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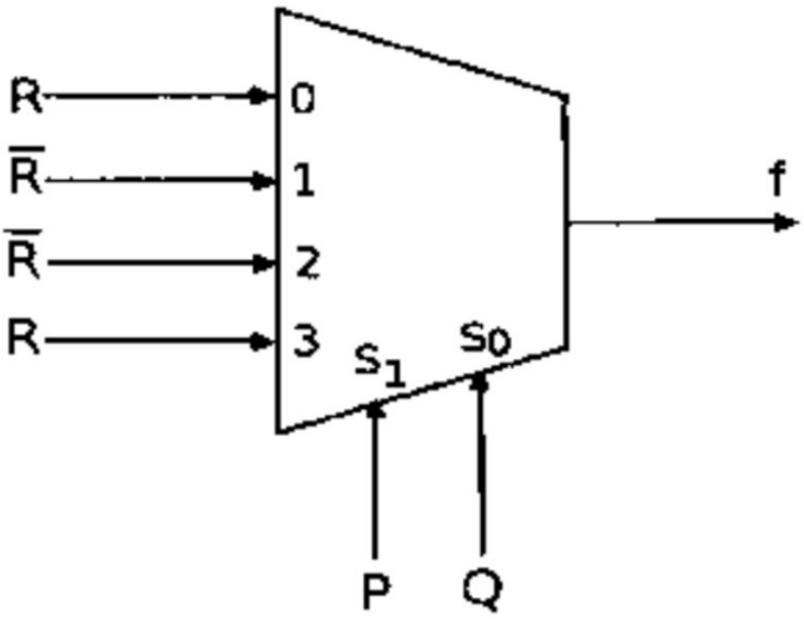
GATE 2010 CS, 9^{th} Question Analysis

Question 9

(GATE 2010 CS, Question 9)
The Boolean expression for the output f of the multiplexer shown below is:



Given:

- Select lines: $S_1 = P$, $S_0 = Q$
- Data inputs: $I_0 = R$, $I_1 = \overline{R}$, $I_2 = \overline{R}$, $I_3 = R$

Required: Find the Boolean expression for f and verify it using hardware.

Question Analysis

- Standard 4:1 MUX output equation:

$$f = I_0\overline{S_1}\,\overline{S_0} + I_1\overline{S_1}S_0 + I_2S_1\overline{S_0} + I_3S_1S_0$$

- Substitute $S_1 = P$, $S_0 = Q$:

$$f = I_0\overline{P}\overline{Q} + I_1\overline{P}Q + I_2P\overline{Q} + I_3PQ$$

- Substitute $I_0 = R$, $I_1 = \overline{R}$, $I_2 = \overline{R}$, $I_3 = R$:

$$f = R\overline{P}\overline{Q} + \overline{R}\,\overline{P}Q + \overline{R}\,P\overline{Q} + RPQ$$

- Simplified result:

$$\boxed{f = P \oplus Q \oplus R}$$

Truth Table

P	Q	R	$f = P \oplus Q \oplus R$
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

Hardware Implementation

The above problem is implemented and tested in hardware using Arduino UNO board. Here we used 7447 and seven segment to display output F is 1 or 0 for input A B C as per truth table and verified the expression.

Required Components & Pin Connections

Components

S.No	Component
1	Arduino UNO Board
2	Breadboard
3	7447 IC (BCD to 7-segment driver)
4	Seven Segment Display (Common Anode)
5	Resistors: 220Ω (for segments)
6	Jumper Wires
7	USB Cable

Arduino → 7447 (BCD Inputs)

7447 Input	7447 Pin	Arduino Pin
A (LSB)	7	D5
B	1	D6
C	2	D7
D (MSB)	6	D8

7447 Power & Control Pins

- 7447 pin 16 (VCC) → +5V
- 7447 pin 8 (GND) → GND
- pin 3 (LT) → +5V
- pin 4 (BI/RBO) → +5V
- pin 5 (RBI) → +5V

7447 → Seven Segment (Common Anode)

- Connect both COM pins of the 7-segment display → +5V
- Connect 7447 outputs to segments **through 220Ω resistors**:

7447 Output	7447 Pin	Segment
a	13	A
b	12	B
c	11	C
d	10	D
e	9	E
f	15	F
g	14	G

Logic Description

- The MUX output is:

$$f = P \oplus Q \oplus R$$

- To show f on 7-segment using 7447, we send BCD:

$$f = 0 \Rightarrow DCBA = 0000 \Rightarrow \text{Display } 0$$

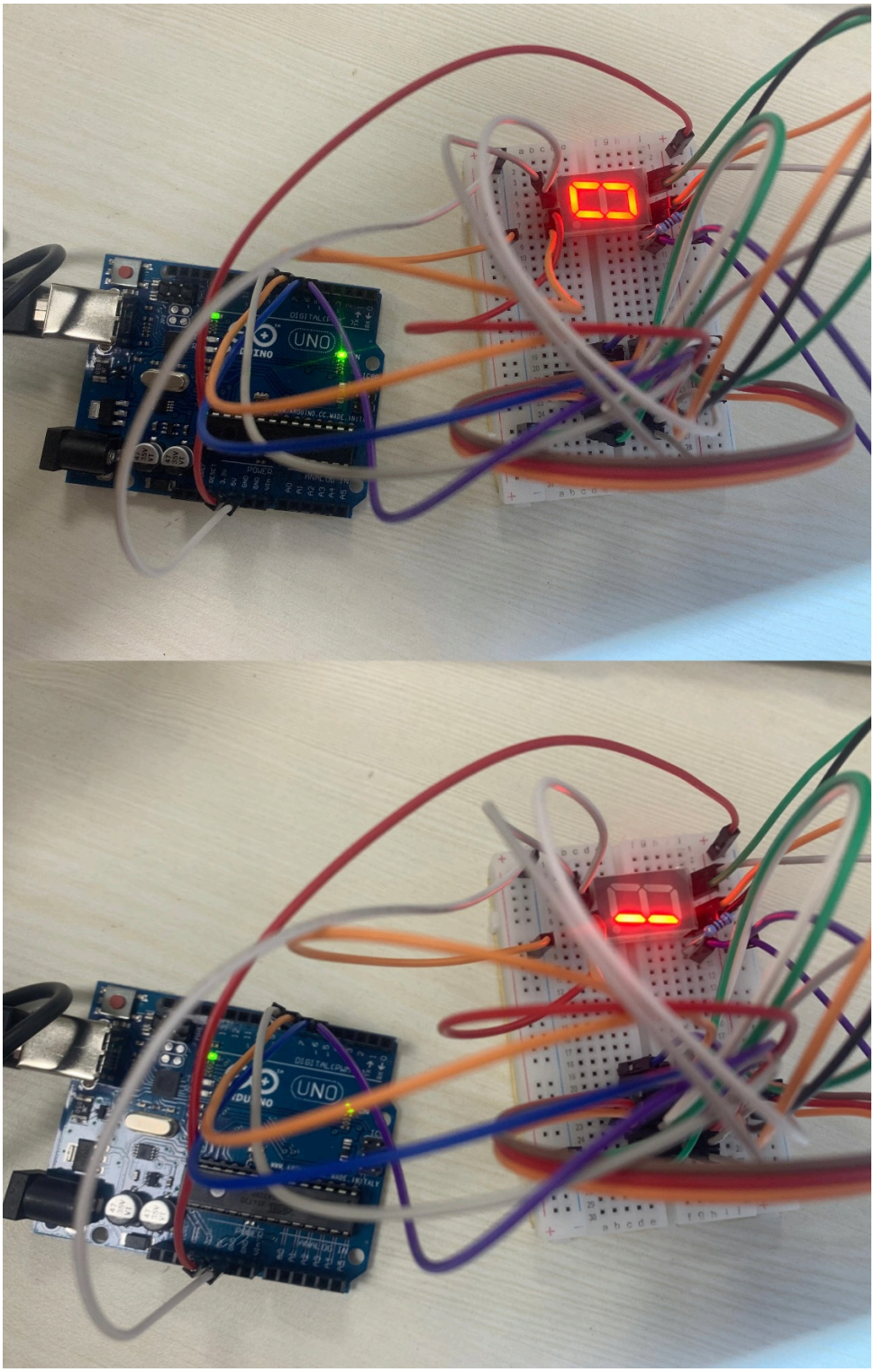
$$f = 1 \Rightarrow DCBA = 0001 \Rightarrow \text{Display } 1$$

Arduino Source Code (Auto Cycling)

Note: This program cycles all PQR combinations from 000 to 111 and displays f.

```
const int A_pin = 5;   // -> 7447 A (pin 7)
const int B_pin = 6;   // -> 7447 B (pin 1)
const int C_pin = 7;   // -> 7447 C (pin 2)
const int D_pin = 8;   // -> 7447 D (pin 6)

void setup() {
  pinMode(A_pin, OUTPUT);
  pinMode(B_pin, OUTPUT);
  pinMode(C_pin, OUTPUT);
  pinMode(D_pin, OUTPUT);
}

void loop() {
  for (int n = 0; n < 8; n++) {
    int P = (n >> 2) & 1;
    int Q = (n >> 1) & 1;
    int R = (n >> 0) & 1;

    int f = P ^ Q ^ R;

    // f=0 -> BCD 0000, f=1 -> BCD 0001
    digitalWrite(A_pin, f);
    digitalWrite(B_pin, LOW);
    digitalWrite(C_pin, LOW);
    digitalWrite(D_pin, LOW);

    delay(1000);
  }
}
```

Setup / Output Image



Experimental Truth Table

P	Q	R	Observed f (7-seg)
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

Conclusion

From the truth table and hardware verification, the multiplexer output is confirmed as:

$$\boxed{f = P \oplus Q \oplus R}$$

Hence the correct option is the XOR of all three inputs.