CS 310 Final Project

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Introduction:

This project is about optimized digital circuit which accepts a 4-bit binary number as input and outputs the corresponding number encoded in the Gray and BCD5421 formats. The circuit has 4 bits (ABCD) representing the binary number input and a 5th selection bit (E) to select whether to output in Gray (E = 1) or BCD5421 (E = 0) encoding. The first four outputs represent the binary number, while the fifth shows if an error occurred or not. The encoder only accepts numbers between 0 and 9, anything beyond that is regarded as an error. For each of the five outputs (QRSTU), the creation of the digital circuit will be explained step by step.

Truth Tables:

Binary					Grey Code				
A	B	C	D	E	Q	R	S	T	U
0	0	0	0	1	0	0	0	0	0
0	0	0	1	1	0	0	0	1	0
0	0	1	0	1	0	0	1	1	0
0	0	1	1	1	0	0	1	0	0
0	1	0	0	1	0	1	1	0	0
0	1	0	1	1	0	1	1	1	0
0	1	1	0	1	0	1	0	1	0
0	1	1	1	1	0	1	0	0	0
1	0	0	0	1	1	1	0	0	0
1	0	0	1	1	1	1	0	1	0
1	0	1	0	1	1	1	1	1	0
1	0	1	1	1	1	1	1	0	0
1	1	0	0	1	1	0	1	0	0
1	1	0	1	1	1	0	1	1	0
1	1	1	0	1	1	0	0	1	0
1	1	1	1	1	1	0	0	0	0

Binary					BCD (5421)				
A	B	C	D	E	Q	R	S	T	U
0	0	0	0	0	0	0	0	0	0

0	0	0	1	0	0	0	0	1	0
0	0	1	0	0	0	0	1	0	0
0	0	1	1	0	0	0	1	1	0
0	1	0	0	0	0	1	0	0	0
0	1	0	1	0	1	0	0	0	0
0	1	1	0	0	1	0	0	1	0
0	1	1	1	0	1	0	1	0	0
1	0	0	0	0	1	0	1	1	0
1	0	0	1	0	1	1	0	0	0
1	0	1	0	0	X	X	X	X	1
1	0	1	1	0	X	X	X	X	1
1	1	0	0	0	X	X	X	X	1
1	1	0	1	0	X	X	X	X	1
1	1	1	0	0	X	X	X	X	1
1	1	1	1	0	X	X	X	X	1

Karnaugh Maps:

Q Karnaugh Map:

AB/CD	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	1	1	1	1
10	1	1	1	1

Grey Code E=1

AB/CD	00	01	11	10
00	0	0	0	0
01	0	1	1	1
11	X	X	X	X
10	1	1	X	X

BCD (5421) E=0

$$Q = BC\overline{E} + BD\overline{E} + A$$

$$Q = B\overline{E}(C + D) + A$$

R Karnaugh Map:

AB/CD	00	01	11	10
00	0	0	0	0
01	1	1	1	1
11	0	0	0	0
10	1	1	1	1

Grey Code E=1

AB/CD	00	01	11	10
00	0	0	0	0
01	1	0	0	0
11	X	X	X	X
10	0	1	X	X

BCD (5421) E=0

$$R = \overline{A}B\overline{C}\overline{D} + A\overline{B}E + \overline{A}BE + A\overline{B}D$$

$$R = \overline{A}B(\overline{C}\overline{D} + E) + A\overline{B}(E + D)$$

S Karnaugh Map:

AB/CD	00	01	11	10
00	0	0	1	1
01	1	1	0	0
11	1	1	0	0
10	0	0	1	1

Grey Code E=1

AB/CD	00	01	11	10
00	0	0	1	1
01	0	0	1	0
11	X	X	X	X
10	1	0	X	X

BCD (5421) E=0

$$S = B\overline{D}\,\overline{E} + CD\overline{E} + B\overline{C}E + \overline{B}C$$

$$S = \overline{E}(B\overline{D} + CD) + B\overline{C}E + \overline{B}C$$

T Karnaugh Map:

