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

145M Microcomputer Interfacing Lab

Final Exam Solutions May 14, 2005

1a D/A Converter: A network of resistors generates a series of currents that increase by powers of two. Works by using the input bits to control switches that send the currents to a summing amplifier that converts the current sum into a voltage.

[4 points off if switches are not used to prevent input zeros from stealing currents controlled by the input ones. It is essential that the current controlled by each bit that goes to the summing junction is not affected by the state of any of the other bits]

1b Comparator: Has two analog inputs and a digital output. Works by high gain differential amplification of the two inputs and limiting the output to produce two logic voltage levels.

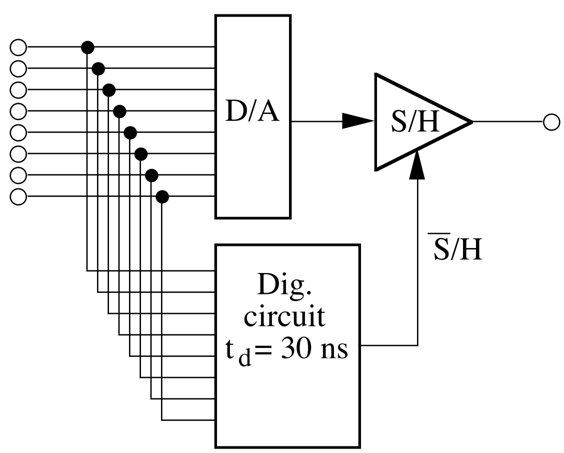
[4 points for defining the comparator without explaining how it works]

[3 points off for an analog difference output rather than two discrete digital levels]

1c Flash 8-bit A/D converter: The analog input is send to the positive inputs of 255 comparators. A 255-resistor voltage divider provides an evenly spaced series of voltages for the negative input to the comparators. For a given analog input, the comparator output is one for all the divider voltages below the input and zero for all the voltages above. A series of exclusive or circuits identifies the highest comparator with an output of one and an encoder circuit determines the numerical value.

1d Half-flash A/D converter: Consists of two 8-bit flash converters, a D/A converter, and a difference amplifier. Conversion is started by using one of the 8-bit flash converters to determine the 8 most significant bits. Then those bits are converted into a corresponding voltage that is subtracted by the difference amplifier. The difference is converted by the second 8-bit flash converter to determine the 8 least significant bits

2a



2b

When input changes, change detector circuit generates a pulse from 5 ns to 35 ns (t_d = 25 ns was also allowed). This puts S/H into hold mode during the glitch. Droop during 30 ns is only 3 μV.

3a See text pp 178-179 for the analysis

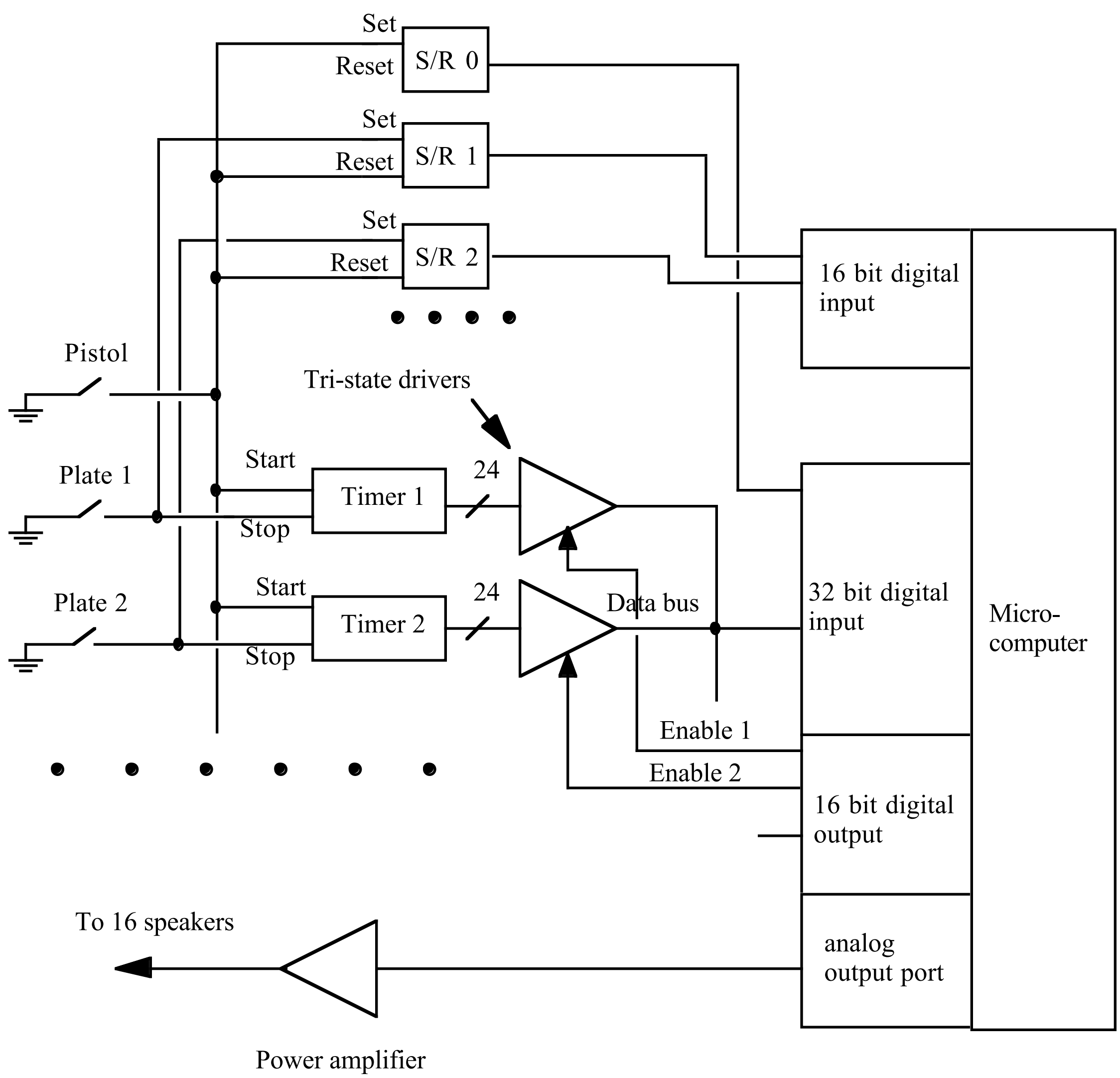
$f_{max} = 1/(2^{N+1} \pi T) = 1/(131{,}072 \pi 10^{-5} s) = 0.24$ Hz

3b $T = 1/(131{,}072 \pi 50{,}000 Hz) = 49$ ps time jitter

[8 points off for 10 μs] [5 points off for 0.1 μs]

3c $f_{max} = 100$ kHz/2 = 50 kHz

4a



Crucial features of design:

- 17 switches connected to ground
- pistol sets S/R #0, resets all other S/Rs
- S/R #0 connected to one line of a digital input port so computer knows when race has started and when to send gunshot to analog output port
- Pistol switch starts all 16 counters
- Touch plate #n sets S/R #n so computer can read the coulter and display results promptly

- Outputs of 16 S/Rs connected to digital input port

  (Note: above two not needed if computer polls counters to detect those that do not change)
- Touch plate #n stops counter #n
- Timer #n output connected to tristate driver #n
- All 16 tristate drivers connected to form a bus that connects to 24 bits of digital input port
- The enable inputs of the 16 tristate drivers are connected to a 16 bit digital output port
- Analog output port connected to a power amplifier that drives all 16 speakers

  [2 points off if switches do not connect circuit to ground]

  [2 points off if S/R not used at pistol]

  [2 points off if S/R not used at S/Rs]

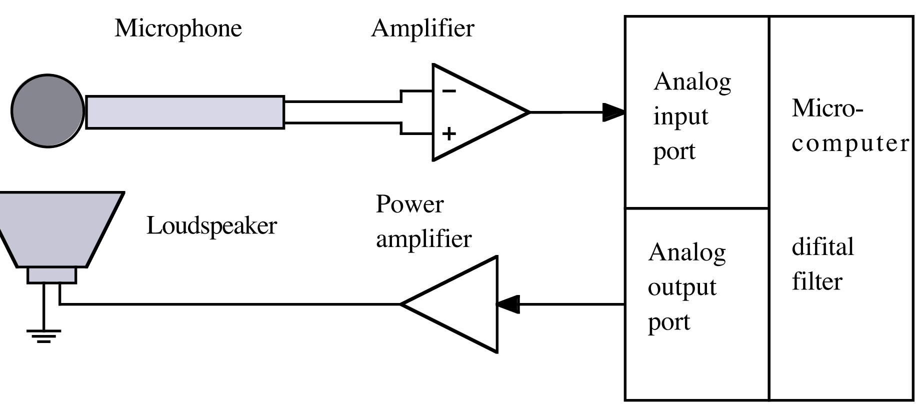
  [2 points off if power amplifier not used to drive the 16 speakers]

4b Hardware and software events

1. Computer loops to detect pistol switch closure
2. Pistol contact closes, setting S/R #0
3. All16 timer boxes start, all 16 set/reset latches are reset
4. Computer detects pistol switch closure and sends series of digital numbers (digital recording of gunshot sound) to analog output port whose output is amplified and sent to the 16 speakers
5. Computer loops to detect closure of any of the 16 touch plate switches
6. Touch plate #n closes and sets S/R latch #n that is detected by the computer
7. Computer enables tri-state #n (all others disabled)
8. Computer reads 24-bit number, multiplies by 10^{-4}, sends to display and disk
9. Loop over all swimmers who have not finished and quit when all plates have been touched.

[no deduction for having the computer start the counters rather than the pistol switch, but using the computer for this purpose is a poor design due to unpredictable system interrupt delays]

5a



A low-pass filter is not needed because the loudspeaker limits the signal bandwidth.

[2 points off for omitting power amplifier]

5b

1 Generate an impulse (maximum voltage, width 1 μs) at the input of the power amplifier

2 immediately sample the output at 100 kHz to acquire the digitized impulse response c_i

3 To capture frequencies as low as 10 Hz, sample for 0.1 s

5c

1 From the 100 kHz sampled impulse response c_i, compute $b_i = FFT^{-1}[1/FFT(c_i)]$

2 Use b_i as an FIR digital filter on the 100 kHz sampled input stream a_i. This convolves a_i with b_i to produce f_i.

$$f_i = \sum_k b_k a_{i-k}$$

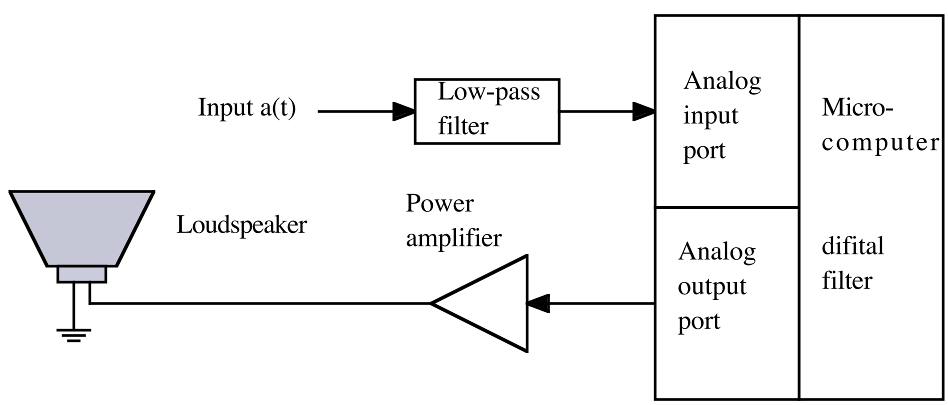
3 Sending f_i through the loudspeaker convolves f_i with c_i, which will result in a signal similar to a_i.

$$a(t) = f(t) \bullet c(t) = [a(t) \bullet b(t)] \bullet c(t) = a(t) \bullet [b(t) \bullet c(t)]$$

Note that b(t)•c(t) = delta function since FFT(b) x FFT(c) = 1

2

5d During the exam the question was clarified as "Sketch the block diagram of a system that processes input a(t), given digital filter b[i].



145M Final Exam Grades:

Problem	1	2	3	4	5	Total
Average	32.0	23.2	14.5	46.4	54.2	170.5
rms	6.0	4.3	5.1	3.8	5.9	18.0
Maximum	40	25	25	50	60	200

145M Numerical Grades:

	Short labs	Long labs	Lab Partic.	Midterm #1	Midterm #2	Final	**Total**
Average	93.4	372.6	98.4	81.2	74.7	170.5	**890.9**
rms	12.2	23.6	4.6	13.5	11.5	18.0	**67.7**
Maximum	105	400	100	100	100	200	**1005**

Note 1: The average of labs 1, 3, 9, 21, and 23 was 1 point 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. One bonus point was added to the long lab total for each of labs 2, 8, 10, 22, and 24 (omitting the lowest long lab grade).
Note 2: The short report for lab 3 was graded on a basis of 30 rather than 25 points. So students who turned in short lab 3 could earn a maximum of 105 points for their short labs. But students who did not turn in short lab 3 could only earn 100 points and 5 points was added in that case.
Note 3: In most cases Note 1 and Note 2 apply to different long lab sets so almost everyone got 4 or 5 extra points.

145M Letter Grade Distribution

Letter Grade	Course Totals (1000 max)
A+	987
A	949, 951, 953, 963, 984
A–	916.5, 924.5, 926, 929, 936, 937.5
B+	890, 900, 901, 902
B	871, 879, 884
B-	835, 848.5, 850, 857.5
C+	812
C	790
C–	765
D+	
D	716.5