UNIVERSITY OF CALIFORNIA
College of Engineering
Electrical Engineering and Computer Sciences Department

145M Microcomputer Interfacing Lab

Final Exam Solutions May 21, 2004

1a Handshaking steps:

When the receiver is ready, it sets “ready for data” (RD) TRUE

The sender detects RD TRUE and asserts the data

After the data have settled, the sender sets “data available” (DA) TRUE

The receiver detects DA true, reads the data, and sets RD FALSE

The sender detects RD false, and sets DA FALSE

[3 points off for asserting DA before asserting data]

1b Tri-state driver:

When the enable input is in one logic state, the output is equal to the input

When the enable input is in the other logic state, the output is in a high impedance state

[3 points off for analog I/O] [3 points off for hold rather than high impedance]

1c D/A glitches:

When the input number changes in more than one bit, it is impossible for both bit switches to change exactly at the same time. During the brief time between the first switch change and the last switch change, an erroneous voltage will be produced.

[4 points off for settling time and no mention of bit changes]

[2 points off for not stating that the bits cannot change simultaneously]

1d Statistical difference of averages:

(1) Determine the average and standard deviations of each of the two sets of measurements.

(2) Compute Student’s t using the formula $t = \dfrac{\overline{a} - \overline{b}}{\sqrt{\sigma_a^2 / m_a + \sigma_b^2 / m_b}}$

(3) Look up the probability of exceeding this t value by chance

[3 points off for not looking up the probability of exceeding $|t|$]

[3 points off for $t <$ some small value like 0.01]

1e Spectral leakage:

Periodically sampling a waveform for a time interval S is equivalent to multiplying the waveform by a rectangular function of width S. By the Fourier frequency convolution theorem, the Fourier transform of the product in the time domain is the convolution of the Fourier transforms of the waveform and the rectangular function in the frequency domain (i.e. the sinc function). This convolution spreads each frequency component of the waveform over many neighboring frequencies.

[3 points off for explaining in time domain]

1f Proportional control:

Connect the sensor output to the negative input of the difference amplifier and connect the desired value (the set point) to the positive input. The output of the amplifier is used to control the actuator. Negative feedback drives the actuator to create a virtual short between the sensor output and the set point.

[4 points off for omitting the set point]

[6 points off for connecting sensor and actuator to the two inputs of the difference amplifier]

2 See Figures 3.16 and 3.17 on page 169 of the textbook

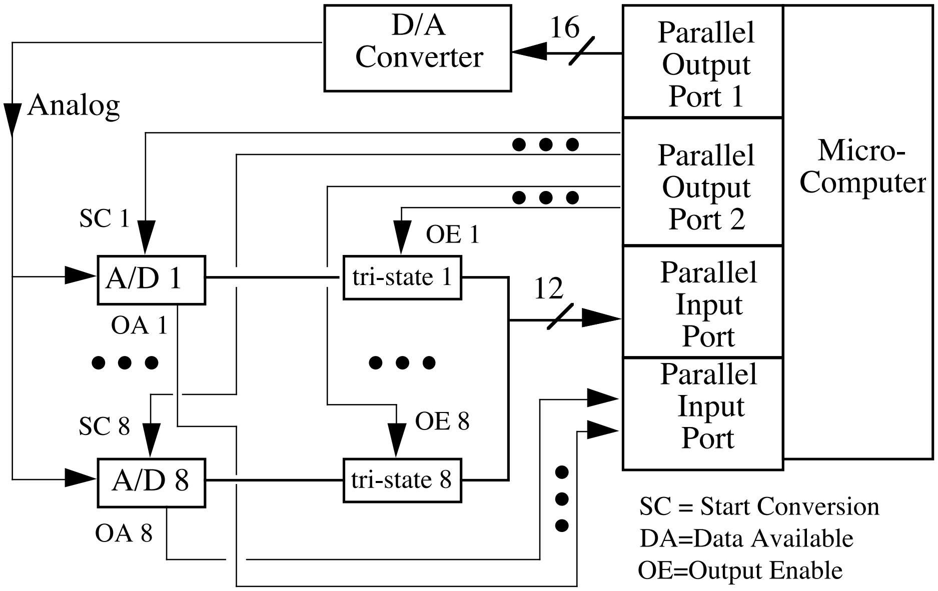
[3 points off if the logic controlling the bit decisions is not clear]

[3 points off for using an A/D converter inside the A/D converter]

[2 points off for not starting with all bits zero]

[5 points off for describing the tracking A/D converter]

3a



The following are essential [3 points off for each omitted]:

- Connect 16 bits of the parallel output port to the input of the 16 bit D/A converter
- Connect the analog output of the D/A to the analog inputs of all A/Ds
- Connect the 12 bit A/Ds to separate tri-state drivers
- Connect the outputs of the tri-state drivers together to form a data bus (can't input 8 x 12 bits in parallel)
- Connect the data bus to 12 bits of the parallel input port
- Provide 8 separate output port lines for initiating conversion of the 8 A/Ds (could be combined with next signal)

- Provide 8 separate output port lines for enabling the 8 separate tri-state drivers (this was essential)
- Provide input for 8 separate input port lines to indicate when individual A/Ds have completed conversion

3b The steps needed to measure the first transition voltage V(0,1) for the first A/D converter.

