# Solutions for Midterm #2 - EECS 145M Spring 1998

**PROBLEM 1**

[The problem asked for a description in terms of specific characteristics- for example, just stating that the flash converter is "fast" without a description caused a one point deduction]

**1a  Successive Approximation**
- The conversion accuracy is limited by the resistor accuracy in the internal D/A- can easily be 16 bits.  [1 point off for "no limit"] [OK for "large number"]
- The differential linearity is limited by the resistor accuracy in the internal D/A
- Relatively low cost, one D/A, one comparator, digital control circuits
- Speed is good, takes N cycles to determine N bits [2 points off for $2^N$ steps to convert]
- An external sample and hold amplifier is needed to assure a constant input during conversion

**1b  Flash**
- Number of bits is limited by the number of resistors and comparators that can be integrated onto a single chip- 8-12 bits was OK for full credit.
- The differential linearity is limited by the resistor accuracy
- High cost- $2^N$ resistors and $2^N–1$ comparators needed
- Speed is very good- conversion is continuous
- no external circuits are needed

**1c  Integrating or dual slope**
- Number of bits is limited by the clock speed and the maximum acceptable conversion time.
- The differential linearity is excellent- limited by the clock accuracy and integrator linearity
- Medium cost- not many components but the integrator must be very linear
- Speed is very poor- requires $2^N$ cycles to convert a full-scale input
- no external circuits are needed

**1d  Half flash**
- Number of bits is limited to 10-12 (no reason it could not be as high as 16).
- The differential linearity is limited by the accuracy of the resistors and the linearity of the difference amplifier
- Medium cost- requires only two N/2-bit flash converters and an accurate difference amplifier
- Speed is very good- conversion takes only two steps
- for best accuracy, a sample and hold amplifier is needed to keep the input constant during the two steps

**PROBLEM 2**

**2a**  v = 10 m/s  f = 100 kHz (1 + 10/2000) = 100,500 Hz

v = 11 m/s  f = 100 kHz (1 + 11/2000) = 100,550 Hz

v = 200 m/s  f = 100 kHz (1 + 200/2000) = 110,000 Hz

[the more accurate f = 100 kHz/(1-200/2000) = 111,111 Hz, either was OK]

**2b**   f = 50 kHz, so length of sampling window S = 1/ f = 0.02 s

**2c**  The spectral leakage from 100 kHz to 100.5 kHz will be severe, so a Hanning window would be useful in nearly eliminating it. Since there is only one echo frequency to worry about, the broadening caused by the Hanning window will still allow the echo frequency to be determined to within one Fourier frequency index, to a resolution of    f = 50 Hz. So there is no need to increase S.

An alternative, a precise number of 100 kHz cycles could be sampled. The much smaller echo signal would still have spectral leakage, but that would be OK.

**2d**  The maximum signal frequency is 110 kHz at 200 m/s. A sampling frequency of 220 kHz would allow white noise from 110 kHz to the low pass filter cut off to be aliased below 110 kHz, but this would not seriously reduce the ability to see the frequency of the echo. A better

design would be to sample at 300 or 400 kHz. Then the low pass filter would reduce the white noise in the echo signal Fourier coefficients.

**2e** Low pass filter accepts frequencies below $f_1 = 110$ (or 111) kHz.

**2e** Sampling at 400 kHz for 0.02048s would produce 8192 samples. [4000 was also accepted]

**2f** To record the echo signal (0.1 V) to 5%, we need a resolution of V = 0.005 V. Since the carrier is 10 V, we need a dynamic range of 2000 V or 2000 A/D step sizes. This would require 11 or 12 bits. [2 points off for 4 to 8 bits]

**2g** Need to convert to 12 bit resolution in 3-5 μs. The first obvious choice is the half-flash A/D used in the DT3010, which converts 12 bits in 2 μs. The successive approximation would also work in this application. [3 points off for tracking or dual slope- too slow]

**2h** Assuming a 400 kHz sampling rate, the echo is 100 times smaller than the 100 kHz tone and the white noise is 10 times smaller than the peak echo. The low pass filter falls off as $1/f^8$.

[3 points off if no FFT frequency index]  [3 points off if no frequency scale in Hz]

[3 points off if white noise not shown]  [5 points off if primary tone or echo not shown]

[3 points off for blank vertical scale]  [2 points if vertical scale is not numbered]
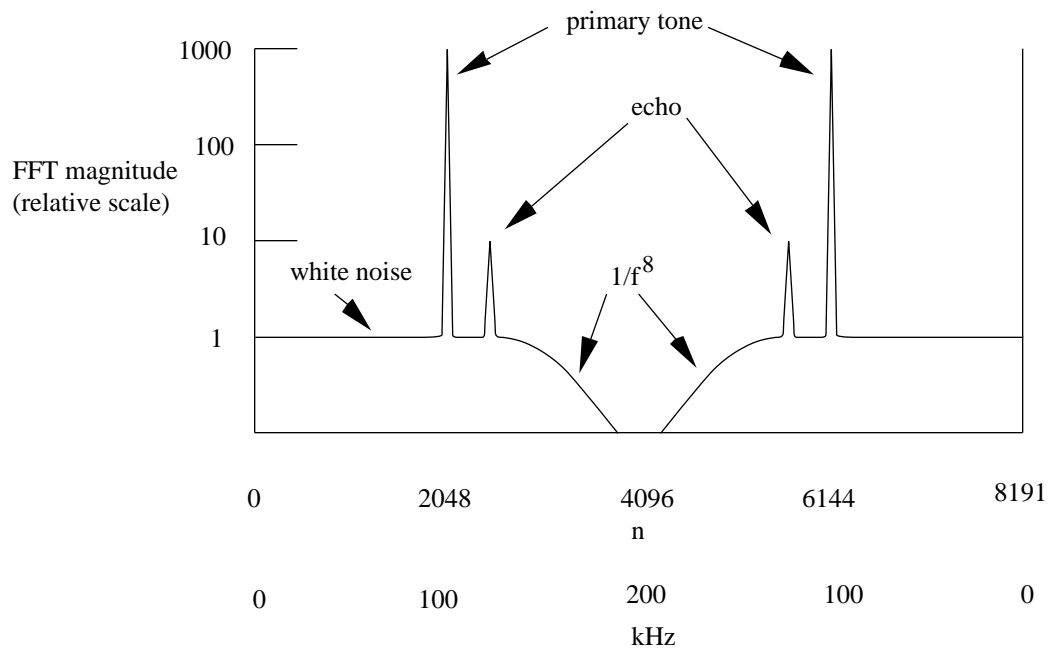


## Midterm #2 class statistics:

| Problem | max | average | rms |
|---------|-----|---------|-----|
| 1 | 40 | 27.0 | 7.6 |
| 2 | 60 | 49.6 | 4.3 |
| total | 100 | 76.64 | 8.3 |

Grade distribution:

| Range | number | approximate letter grade |
|-------|--------|--------------------------|
| 61-65 | 2 | C+ |
| 66-70 | 1 | B- |
| 71-75 | 3 | B |
| 76-80 | 3 | B+ |
| 81-85 | 4 | A- |
| 86-90 | 0 | A |
| 91-95 | 1 | A+ |
| 96-100 | 0 | A+ |