Student ID: ______________

CS 151
Midterm

Name: ___________________________ (Last Name) ___________________________ (First Name)

Student ID: ______________
Signature: ______________

Instructions:

1. Please verify that your paper contains 11 pages including this cover.
2. Write down your Student-Id on the top of each page of this quiz.
3. This exam is closed book. No notes or other materials are permitted.
4. Total credits of this midterm are 50 points.
5. To receive credit you must show your work clearly.
6. No re-grades will be entertained if you use a pencil.
7. Calculators are NOT allowed.

CS 151 Digital Logic Design, Fall Quarter 2006, Midterm
Page 1
Q1: Memory hierarchy [10 points]

Design a 64K*32-bit RAM using 16K*16-bit RAM modules shown below.

16K*16-bit RAM Module

Use a minimum number of the following logic components in your design (no other components may be used for this design):

1) Priority Encoder
2) Decoder
3) Multiplexer
Address bus width for $64k \times 32$ bit RAM = $\log_2 64k = 16$ bits

Data bus width for $64k \times 32$ bit RAM = 32 bits

Address bus width for $16k \times 16$ bit RAM = $\log_2 16k = 14$ bits

Data bus width for $16k \times 16$ bit RAM = 16 bits
Q2: Design of a Traffic Light Controller [40 points]

Consider the intersection of Campus and California shown below and consider only the two Traffic Lights (TL) on Campus and California as shown below. Furthermore, assume that traffic on Campus and California are one-way.

Design a digital system that controls the two traffic lights at this intersection with the goal of minimizing congestion by balancing the traffic load. The basic idea is to give more time for cars passing through the road with a higher traffic load.

To determine the traffic load, assume that a sensor on each road registers a pulse when it senses a car passing through that intersection. Assume further that cars pass the intersection ONLY when the traffic light is green, and we count the number of the cars that pass through the intersection.

![Diagram of Campus-California Intersection]

We estimate the traffic load on each road using the rate at which cars pass through intersection. That is, Rate(TL) = The number of cars passing through the intersection (while the traffic light is green) divided by number of cycles for that period.

Based on the comparative traffic loads, the TLs are in one of the following modes:

a) Campus High Mode, where Rate(TL_{Campus}) >= 2*Rate(TL_{California}):
TL_{Campus} is Green for 64 cycles, followed by Yellow for 8 cycles and Red for 40 cycles; concurrently, TL_{California} is Red for 72 cycles, Yellow for 8 cycles and Green for 32 cycles.

b) California High Mode, where Rate(TL_{California}) >= 2*Rate(TL_{Campus}):
TL_{California} is Green for 64 cycles, followed by Yellow for 8 cycles and Red for 40 cycles; concurrently, TL_{Campus} is Red for 72 cycles, Yellow for 8 cycles and Green for 32 cycles.

c) Comparable Load Mode, where we assume that the rates are comparable:
TL_{California} and TL_{Campus} are Green for 32 cycles, Yellow for 8 cycles and Red for 40 cycles. (Obviously when TL_{Campus} is green or yellow, TL_{California} is red and vice versa.)
Assume the initial condition:
$TL_{Campus} = \text{Green, } TL_{California} = \text{Red and } Rate(TL_{California}) = Rate(TL_{Campus})$. (We are in Comparable Load Mode)

i. **Draw a template of the FSM and datapath. (5 points)**
   (Hint: You just need to show the external inputs and outputs of the system to the controller and datapath shown below. You will design the interface between the datapath and the controller later in this question)
ii. Design the High-Level State Machine for this traffic light system. (10 points)
(Hint: In your state machine you have 3 different modes and each state in each mode
in your state machine shows the status of your traffic lights)
(If necessary, clearly state any reasonable assumptions you might make for this part.)
iii. **Draw the state action table for this controller. (5 points)**
   (A table indicating in each state what actions should be taken.)

<table>
<thead>
<tr>
<th>State</th>
<th>RedCampus</th>
<th>YerCampus</th>
<th>CCampus</th>
<th>Ranif.</th>
<th>Y Calif.</th>
<th>G Calif.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparable LM</td>
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<td>0</td>
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<td>0</td>
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<tr>
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<tr>
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<td>0</td>
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<td>1</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Campus HM</td>
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<td>Campus HM</td>
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<tr>
<td>California HM</td>
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<td>1</td>
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<td>init</td>
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<td>1</td>
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</tr>
</tbody>
</table>
iv. Design the datapath using components. (10 points)
Use the following block to get the rate on each road. This block gives Rate(TL) = number of cars passed/number of clock cycles while Enable=1.
(Hint: You should first store Rate(TL) and then use it.)
v. Controller interface: draw the signals between Controller and the Datapath. (5 points)
vi. **Annotate the state diagram with control signals for each state. (5 points)**
(You need not design the FSM controller using Flip Flops and Logic; simply indicate which control signals should be activated in each state for correct operation of the design.)

```
init
G-Cnt-clr=1
Y-Cnt-clr=1

Comparable LM
Green campus=1
Red campus=1
G-Cnt-en=1
Y-Cnt-en=1
G-time-sel=0
Y-Cnt-clr=1

Comparable LM
Yellow campus=1
Red california=1
G-Cnt-clr=1
Y-Cnt-clr=1

Comparable LM
Green Calif.=1
Red campus=1
G-Cnt-en=1
Y-Cnt-en=1
G-time-sel=0
Y-Cnt-clr=1

Comparable LM
G-Campus
Green Campus=1
Red Calif.=1
G-Cnt-en=1
Y-Cnt-en=1
G-time-sel=1
Y-Cnt-clr=1

Comparable LM
Y-Campus
Green campus=1
Red Calif.=1
G-Cnt-clr=1
Y-Cnt-clr=1

Comparable LM
G-Calif.
Green Calif.=1
Red Calif.=1
G-Cnt-en=1
Y-Cnt-en=1
G-time-sel=0
Y-Cnt-clr=1

Comparable LM
Diego Calif.
Green Calif.=1
Red Calif.=1
G-Cnt-en=1
Y-Cnt-en=1
G-time-sel=0
Y-Cnt-clr=1
```

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\begin{itemize}
\item California HM
  \begin{itemize}
  \item Green campus = 1
  \item Red Calif = 1
  \item G-Cnt-en = 1
  \item G-time-sel = 0
  \item Y-Cnt-chr = 1
  \end{itemize}
\item California YHM
  \begin{itemize}
  \item Yellow campus = 1
  \item Red Calif = 1
  \item Y-Cnt-en = 1
  \item G-Cnt-chr = 1
  \end{itemize}
\item California GCalif
  \begin{itemize}
  \item Green Calif = 1
  \item Red campus = 1
  \item G-Cnt-en = 1
  \item G-time-sel = 1
  \item Y-Cnt-chr = 1
  \end{itemize}
\item California YCalif
  \begin{itemize}
  \item Yellow Calif = 1
  \item Red campus = 1
  \item G-Cnt-en = 1
  \item G-time-sel = 1
  \item Y-Cnt-chr = 1
  \end{itemize}
\end{itemize}