m refer to you receiving an assignment. $\bar{c}, \bar{e}, \bar{m}$ refer to you completing an assignment. Draw the transition arc for each state/input pair. For example, if you had previously only had an unfinished assignment in Math and you received an assignment in computing, you would transition from state M to state CM, as shown below.

Part c. (5 points): The output of each state is your behavior, 1 if you are working on an assignment, 0 if you are procrastinating. Label the outputs of each state.



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Problem 4. (20 points):

A warehouse is controlled by an electronic lock having an n-digit combination. The electronic lock has ten buttons, labeled 0 to 9 on its face. To open the lock, a user presses a sequence of n buttons. The corresponding ASCII characters get loaded into sequential locations of memory, starting at location x3150. After n buttons have been pressed, the null character x00 is loaded into the next sequential memory location.

The program shown below determines whether or not the lock should open, depending on whether the combination entered agrees with the combination stored in the n memory locations starting at x3100. If the lock should open, the program stores a 1 in location x3050. If the lock should not open, the program stores a 0 in location x3050.

Note that some of the instructions are missing.

Part a. (15 points): Complete the program by filling in the missing instructions.

x3000	0101 101 101 1 00000	; R5 ← x0000
x3001	0010 000 000001111	; R0 ← M[x3011]
x3002	0010 001 000001101	; R1 ← M[x3010]
x3003	0110 010 000 000000	; R2 ← M[R0]
x3004	0000 010 00001000	; Branch to x300D if Z is set
x3005	0110 011 001 000000	; R3 ← M[R1]
x3006	1001 011 011 111111	; NOT R3
x3007	0001 011 011 1 00001	; R3 ← R3 + 1
x3008	0001 011 011 000 010	; R3 ← R3 + R2
x3009	0000 101 000000100	; Branch to x300E if N or P is set
x300A	0001 000 000 100001	; R0 ← R0 + 1
x300B	0001 001 001 100001	; R1 ← R1 + 1
x300C	0000 111 111110110	; Branch always to x3003
x300D	0001 101 101 100001	; R5 ← R5 + 1
x300E	0011 101 001000001	; Store R5 in x3050
x300F	1111 0000 0010 0101	; HALT
x3010	0011 0001 0000 0000	; x3100
x3011	0011 0001 0101 0000	; x3150

Part b. (5 points): A simple change to the contents of memory will allow us to eliminate the instructions at memory locations x3006 and x3007 in our program. What is the change?

Store the negatives of target combination in memory locations starting at x3100

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Problem 5. (25 points):

Part a. (15 points): The PC is loaded with x3000, and the instruction at address x3000 is executed. In fact, execution continues and four more instructions are executed. The table below contains the contents of various registers at the end of execution for each of the five (total) instructions.

Your job: complete the table.

	PC	MAR	MDR	IR	R0	R1
Before execution starts	x3000	—	—	—	x0000	x0000
After the first finishes	x3001	x3006	xB333	x2005	xB333	x0000
After the 2nd finishes	x3002	x3001	x0601	x0601	xB333	x0000
After the 3rd finishes	x3003	x3002	x1261	x1261	xB333	x0001
After the 4th finishes	x3004	x3003	x1000	x1000	x6666	x0001
After the 5th finishes	x3001	x3004	x0BFC	x0BFC	x6666	x0001

Part b. (10 points): Let's start execution again, starting with PC = x3000. First, we re-initialize R0 and R1 to 0, and set a breakpoint at x3004. We press RUN eleven times, each time the program executes until the breakpoint. What are the final values of R0 and R1?

