Prob. 1

The basic equation is

$$\hat{x} = \left\lfloor \frac{x}{\Delta} \right\rfloor \Delta + \Delta/2. \quad (1)$$

The first part of the equation $\left\lfloor \frac{x}{\Delta} \right\rfloor \Delta$ rounds us down to the quantization level and then we add $\Delta/2$ to force a mid-tread design.

Prob. 2

The SNRs for the quantized uniformly-distributed random noise are shown in Table 1. The SNRs agree well with the 6 dB-per-bit-rule. Note because of the random nature of the signal, your SNRs might not exactly agree with below but should be very close.

Table 1: Problem 2: SNR for quantized uniformly-distributed noise.

B	SNR (dB)
3	18.0286
5	30.1087
8	48.1518

Variance, σ^2 of a random variable x is defined as $E\left[(x-\bar{x})^2\right]$ where E is the expectation operator and $\bar{x}$ is the mean value of x. For a zero-mean random variable, $\sigma^2 = E\left[x^2\right]$. With zero-mean data, the *sample variance* is given by $\sigma^2 = \frac{1}{N}\sum_{n=0}^{N-1} x_n^2$ which is the same as power.

Prob. 3

The SNRs for the quantized cosinusoid are shown in Table 2. When the amplitude is lowered, the signal does not span the full range and hence we are not making the best use of the bits.

Table 2: Problem 3: SNR for quantized uniformly-distributed noise.

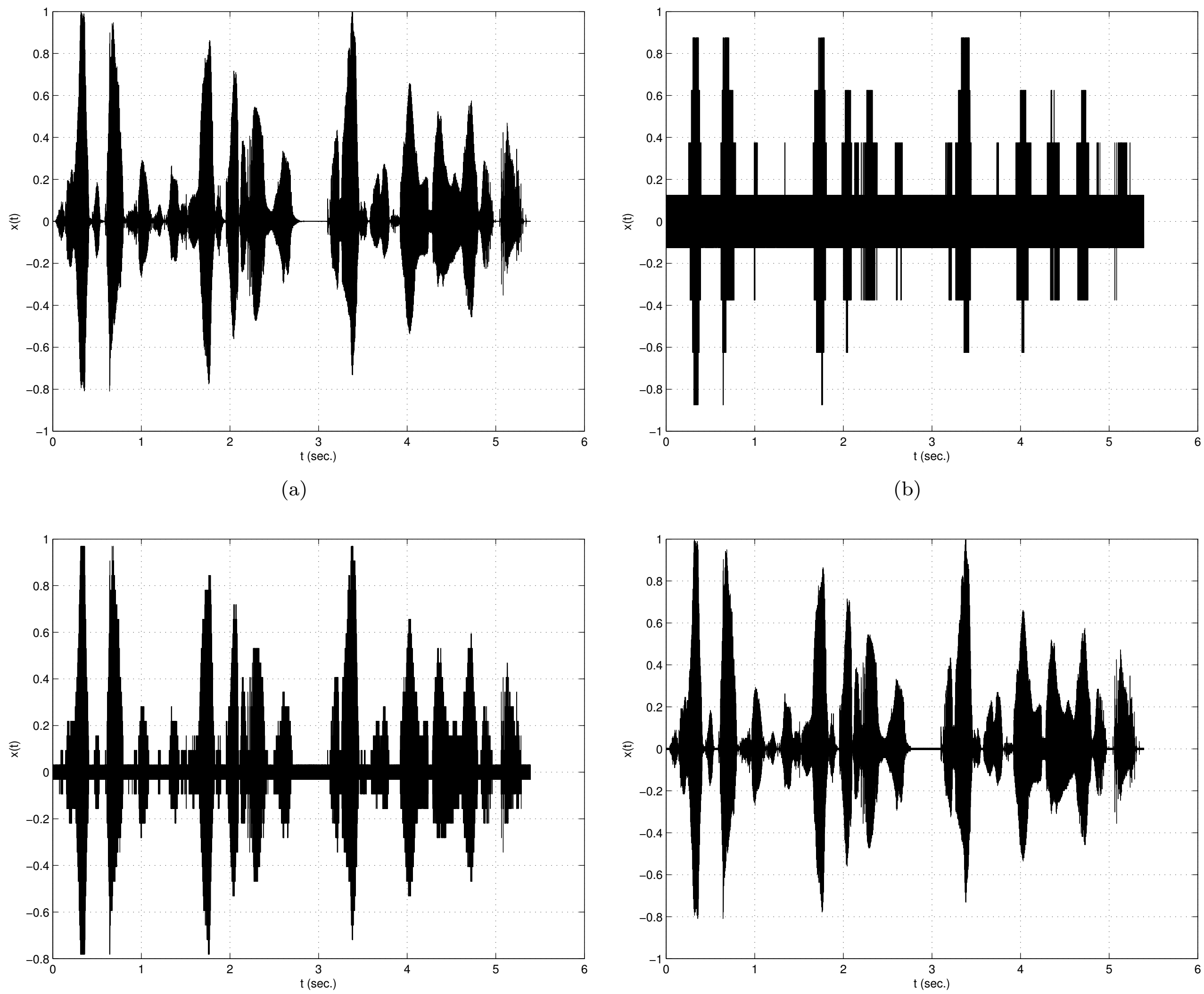
A	B	SNR (dB)
1	3	19.0646
	5	31.0939
	8	48.7230
0.5	3	12.8068
	5	25.2275
	8	42.3531
0.25	3	6.4433
	5	19.0657
	8	36.3386

Prob. 4

(a) $f_s = 16000$ Hz and $B = 16$ bits.

