INDIAN INSTITUTE OF TECHNOLOGY BOMBAY
ELECTRICAL ENGINEERING DEPARTMENT

EE-Quiz-2

Wednesday	**MS-101 Maker Space**	Time: 08:30-09:15
Jan. 11, 2023	Autumn Semester 2022-23	Marks: 30

Answer the following in the space provided to the right of the questions.

Q–1 We want to compare two 2-bit wide numbers A (a_1a_0) and B (b_1b_0).

a)

Fill entries in the truth table shown on the right for a function **f** which will be TRUE if and only if $A > B$.

Be very careful with these entries. Errors in this part will lead to wrong results in the remaining parts!

Answer:

a_1	a_0	b_1	b_0	$A > B$
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	1
0	1	0	1	0
0	1	1	0	0
0	1	1	1	0
1	0	0	0	1
1	0	0	1	1
1	0	1	0	0
1	0	1	1	0
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	0

– **[1]**

b)

Express the above function in canonical form as a sum of products.

Answer:

$$\overline{a_1} \cdot a_0 \cdot \overline{b_1} \cdot \overline{b_0} \quad + a_1 \cdot \overline{a_0} \cdot \overline{b_1} \cdot \overline{b_0} \quad +$$
$$a_1 \cdot \overline{a_0} \cdot \overline{b_1} \cdot b_0 \quad + a_1 \cdot a_0 \cdot \overline{b_1} \cdot \overline{b_0} \quad +$$
$$a_1 \cdot a_0 \cdot \overline{b_1} \cdot b_0 \quad + a_1 \cdot a_0 \cdot b_1 \cdot \overline{b_0}$$

– **[1]**

c)

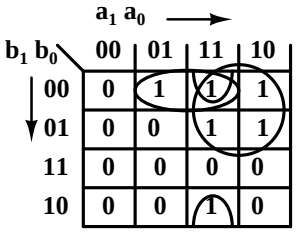
Express the above function in canonical form as a product of sums.

Answer:

$$(a_1 + a_o + b_1 + b_0) \cdot (a_1 + a_0 + b_1 + \overline{b_0}) \cdot$$
$$(a_1 + a_0 + \overline{b1} + b_0) \cdot (a_1 + a_0 + \overline{b_1} + \overline{b_0}) \cdot$$
$$(a_1 + \overline{a_0} + b_1 + \overline{b_0}) \cdot (a_1 + \overline{a_0} + \overline{b_1} + b_0) \cdot$$
$$(a_1 + \overline{a_0} + \overline{b_1} + \overline{b_0}) \cdot (\overline{a_1} + a_0 + \overline{b_1} + b_0) \cdot$$
$$(\overline{a_1} + a_0 + \overline{b_1} + \overline{b_0}) \cdot (\overline{a_1} + \overline{a_0} + \overline{b_1} + \overline{b_0})$$

– **[1]**

d)

Fill entries in the Karnaugh map shown on the right for the above function.	Answer: 
Derive a minimized expression in terms of a_1, a_0, b_1, b_0 for the function **f** using this K map.	$\mathbf{f} = a_1 \cdot \overline{b_1} + a_0 \cdot \overline{b_1} \cdot \overline{b_0} + a_1 \cdot a_0 \cdot \overline{b_0}$

– **[3]**

– **Q1: 1+1+1+3= 6 marks**

Q–2

What is the highest magnitude **positive** number which can be expressed using **signed representation** with **8 bits**?	Answer (decimal number): 127
What is the highest magnitude **negative** number which can be expressed using **signed representation** with **6 bits**?	Answer (decimal number): -32

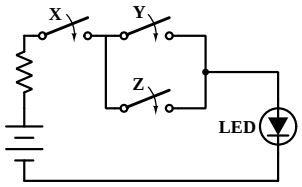
– **Q2: 2 marks**

Q–3 We want to express numbers using base 12 representation. (In base 12 representation, place values are powers of 12, and the twelve symbols used are 0-9, A and B). Express the following decimal numbers using 3 digits of base 12 representation.

i) 100	Answer (in base 12): 084
ii) 256	Answer (in base 12): 194
iii) 1200	Answer (in base 12): 840
iv) 321	Answer (in base 12): 229

– **Q3: $1 \times 4 = 4$ marks**

Q–4 Each switch in the circuit diagram below is closed whenever its controlling variable (X,Y,Z) is TRUE.



We want to replace these 3 switches by a single switch driven by a Boolean function of X, Y and Z.

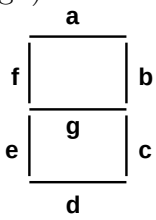
What is the logic function which should control the single switch?

