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

145M Microcomputer Interfacing Lab

Final Exam Solutions May 21, 1999

1a The transition voltages of an A/D converter are the analog input voltages where the digital output changes between neighboring numbers *n* and *n*+1.

1b The Nyquist sampling theorem states that to recover completely an analog waveform from its sampled values, the highest frequency present must be less than one-half the sampling frequency

1c The tri-state buffer is a circuit with digital inputs and outputs, plus a digital select line. The logic state of the select line controls whether the outputs are equal to the inputs or whether the outputs are in a high impedance state.

1d Infinite impulse response digital filter is the special case of the general digital filter

$$y_i = A_1 x_{i-1} + A_2 x_{i-2} + \ldots + A_M x_{i-M} + B_1 y_{i-1} + \ldots + B_N y_{i-N}$$

where at lest one of the B_i are non-zero.

[2 points off for giving the general definition only]

[2 points off for stating only that the impulse response is infinite- while this is true it does not demonstrate a understanding of what it is]

1e The comparator circuit has two analog inputs (V_+ and V_-) and one digital output (L).

If $V_+ > V_-$ then L is high; if $V_+ < V_-$ then L is low. (L is not defined when $V_+ = V_-$)

[2 points off for stating that the logic output depends on whether the two inputs are equal or not]

1f The sample and hold circuit has an analog input and an analog output, plus a digital control line. The logic state of the control line controls whether the output is equal to the input or whether the output is held constant.

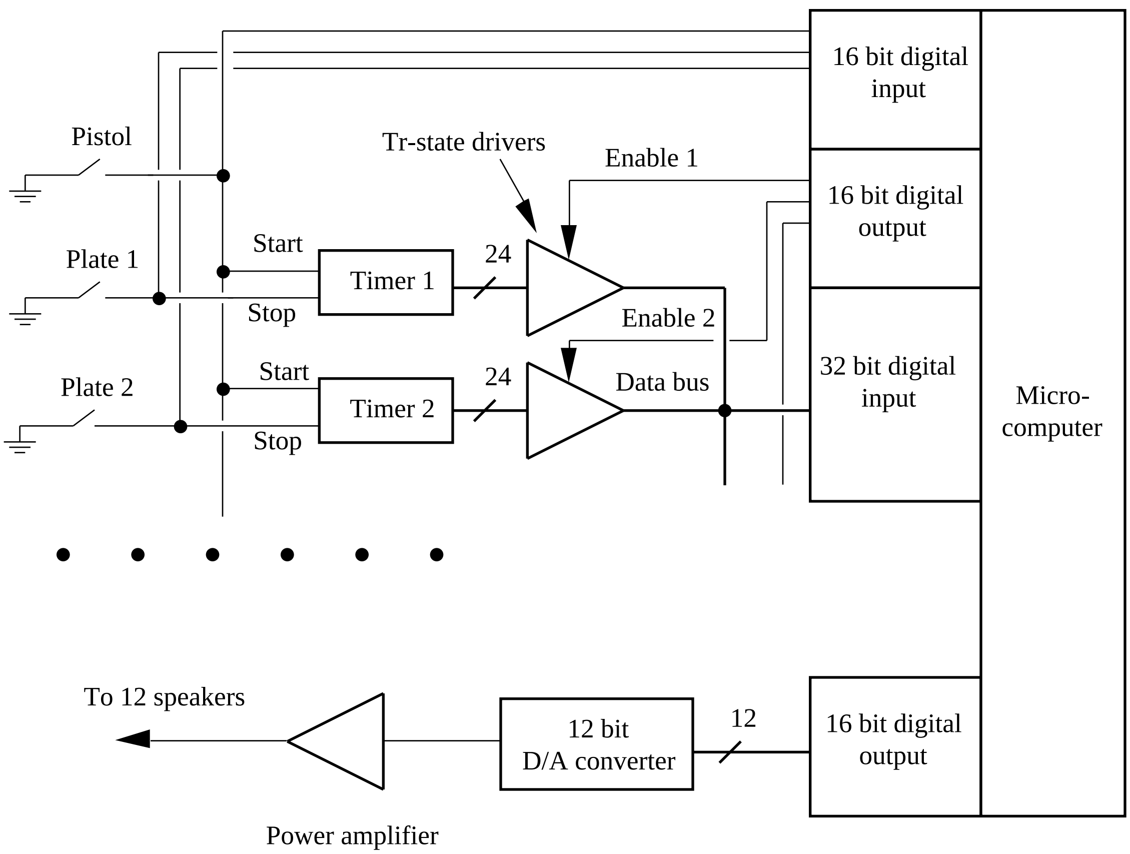
2a Essential features for the circuit design:

- Pistol switch starts all timers and notifies computer (via input port) to play gunshot sound
- Digital output –> 12-bit D/A converter –> power amplifier –> all 12 speakers
- Each touch plate switch is connected to the corresponding timer stop input and is also connected to a digital input line so that the computer knows when the corresponding swimmer has finished
- All timer outputs are connected via tri-state drivers to form a data bus that is connected to 24-bits of digital input
- Each tristate can be individually selected by the computer using an individual digital output line

- All timers are started by the pistol switch and stopped by the corresponding touch plate switch- this avoids computer delay, which can be unpredictable.

Digital I/O requirements

- 13 bits digital input for pistol and 12 touch plate switches
- 24 bits digital input for timer data values
- 12 bits digital output to D/A for gunshot sound
- 12 bits digital output to select individual tri-state circuits



2b Hardware and software events

1 Computer loops to detect pistol switch closure

2 Pistol contact closes

3 All12 timer boxes start

4 Computer detects pistol switch closure and sends series of 12-bit words (gunshot sound) to D/A, whose output is amplified and sent to the 12 speakers

5 Computer loops to detect closure of any of the 12 touch plate switches

6 Touch plate *n* closes and 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 screen and disk

9 Loop over all swimmers who have not finished and quit when all plates have been touched.

[3 points off for using latches rather than tri-state buffers to form the data bus]

[10 points off for connecting 12 x 24 = 288 separate digital inputs to the computer]

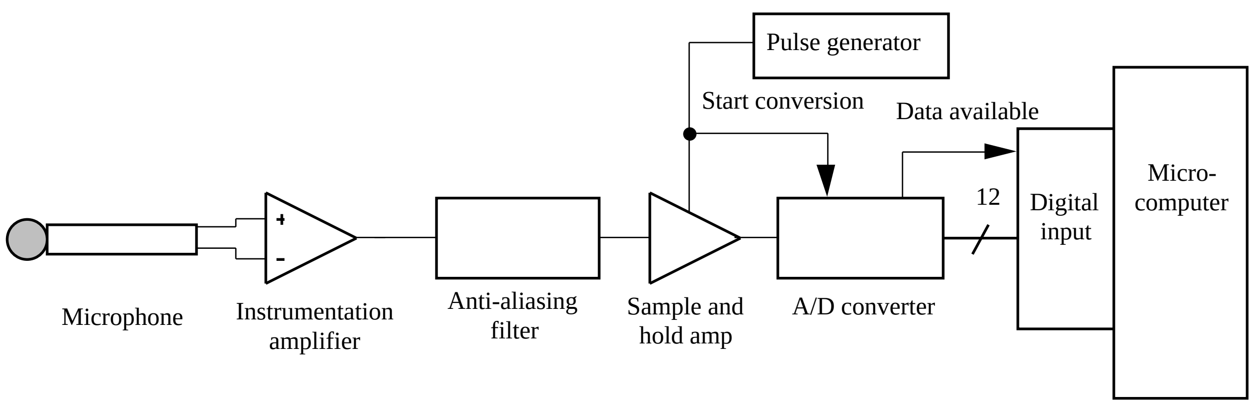
[10 points off for connecting all 12 timer outputs directly together]

[5 points off for enabling all tri-states with the same signal]

[5 points off for not stopping timers before reading final values- this can cause erroneous data when read occurs when bits are changing]

[5 points off if touch plate switches are not connected to input port and there is no workable plan to detect when the swimmers finish- this design causes many redundant numbers to be written to the screen and to disk]

3a



[8 points off if the pulse generator is not used to synchronize periodic samples]

3b f_1 = 20 kHz, G_1 = 0.999, G_2 = 0.01, f_s = 65 kHz

try n = 10 $f_1/f_c = 0.733$ f_c = 27.3 kHz

$f_2/f_c = 1.585$ f_2 = 43.2 kHz

$f_1 + f_2$ = 63.2 kHz OK- since $f_s > f_1 + f_2$

[both *n*=10 and *n* =12 were accepted]

[2 points off for n = 12, f_c = 25.9 kHz, but f_2 (highest frequency that could alias to 20 kHz) not computed]

[2 points off for $f_2 = f_s/2$- excessive design]

[6 points off for *n*=10 but gain at f_s-f_1 not checked]

3c Hardware and software steps

1 The low pass filter continuously removes high frequencies from the analog waveform

2 The pulse generator produces a sequence of 10 µs-wide pulses at 65,536 Hz.

3 The leading edge of each 10 µs pulse puts the sample and hold amplifier into hold mode and starts A/D conversion

4 During the 10 µs pulse, the A/D input is held constant during conversion

5 When conversion is complete, the A/D generates a data available pulse

6 The data available pulse is detected by the computer and the data are read

7 The computer repeats step 6 until 2^{17} = 131,072 samples are read.

8 The computer multiplies the data by the Hanning window and takes the FFT

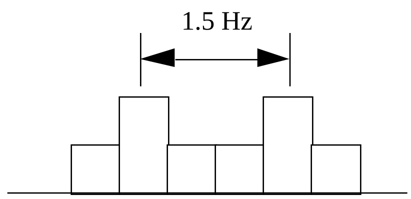
[2 points off if no Hanning window]

[3 point off if no FFT]

3d H_0 corresponds to 0 Hz; H_1 corresponds to 0.5 Hz; $H_{65,536}$ corresponds to 32,768 Hz; $H_{131,071}$ corresponds to 0.5 Hz

3e A pure harmonic 1000 Hz signal would have equal magnitudes at H_{2000} and $H_{M\text{-}2000}$ and smaller side lobes at $H_{2000\pm1}$ and $H_{M\text{-}2000\pm1}$.

3f Because the Hanning window adds side lobes at indices ±1, to appear as separate peaks the two components must be separated by at least three frequency indices, or 1.5 Hz



[1.5 to 2.5 Hz was accepted] [2 points off for 1 Hz] [3 points off for 0.5 Hz]

3g The 20,000 Hz harmonic would have equal magnitudes at $H_{40,000}$ and $H_{M\text{-}40,000} = H_{91,072}$ plus side lobes at $H_{40,000\pm1}$ and $H_{91,072\pm1}$. The 46,536 Hz harmonic would be reduced by a factor of 100 or more by the antialiasing filter before sampling and would appear at $H_{38,000}$ and $H_{93,072}$ (plus side lobes at $H_{38,000\pm1}$ and $H_{93,072\pm1}$).

[1 point off for a smaller amplitude for the higher frequency but the ratio not given]

[2 points off if amplitude ratio not mentioned]

3h A 100 Hz fundamental would occur at H_{200} and $H_{M\text{-}200}$

plus side lobes at $H_{200\pm1}$ and $H_{M\text{-}200\pm1}$.

3i The mth harmonic would occur at H_{m200} and $H_{M\text{-}200m}$

plus side lobes at $H_{m200\pm1}$ and $H_{M\text{-}200m\pm1}$.

[1 point off if $H_{M\text{-}200m}$ not mentioned]

145M Final Exam Grades (18 undergraduate and 6 graduate students):

Problem	1	2a	3	Total
Average	33.5	52.2	85.5.	171.1
rms	3.0	8.5	19.5	27.6
Maximum	36	60	104	200

145M Numerical Grades (18 undergraduates only):

	Lab total	Lab Partic.	Midterm #1	Midterm #2	Final	**Total**
Average	487.2	93.9	77.0	75.4	170.4	**910.4**
rms	11.1	4.7	13.8	13.2	31.4	**57.3**
Maximum	500	100	100	100	200	**1000**

145M Letter Grade Distribution

Letter Grade	Course Totals (1000 max)
A+	966
A	965, 961, 946, 942(G), 941, 941, 937.5
A–	
B+	922, 917, 917, 916, 916(G), 912, 910, 900(G)
B	898(G), 896(G), 885, 884(G), 882
B-	
C+	824
C	
C–	
D+	
D	735

(G) = graduate student