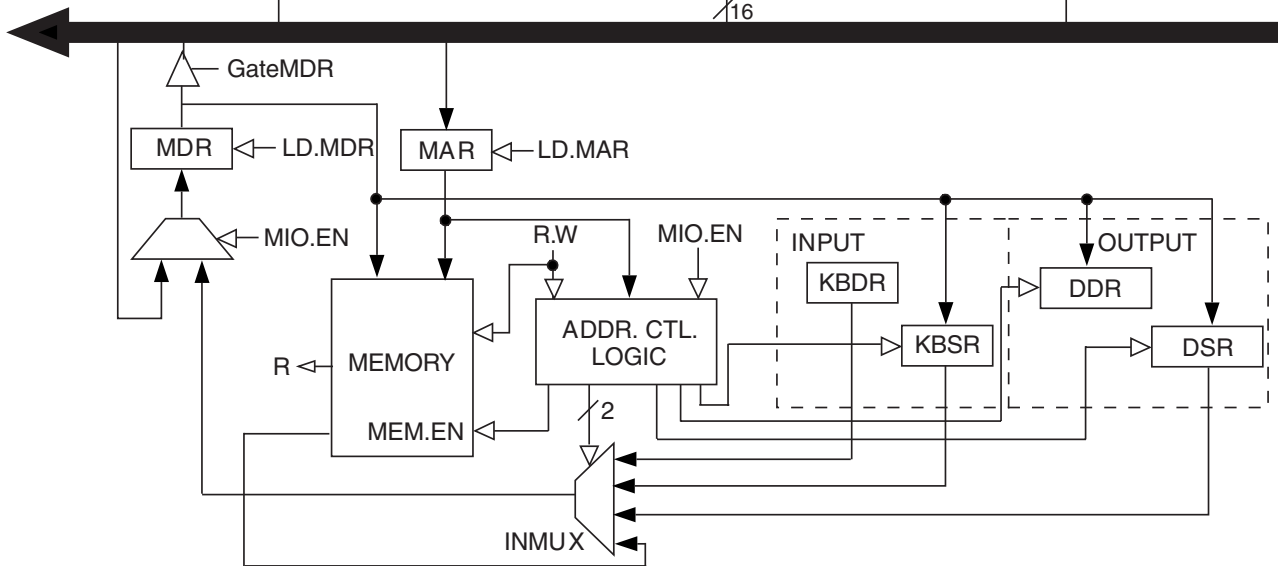
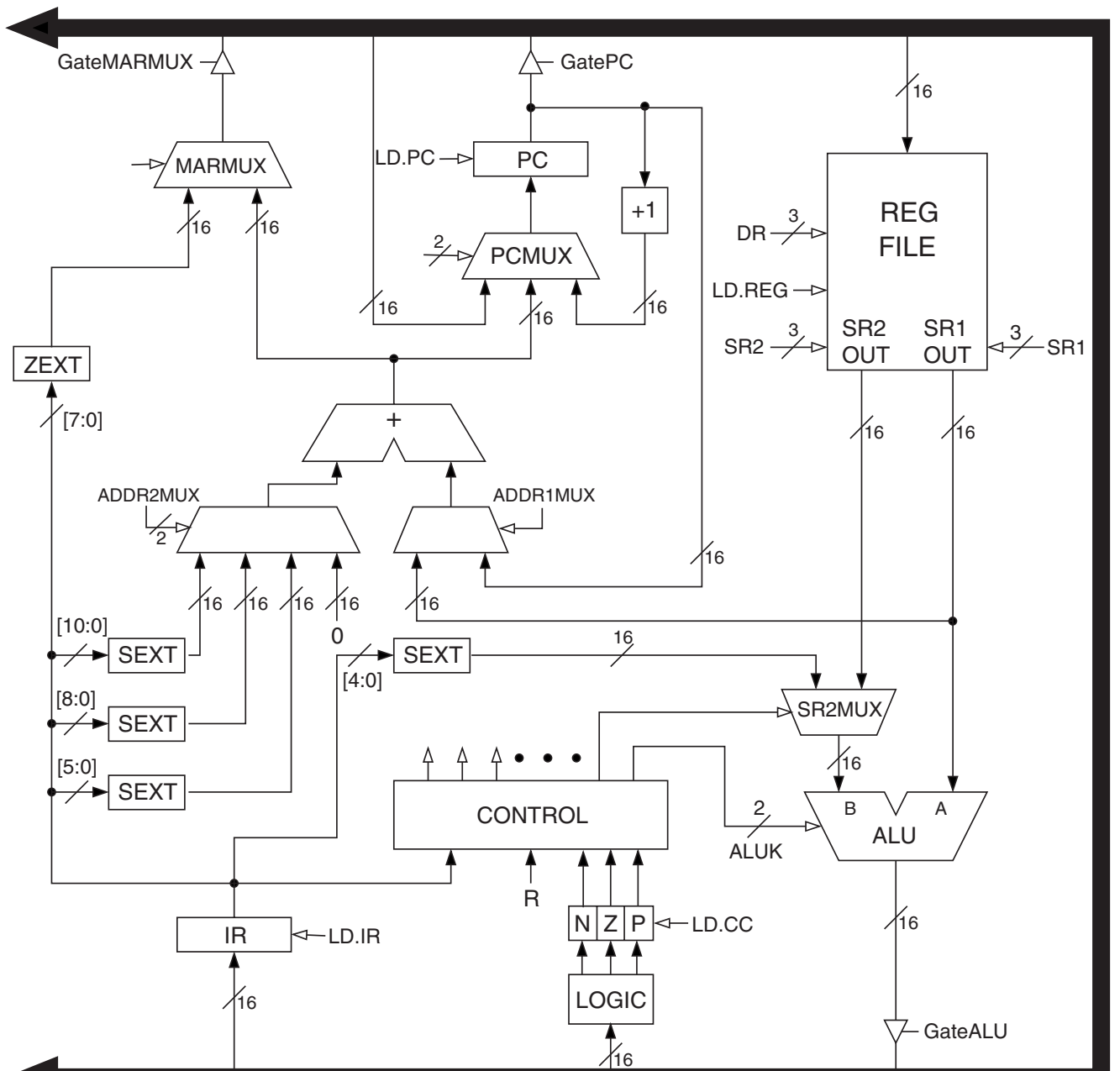
R0 x9800 R1 6

Description of program

- x3000: load Mem[x3006] = xB333 into R0
- x3001: skip next instruction if number is not negative
- x3002: ADD 1 to R1 0001 001 001 100001 x1261
- x3003: left shift R0 by adding it to itself
 0001 000 000 000 000
- x3004: if R0 is not zero, branch back to x3001

