Final Exam

- Fill in your name:
- This exam is open book and open notes.
- The exam is 120 minutes and worth 120 points. Spend about one minute per point.
- Explain your solutions well, but you do not need to write an essay.
- The exam is a design problem so some questions are deliberately left open-ended. Be creative.

<table>
<thead>
<tr>
<th>Question</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>
You are an engineer at VacuumsRUs in charge of the design of the new RugBug. The RugBug is a small autonomous vacuum cleaner (see diagrams below).

The rugbug includes a keypad and LCD display for the user interface to configure the rugbug operation. The keypad is a 16-key multiplexed keypad. The LCD display is interfaced using the HD44780 LCD controller (see Fig. 8.55). It also includes an antenna to communicate with the base station and other rugbugs in the house. Assume that you have a chip (SCI2RF) that interfaces between the SCI interface and the antenna.

On the bottom it has four dirt sensors which measure the number of dirt particles per cm². The range of the dirt sensor, \( D \), is 0 to 10,000, and it has a resolution of 100 dirt particles (DP) per cm². The transducer has a maximum slope of 1000 DP/s. The dirt sensor transducer produces a voltage between 0 and 30mV.

There are two wheels which are rotated using DC motors. Due to pin limitations we are using only one 5-bit DAC to control the speed of both motors. The microcontroller should provide two additional control bits to determine the motors’ directions (00 - both stopped, 01 - left motor goes in reverse while right motor goes forward, 10 - left motor goes forward while right motor goes in reverse, 11 - move forward). Finally, there is a vacuum which should be turned on and off using a relay interface.
1. (20 points) The dirt sensor measures dirt in numbers of dirt particles per cm$^2$. The range of the dirt sensor, $D$, is 0 to 10,000, and it has a resolution of 100 dirt particles (DP) per cm$^2$. The transducer has a maximum slope of 1000 DP/s. The dirt sensor transducer produces a voltage between 0 and 30mV.

(a) What is the needed ADC precision? How many bits does the ADC need to be?

(b) Assume an ADC conversion time of 64μs. Is a sample-and-hold necessary? Why or why not?

(c) Will the ADCs on the 68HC11 be sufficient? If so, what value will you set ADCTL to, to take your measurements?

(d) What is the maximum allowable noise at the input to your amplifier?

(e) What does your amplifier’s gain need to be?

2. (5 points) The motor controllers accept a voltage between -12V and +12V. A positive voltage causes them to spin the wheel attached to them in a forward direction. A negative voltage causes them to spin in a reverse direction. What is the resolution of the DACs used to control the motors?
3. **(30 points)** Draw a block diagram for the RugBug. Include as much detail as possible. Be sure to consider what ports the I/O devices are connected to. Be sure to include all external circuitry (Sensors, amplifiers, filters, DACs, logic, etc.). You may assume the existence of any component that you need as long as you describe what it does.
4. **(20 points)** Answer the following questions about the software for the LCD device driver. You may assume that the LCD interface will be interfaced using a HD44780 LCD controller (see Figure 8.55).

   (a) What global data structures would you provide?

   (b) What initialization routines would you provide? What would they do?

   (c) What regular I/O calls would you provide that the client software could use to perform I/O? Describe each in a few words.

   (d) What software support (interrupt handlers) would be needed? Assume that gadfly is not an acceptable option.
5. **(20 points)** The output to the motor (direction control and speed) will be updated every 1ms. Write the software required to update the values presented to the motor controllers. Be sure to use the ports from your diagram. You may assume that the values to be output is determined elsewhere.

(a) What global variables do you need?

(b) Give the assembly code for the ritual.

(c) Give the assembly code for the interrupt handler.
6. **(5 points)** You notice that your wireless network is experiencing a lot of collisions. What are collisions and how can they be avoided?
7. **(20 points)** We’d like to design a fuzzy logic controller that searches for dirt. In other words, it should use the input for the dirt sensors to determine the control signals for the motor. The controller should also adjust the motor speed based on the amount of dirt. When there is a lot of dirt, it should move slowly as to make sure to collect all the dirt. In other words, it should try to maximize the difference in dirt measurements by its front and back sensors. Be creative in your controller design.

(a) What are your control inputs and outputs?

(b) What crisp inputs will you use?

(c) What input fuzzy membership sets will you use?

(d) What output fuzzy membership sets will you use?

(e) Give four example fuzzy rules.