(b) As the resolution is lowered, we clearly hear more noise in the signal.

(c) Plots are shown in Fig. 1



(a) (b) (c) (d)

Figure 1: TIMIT signals with (a) 16 bits, (b) 3 bits, (c) 5 bits, and (d) 8 bits resolution.

(d) Histograms are shown in Fig. 2. For lower sample resolution, we clearly see much higher quantizer error. Histograms are mostly uniform-distributed.

Textbook Problems

Solutions to 1.2, 1.3, 1.9, 1.18 may be found in the online solution manual.

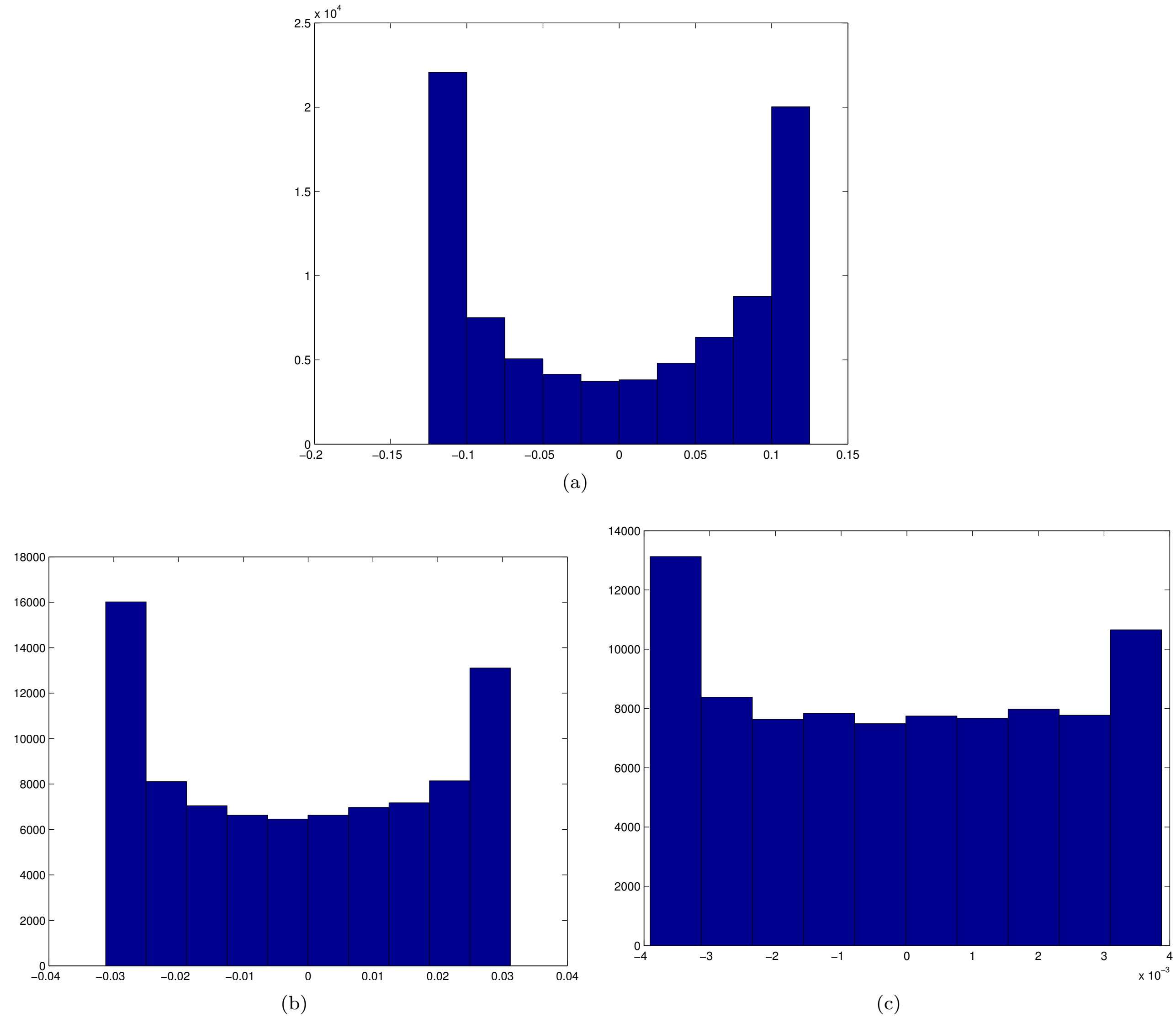


Figure 2: Histograms.