1) (8 Points)
Consider the op-amp circuit shown in Figure 1. (Assume the op-amp to be ideal)
   a) What is $V_{Out}$ as a function of $V_A$, $R_1$ and $R_2$ if $V_B = 0$ V?
   b) What is $V_{Out}$ as a function of $V_B$, $R_1$ and $R_2$ if $V_A = 0$ V?
   c) Find the differential gain of the circuit, $V_{out} / (V_A - V_B)$, as a function of $R_1$ and $R_2$.

2) (9 Points)
A Majority Voting Circuit produces a HI if two or more of its inputs A, B or C are HI, otherwise its output is LO. (See Figure 2.)
   a) Give the truth table for the Majority Voting Circuit.
   b) Using standard combinational logic express Q as a function of the inputs. Simplify your expression as much as you can.
   c) Using a circuit diagram implement the Majority Voting circuit using standard two input gates (standard gates include AND, NAND, OR, NOR, NOT or XOR gates.)
3) (8 Points)  
The circuit in Figure 3 is a variant of a synchronous counter circuit. Unlike your typical counter that starts at 0 and then counts up or down, this counter, if properly seeded, continuously repeats a number sequence that should look familiar to you. In this problem we will find this sequence. Note: $Q_2$ is the most significant bit (MSB) and $Q_0$ is the least significant bit, i.e., the LSB.

![Diagram of the circuit](image)

Figure 3

a) Determine the (decimal=base 10) values of the sequence if the counter starts with the numerical value 4, i.e., $Q_2 = 1$, $Q_1 = 0$, $Q_0 = 0$. To confirm your answer, you must provide a timing diagram showing at least 5 clock periods.

b) Determine what happens if the counter is seeded with any value that is not part of its sequence, for example, 7? (Note: you only need to determine the result for one such value; the result is identical for all other values that are not part of the counting sequence.)
Solution Quiz 2
Phys 4051 Fall 05

1) a) if \( V_B = 0 \) what becomes:

\[
V_{A} = 0 - \frac{V_{out}}{R_2}
\]

\[i_1 = i_2\]

\[V_{A} = 0 - \frac{V_{out}}{R_2}\]

\[V_{out} = -R_2 \frac{V_{A}}{R_1}\]

1b) if \( V_A = 0 \)

\[
V_{+} = \frac{V_{B} R_2}{R_1 + R_2} \approx V_{-}
\]

\[i_1 = i_2\]

\[i_2 = 0 - \frac{V_{+} - V_{out}}{R_1} = \frac{V_{out} (R_1 + R_2)}{R_1} V_{+}\]

\[V_{out} = (\frac{R_1 + R_2}{R_1}) \frac{R_2}{R_1 + R} V_B = \frac{R_2}{R_1} V_B\]

2) By superposition principle

2a) Truth table

<table>
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<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Q</th>
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<tr>
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</table>

2b) \( Q = \overline{ABC} + \overline{A}BC + ABC + \overline{AB}C \)

simplify:

\[ Q = \overline{A}B(C + C) + AC(\overline{B} + B) + BC(\overline{A} + A) \]

\[ Q = AB + AC + BC \]

2c) Circuit diagram

\[
V_{out} = V_{out} (\frac{V_A - V_B}{R_1})
\]

\[
V_{out} = \frac{R_2}{R_1} V_B
\]
3a) Find logic relationships:

\[ D_0 = \overline{Q_1} \cdot Q_0 + Q_2 = Q_0 \oplus Q_2 \text{ (since } \overline{Q_1} = 1) \]

\[ D_1 = 0 \Rightarrow Q_1 = 0 \text{ always!} \]

\[ D_2 = Q_1 + Q_2 \text{ (since } Q_1 = 0 \text{ always } D_2 = \overline{Q_2}) \]

initial state: \( Q_0 = Q_1 = 0 \quad Q_2 = 1 \)

<table>
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<tr>
<th>Clock Cycle</th>
<th>( Q_2 )</th>
<th>( Q_1 )</th>
<th>( Q_0 )</th>
<th>( D_2 )</th>
<th>( D_1 )</th>
<th>( D_0 )</th>
<th>Dec. Value</th>
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<td>4</td>
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</tbody>
</table>

sequence is 4, 0, 5, 1, 4, ...

3b) Assume at \( t=0 \) \( Q_2 = Q_1 = Q_0 = 1 \)

using \( D_0 = \overline{Q_1} \cdot Q_0 + Q_2 \cdot \overline{Q_1} \)

\[ D_1 = Q_0 \]

\[ D_2 = Q_1 + Q_2 \text{ we get} \]

cycle over 7 \( \Rightarrow 0 \Rightarrow 5 \Rightarrow 1 \Rightarrow 4 \)
so after 7 jumps to 0 which is part of the sequence and it repeats cyclic 0, 5, 1, 4...