AB/CD	00	01	11	10
00	0	1	0	1
01	0	1	0	1
11	0	1	0	1
10	0	1	0	1

Grey Code E=1

AB/CD	00	01	11	10
00	0	1	1	0
01	0	0	0	1
11	X	X	X	X
10	1	0	X	X

BCD (5421) E=0

$$T = \overline{AB}D\overline{E} + A\overline{D}\,\overline{E} + BC\overline{D} + \overline{C}DE + C\overline{D}E$$

$$T = \overline{E}(\overline{AB}D + A\overline{D}) + \overline{D}(BC + CE) + \overline{C}DE$$

U Karnaugh Map:

AB/CD	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	0	0	0	0
10	0	0	0	0

Grey Code E=1

AB/CD	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	1	1	1	1
10	0	0	1	1

BCD (5421) E=0

$$U = AC\overline{E} + AB\overline{E}$$
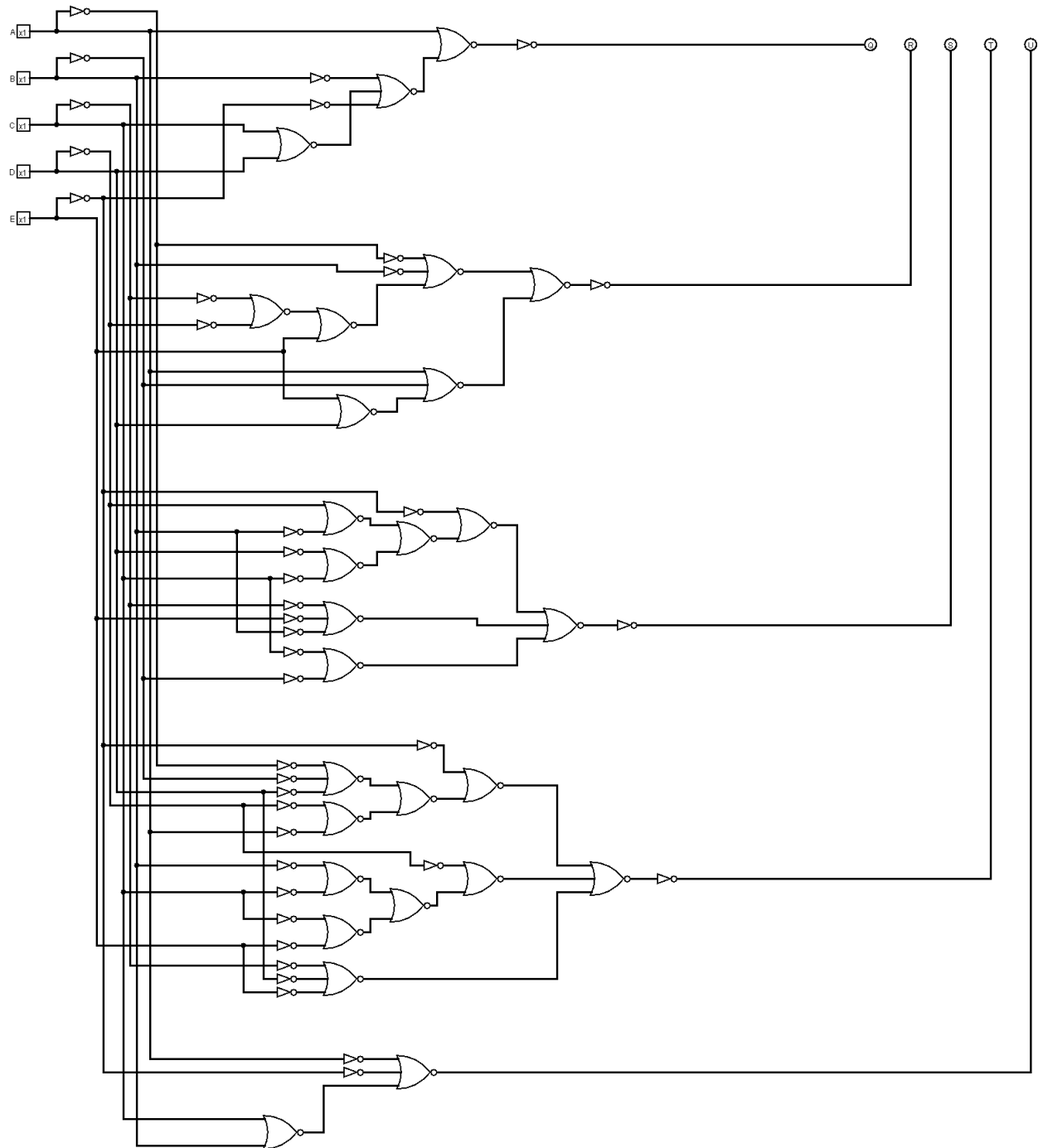
$$U = A\overline{E}(C + B)$$