Answer: $X \cdot (Y + Z)$

– **Q4: 2 marks**

Q–5 We want to display a decimal digit using a seven segment display.
Decimal digits are expressed using 4 bits A, B, C and D; with A as the most significant bit. Combinations of ABCD representing 10, 11, 12, 13, 14 and 15 are not used and can be considered as 'don't care'. (Logic functions of ABCD can be taken to be '0' or '1' as convenient for these combinations for reducing the complexity of design).

A seven segment display has segments a to g as shown in the figure on the right. Combinations of these segments light up to display different decimal digits.



a) In the list of digits for which segment a should light up, 0 was left out. For the given list of digits (without 0):

The 'a' segment should light up for digits 2, 3, 5, 6, 7, 8 and 9. Make a Karnaugh map for a function of ABCD which will be TRUE when the 'a' segment should be lit. Mark "don't care" entries as X.

Karnaugh Map:

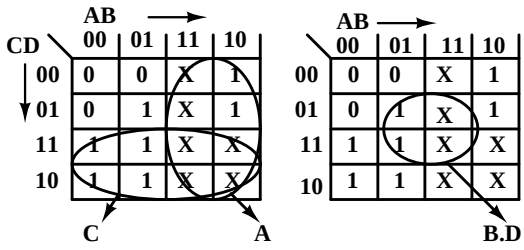
AB→ / CD↓	00	01	11	10
00	0	0	X	1
01	0	1	X	1
11	1	1	X	X
10	1	1	X	X

– **[2]**

b)

Show the maximal groupings of '1's (including X's when convenient) in the Karnaugh map above and derive the minimal logic expression in terms of ABCD for lighting up segment 'a'.

Answer:

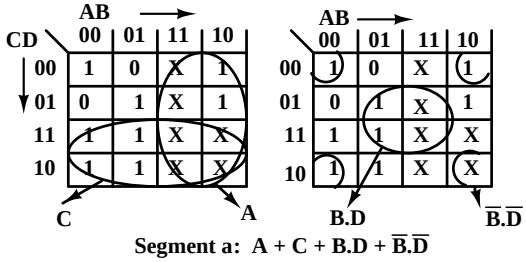


Segment a: A + C + B.D

Alternative solution when digit 0 is included:

The 'a' segment should light up for digits 0, 2, 3, 5, 6, 7, 8 and 9. Make a Karnaugh map for a function of ABCD which will be TRUE when the 'a' segment should be lit. Mark "don't care" entries as X.

Answer:



Segment a: A + C + B.D + $\overline{B}.\overline{D}$

– **[3]**

– Q5: 2+3=5 marks

Q–6 **a)** We want to drive an LED using an Arduino board through digital pin 3 and read a digital value from digital pin 9.

Write the lines of code which should be inserted in the **setup( )** function to configure these pins.	Answer:
	pinMode(3, OUTPUT);
	pinMode(9, INPUT);

– **[1]**

b) The map function is used to map a range of integer values onto another range.

What will be value returned by the map function if we call it as: map(256, 0, 1023, 0, 500)?	Answer: 125

– **[2]**

c) The default reference voltage of 5V is too high for temperature measurement using an LM35, since it provides an analog output of just 10mV per ^{o}C.

We want to use the internal band-gap reference voltage of 1.1V. What function call is required to use this V_{ref}?	Answer: analogReference (INTERNAL);

– **[2]**

d) We read the output voltage from the LM35 using **analogRead**.

What function call should we use to convert the value returned by **analogRead** to ^{o}C, if we are using a reference voltage of 1.1V?	Answer: If the value returned by analogRead is SensorValue, we can call the map function as: temp = map(SensorValue, 0, 1023, 0, 110);

The internal reference voltage is 1.1 V. Thus an ADC count of 1023 corresponds to 1.1 V, which in turn is the expected output from LM35 at 110^{o}C (because the LM35 provides an output of 10mV/ ^{o}C). Thus the map function will interpolate to give the output in ^{o}C. – **[2]**

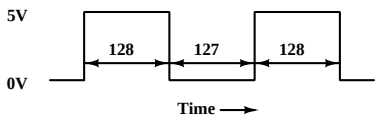
e)

How can we use an externally supplied reference voltage in an Arduino card? What precaution is necessary when using an external V_{ref}?	Answer: The external reference voltage should be connected to the Aref pin on Arduino. We should call the function analogReference to set this external voltage (which should be between 0 and 5V) as the V_{ref}: analogReference(EXTERNAL); Any subsequent analogRead command will then be relative to the externally applied reference voltage. The call to analogReference should be made **before** any analogRead call, otherwise the internal and external references will be shorted.

– **[3]**

– **Q6: 1+2+2+2+3=10 marks**

Q–7

Sketch the approximate waveform produced at pin 9 when you use the function: **analogWrite(9, 128)**	Answer: 

– **Q7: 1 mark**