1 set SC1 low, disable all tri-state drivers, set N = 0
2 Put N on D/A
3 wait 10μs until D/A has settled [using wait(10)]
4 Put low-high edge on SC1 output line to start conversion
5 Wait until output data available
6 enable tri-state 1 (disable all others)
7 read input port to get value M
8 Put high-low edge on SC1 output port to end conversion cycle
9 if M=0, increase N by one and loop back to step 2
10 If M=1, save (D/A voltage step)(N-1/2) as the transition voltage

[3 points off for writing to D/A and reading a value from A/D but not determining V(0,1)]

3c Send successive 16-bit numbers 0 to 2^{16}–1 to the D/A converter and convert the analog output with the A/D. Whenever the A/D output value changes, store the corresponding D/A value in a transition voltage table

To determine **absolute accuracy**, compare the D/A values for each A/D output transition with the ideal transition values. Since the step size of the D/A is 16 times finer than the average step size of the A/D, this design can measure the A/D transition voltages to an accuracy of 1/16 LSB.

[3 points off if table of all A/D transition voltages not generated.]

3d Determine the D/A values corresponding to first and last A/D transition voltages, and the equation of the line that passes through them. **Linearity** is a measure of how closely the other measured transition values pass through the line.

3e Determine the difference in D/A values between each A/D transition voltage. The **differential linearity** is a measure of the equality of those differences. Alternatively, the A/D step sizes could be determined as the number of successive D/A inputs that produce the same A/D output.

3f The method can determine the A/D accuracies to 1/16 LSB (±1/32 LSB was OK).

Note that 1 A/D LSB = 16 D/A LSBs.

[5 points off for an answer of 1/2 A/D LSB]

4a the lowest frequency index is 0, and corresponds to 0 Hz

4b Since there are 32,768 samples, the highest frequency index is 32,767 and it corresponds to 2 Hz.

[3 points off for 0 Hz or 65 kHz]

4c The highest frequency in the fft is 32,768 Hz, and it occurs at frequency index 16,384.

(440 Hz at Fourier coefficient index 220 was also allowed)

4d The 440 Hz signal will produce non-zero coefficients at frequency indices 220 and 32,768-220 = 32,548. In addition, the raised cosine window will produce side bands at frequency indices 219, 221, 32,547, and 32,549.

[3 points off for omitting the short-range leakage of the raised cosine, which occurs even for an integer number of cycles]

[2 points off for omitting 32,548]

4e Since the anti-aliasing filter has significant gain at the Nyquist limit, harmonics as high as 32,768/440 = 74 would be visible.

[1 point off for 45th harmonic]

4f Only harmonics below 20 kHz would have amplitudes accurate to 1%. The highest of these is the 45th harmonic, which would occur near frequency index 10,000.

4g Using the 45th harmonic near frequency index 10,000, a difference in frequency of 1/2 index should be detectable, which is 1 part in 20,000 or 0.022 Hz out of 440 Hz.

[3 points off for using only first harmonic, which would have an accuracy of only 1/2 index at 220 or 1 Hz]

4h The filter is known to have a gain of 0.99 at f1 = 20 kHz and 0.01 at f2 = 45.3 kHz. The ratio of f2/f1 is 2.27. Looking at the table of filters, we have a frequency ratio for these gains as follows:

f2/f1 = 1.468/0.850 = 1.73 at order n = 12 (too low)

f2/f1 = 1.585/0.823 = 1.92 at order n = 10 (too low)

f2/f1 = 1.778/0.784 = 2.27 at order n = 8 (OK, this is the filter)

So the filter is of order 8 and fc = 20 kHz/0.784 = 25.5 kHz.

(n = 10, fc = 24 kHz was also accepted)

145M Final Exam Grades:

Problem	1	2	3	4	Total
Average	47.5	17.9	61.2	48.4	174.9
rms	4.9	2.6	11.2	4.8	18.2
Maximum	52	20	70	58	200

145M Numerical Grades:

	Short labs	Long labs	Lab Partic.	Midterm #1	Midterm #2	Final	**Total**
Average	95.6	383.2	91.3	64.2	77.6	174.0	**885.8**
rms	2.6	31.1	5.0	12.4	10.9	18.4	**57.7**
Maximum	100	400	100	100	100	200	**1000**

Note 1: The average of labs 1, 3, 9, 21, and 23 was 2 points per lab higher than the average of labs 2, 8, 10, 22, and 24. This was due to the nature of the labs and small differences in grading standards. Two bonus points were added to the long lab total for each of labs 2, 8, 10, 22, and 24 (omitting the lowest long lab grade).

145M Letter Grade Distribution

Letter Grade	Course Totals (1000 max)
A+	966
A	935, 943
A–	913, 915, 916, 922,
B+	902, 904, 906, 910
B	
B-	873, 875
C+	824, 839, 853
C	
C–	
D+	
D	721