1.) (5 points) Trace the behavior of an 8-bit parallel load register with input \( I \), output \( Q \), and load control input \( ld \) by completing the following timing diagram.

\[ \begin{array}{cccccccc}
I & 5 & 1 & 12 & 65 & 92 & 0 & 0 & 21 \\
ld & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} \\
clk & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} \\
Q & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm}
\end{array} \]

2.) (5 points) Design an 8-bit register with 2 control inputs \( s_1 \) and \( s_0 \), 8 data inputs \( I_{7..0} \), and 8 data outputs \( Q_{7..0} \). \( s_1s_0=00 \) means maintain the present value, \( s_1s_0=01 \) means load, and \( s_1s_0=10 \) means clear. \( s_1s_0=11 \) means to swap the high nibble with the low nibble (a nibble is 4 bits), so 11110000 would become 00001111, and 11000101 would become 01011100.

3.) (5 points) Assuming all gates have a delay of 1, compute the time required to add two numbers using an 8-bit carry-ripple adder.

4.) (5 points) Design a digital thermometer that can compensate for errors in the temperature sensing device’s output \( T \), which is an 8-bit input to our system. The compensation amount can be positive only, and comes to our system via inputs \( a \), \( b \) and \( c \), from a 3-pin DIP switch. Our system should output the compensated temperature on an 8-bit output \( U \).

5.) (5 points) Design a circuit that outputs the average of four 8-bit inputs

6.) (5 points) Trace through the execution of the barrel shifter shown below, when \( I=01100101 \), \( x = 1 \), \( y = 0 \), \( z = 1 \). Be sure to show how the input \( I \) is shifted at each stage.

\[ \begin{array}{cccc}
x & \text{sh} & \ll 4 & \text{in} & 0 \\
y & \text{sh} & \ll 2 & \text{in} & 0 \\
z & \text{sh} & \ll 1 & \text{in} & 0 \\
Q & \hspace{1cm} & \hspace{1cm} & \hspace{1cm} & \hspace{1cm}
\end{array} \]

7.) (5 points) Using the barrel shifter shown above, what settings of the inputs \( x \), \( y \), and \( z \) are required to shift the input \( I \) six positions.
8.) (5 points) Design a 5-bit magnitude comparator.

9.) (10 points) Design a circuit that outputs 1 if the circuit’s 8-bit input equals 99: (a) using an equality comparator, (b) using gates only. *Hint:* In this case, you need only 1 AND gate and some inverters.

10.) (10 points) Design a 4-bit up/down-counter that has four control inputs: \( \text{cnt\_up} \) enables counting up, \( \text{cnt\_down} \) enables counting down, \( \text{clear} \) synchronously resets the counter to all 0s, and \( \text{set} \) synchronously sets the counter to all 1s. If both count control inputs \( \text{cnt\_up} \) and \( \text{cnt\_down} \) are 1, the counter will retain its current count value.

11.) (10 points) Design an 8-bit multiplier.

12.) (5 points) Convert the following two’s complement binary numbers to decimal numbers:
   a. 00001111
   b. 10000000
   c. 10000001
   d. 11111111
   e. 10010101

13.) (5 points) Convert the following decimal numbers to 8-bit two’s complement binary form:
   a. 6
   b. 26
   c. -8
   d. -30
   e. -60
   f. -90
   g. -120

14.) (10 points) Design an ALU with two 8-bit inputs A and B, and control signals x, y, and z. The ALU should support the operations described in the following table. Use an 8-bit adder an arithmetic/logic extender.

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>y</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
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<tr>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>1</td>
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15.) (10 points) Design an 8x32 two port (1 read, 1 write) register file.