Part b) After 11 iterations of executing the loop, R0 is shifted 11 times and R1 contains the number of 1s in the most significant 11 bits,

Initial R0 = 1011 0011 0011 0011 final R0: 1001,1000,0000,0000
gets shifted out
contains six 1s x9800



	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ADD ⁺	0001			DR			SR1			0	00		SR2			
ADD ⁺	0001			DR			SR1			1	imm5					
AND ⁺	0101			DR			SR1			0	00		SR2			
AND ⁺	0101			DR			SR1			1	imm5					
BR	0000			n	z	p	PCoffset9									
JMP	1100			000			BaseR			000000						
JSR	0100			1	PCoffset11											
JSRR	0100			0	00		BaseR			000000						
LD ⁺	0010			DR			PCoffset9									
LDI ⁺	1010			DR			PCoffset9									
LDR ⁺	0110			DR			BaseR			offset6						
LEA	1110			DR			PCoffset9									
NOT ⁺	1001			DR			SR			111111						
RET	1100			000			111			000000						
RTI	1000			000000000000												
ST	0011			SR			PCoffset9									
STI	1011			SR			PCoffset9									
STR	0111			SR			BaseR			offset6						
TRAP	1111			0000			trapvect8									
reserved	1101															

Figure A.2 Format of the entire LC-3 instruction set. Note: + indicates instructions that modify condition codes

Table 2.2 ASCII character set

Oct	Dec	Hex	Char	Oct	Dec	Hex	Char	Oct	Dec	Hex	Char	Oct	Dec	Hex	Char
000	0	00	<i>NUL</i>	040	32	20	<i>SPACE</i>	100	64	40	@	140	96	60	`
001	1	01	<i>SOH</i>	041	33	21	!	101	65	41	A	141	97	61	a
002	2	02	<i>STX</i>	042	34	22	"	102	66	42	B	142	98	62	b
003	3	03	<i>ETX</i>	043	35	23	#	103	67	43	C	143	99	63	c
004	4	04	<i>EOT</i>	044	36	24	\$	104	68	44	D	144	100	64	d
005	5	05	<i>ENQ</i>	045	37	25	%	105	69	45	E	145	101	65	e
006	6	06	<i>ACK</i>	046	38	26	&	106	70	46	F	146	102	66	f
007	7	07	<i>BEL</i>	047	39	27	'	107	71	47	G	147	103	67	g
010	8	08	<i>BS</i>	050	40	28	(	110	72	48	H	150	104	68	h
011	9	09	<i>HT</i>	051	41	29	)	111	73	49	I	151	105	69	i
012	10	0A	<i>LF</i>	052	42	2A	*	112	74	4A	J	152	106	6A	j
013	11	0B	<i>VT</i>	053	43	2B	+	113	75	4B	K	153	107	6B	k
014	12	0C	<i>FF</i>	054	44	2C	,	114	76	4C	L	154	108	6C	l
015	13	0D	<i>CR</i>	055	45	2D	-	115	77	4D	M	155	109	6D	m
016	14	0E	<i>SO</i>	056	46	2E	.	116	78	4E	N	156	110	6E	n
017	15	0F	<i>SI</i>	057	47	2F	/	117	79	4F	O	157	111	6F	o
020	16	10	<i>DLE</i>	060	48	30	0	120	80	50	P	160	112	70	p
021	17	11	<i>DC1</i>	061	49	31	1	121	81	51	Q	161	113	71	q
022	18	12	<i>DC2</i>	062	50	32	2	122	82	52	R	162	114	72	r
023	19	13	<i>DC3</i>	063	51	33	3	123	83	53	S	163	115	73	s
024	20	14	<i>DC4</i>	064	52	34	4	124	84	54	T	164	116	74	t
025	21	15	<i>NAK</i>	065	53	35	5	125	85	55	U	165	117	75	u
026	22	16	<i>SYN</i>	066	54	36	6	126	86	56	V	166	118	76	v
027	23	17	<i>ETB</i>	067	55	37	7	127	87	57	W	167	119	77	w
030	24	18	<i>CAN</i>	070	56	38	8	130	88	58	X	170	120	78	x
031	25	19	<i>EM</i>	071	57	39	9	131	89	59	Y	171	121	79	y
032	26	1A	<i>SUB</i>	072	58	3A	:	132	90	5A	Z	172	122	7A	z
033	27	1B	<i>ESC</i>	073	59	3B	;	133	91	5B	[	173	123	7B	{
034	28	1C	<i>FS</i>	074	60	3C	<	134	92	5C	\	174	124	7C	|
035	29	1D	<i>GS</i>	075	61	3D	=	135	93	5D	]	175	125	7D	}
036	30	1E	<i>RS</i>	076	62	3E	>	136	94	5E	^	176	126	7E	~
037	31	1F	<i>US</i>	077	63	3F	?	137	95	5F	_	177	127	7F	<i>DEL</i>