The Circuit:
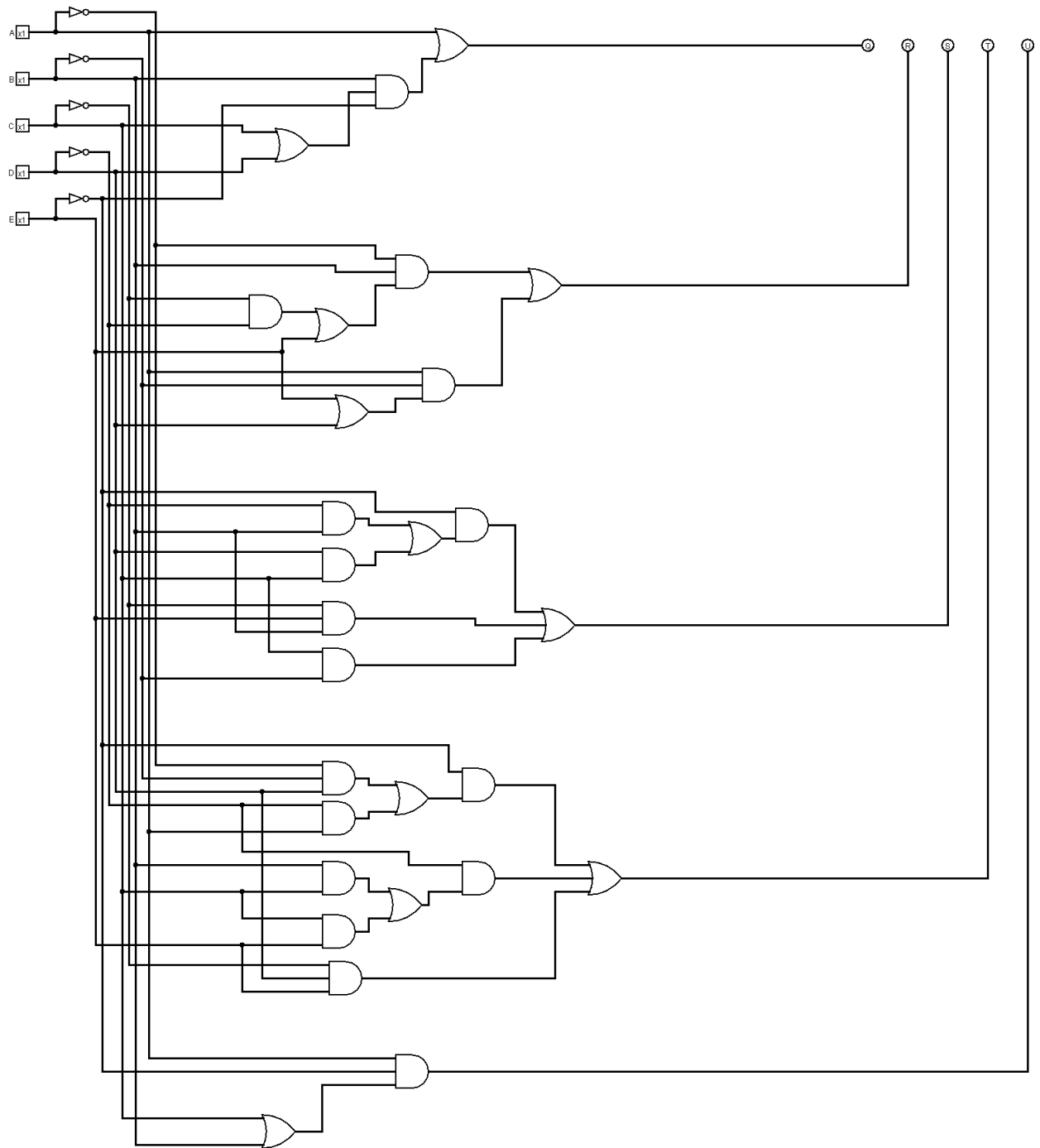
NAND Circuit:
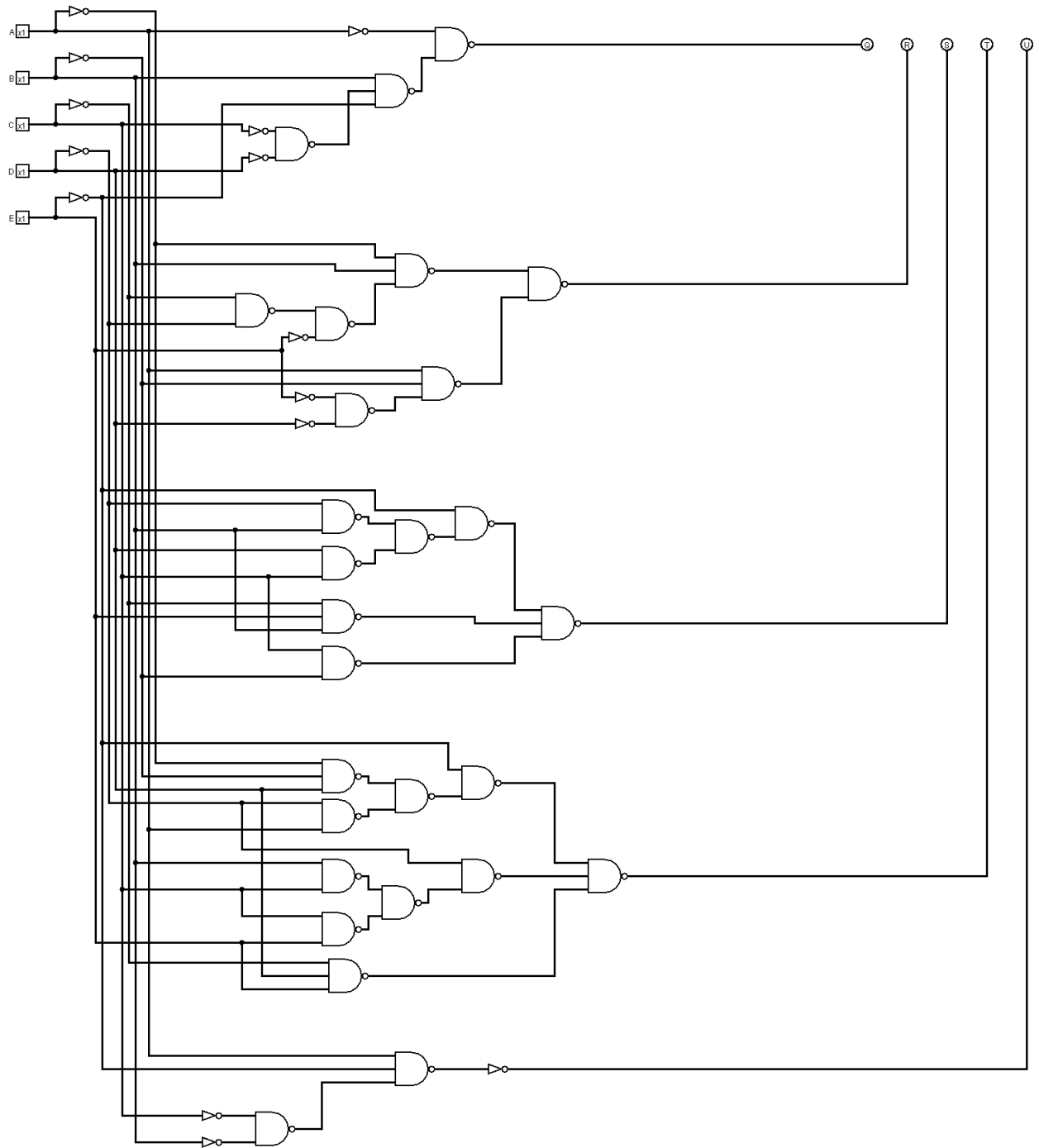
NOR Circuit:

Tinkercad Circuit: