

UNIVERSITY OF CALIFORNIA
 College of Engineering
 Electrical Engineering and Computer Sciences Department
 145M Microcomputer Interfacing Lab
 Final Exam Solutions May 17, 2002

- 1a Tri-State buffer:** Digital circuit with input and output lines, and a select line. When the select line is in one logic state, output = input. Otherwise the output is in a high-impedance state and neither drives nor loads any circuit connected to it.
- 1b Transition voltages** (of an A/D converter): Specific input voltages at which the output switches between one output number and the next.
- 1c Digital filter:** Filter whose digital output is a linear combination of previous digital input and output values. The finite impulse response (FIR) filter does not depend on previous output values. The infinite impulse response (IIR) depends on previous output values.
- 1d Anti-Aliasing Filter:** Analog filter designed to eliminate high frequencies above the Nyquist sampling limit (one-half the sampling frequency) that would otherwise appear as erroneous lower frequencies in the sampled data.
- 1e Fourier frequency convolution theorem:** The Fourier transform of the simple product of two functions is the convolution of the Fourier transforms of the two functions.
 [2 points off for giving Fourier convolution theorem] [OK for giving both]
- 1f Nyquist sampling theorem:** To recover a waveform from its sampled values, the highest frequency present must be less than one-half the sampling frequency.

2a $f = a + b$ $\sigma_f^2 = \left(\frac{\partial f}{\partial a}\right)^2 \sigma_a^2 + \left(\frac{\partial f}{\partial b}\right)^2 \sigma_b^2 = \sigma_a^2 + \sigma_b^2$

$$\boxed{\sigma_f = \sqrt{\sigma_a^2 + \sigma_b^2}}$$

2b $f = \frac{1}{N} \sum_{i=1}^N a_i$ $\sigma_f^2 = \sum_{i=1}^N \left(\frac{\partial f}{\partial a_i}\right)^2 \sigma_a^2 = \sum_{i=1}^N \left(\frac{1}{N}\right)^2 \sigma_a^2 = N \sigma_a^2$

$$\boxed{\sigma_f = \sigma_a / \sqrt{N}}$$

3a TR, FL, 1B

3b SA, DS, HF

3c FL

3d SA, HF, 1B

[DS would require $20 \text{ kHz} \times 2^{12} = 1.3 \text{ GHz}$ clock speed]

3e DS, 1B

3f SA, HF

[DS takes a time average and does not need a steady input]

[1 point off for each wrong answer] [1 point off for each missing correct answer]

Problem 4

Since 5 square waves were sampled, we expect non-zero magnitudes at frequency indexes at odd multiples of 5 and 128 minus odd multiples of 5. These are $n = 5$ and 123 (first harmonic at 15 Hz), $n = 15$ and 113 and (third harmonic at 45 Hz), $n = 25$ and 103 (fifth harmonic at 75 Hz), etc. The additional large magnitudes at $n = 20$ and 108 corresponds to a pure 60 Hz harmonic, which must be due to power line interference in the lab.

If magnitude at $n = 20$ were due to distortion generating even harmonics, additional magnitudes at $n = 10, 30, 40, 50$, etc. would also be expected.

[3 points off if odd harmonics not identified]

[3 points off if magnitudes above index 64 not explained]

[4 points off if 60 Hz electromagnetic interference not identified]

5a Multiplying the data with a square window convolves the true frequency spectrum with the Fourier transform of the square wave, which produces long-range spectral leakage that falls off as $1/\text{frequency}$.

[5 points off for not explaining what is happening in the frequency domain]

5b To recover the original square-wave-windowed time samples, just use the inverse transform.

Then multiply the time samples with the raised cosine window and take the fft.

[10 points off for convolving the original fft with the fft of the raised cosine and not removing effects of the square window]

5c Multiplying the data with the raised cosine window convolves the true frequency spectrum with the Fourier transform of the raised cosine window, which produces short-range spectral leakage (nearest-neighbor frequency amplitudes) but very small long-range spectral leakage.

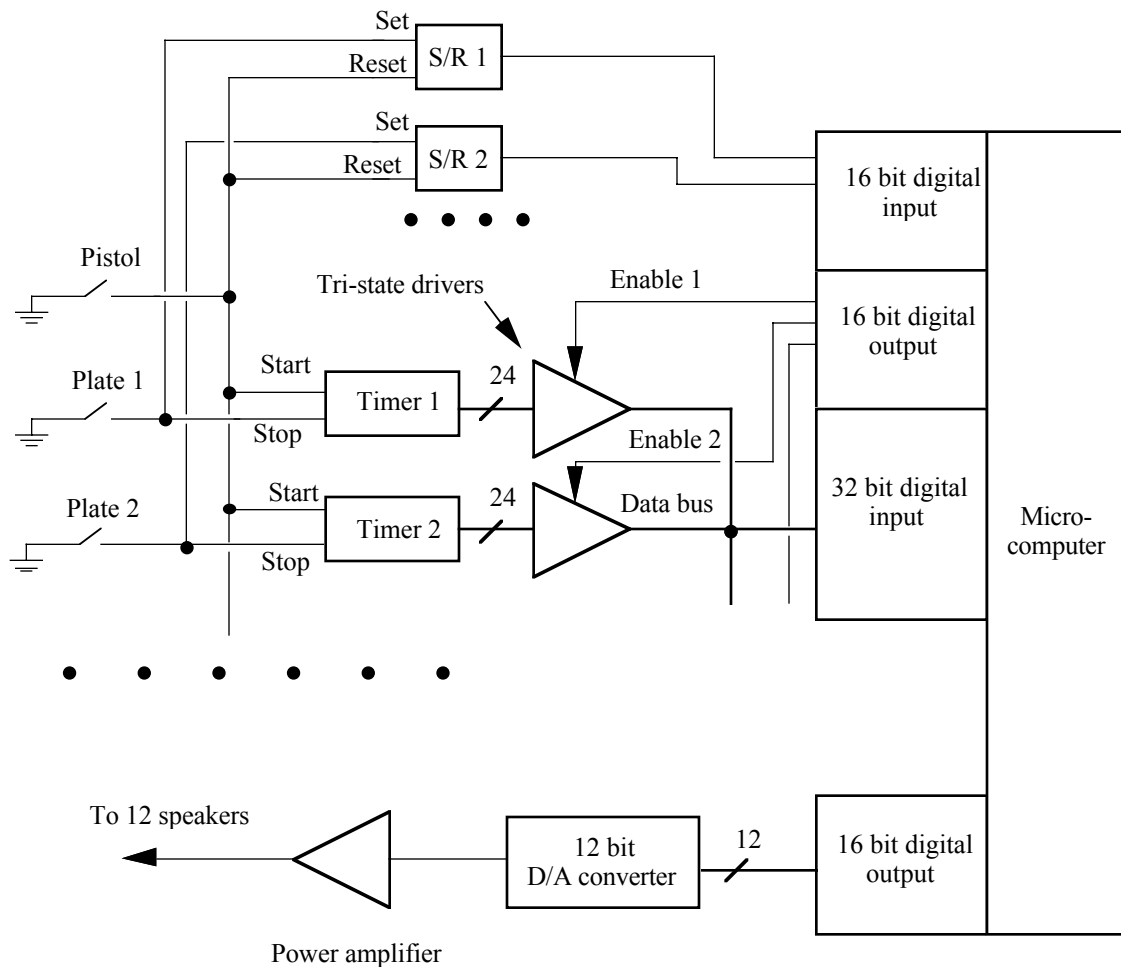
[5 points off for not explaining what is happening in the frequency domain]

6a Essential features for the circuit design:

- Pistol switch starts all timers and notifies computer (via input port) to play gunshot sound
- Digital output \rightarrow 12-bit D/A converter \rightarrow power amplifier \rightarrow all 12 speakers
- Each touch plate switch is connected to the corresponding timer stop input and is also connected to a digital input line via a set/reset latch so that the computer can determine 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



[3 points off if no pistol switch shown]

6b Hardware and software events

- 1 Computer loops to detect pistol switch closure
- 2 Pistol contact closes
- 3 All 12 timer boxes start, all 12 set/reset latches are reset
- 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 sets S/R latch 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.

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

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

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

[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]

[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]

145M Final Exam Grades:

Problem	1	2	3	4	5	6	Total
Average	28.8	24.2	24.2	11.9	29.4	56.6	175.0
rms	1.1	2.0	3.7	2.2	7.9	4.4	11.4
Maximum	30	25	30	15	40	60	200

145M Numerical Grades:

	Lab total	Lab Partic.	Midterm #1	Midterm #2	Final	Total
Average	446.0	89.9	82.5	86.8	175.0	880.2
rms	35.0	5.9	12.7	10.2	11.4	45.4
Maximum	500	100	100	100	200	1000

145M Letter Grade Distribution

Letter Grade	Course Totals (1000 max)
A+	932
A	914, 930
A-	891, 898, 906.5
B+	867, 872, 872.5, 875
B	
B-	839.5
C+	
C	765
C-	
D+	
D	