EE302 Problem Set 20

1. A D/A converter has a 12-bit binary input and the output voltage range is 0 to 5 V. How many discrete levels does this 12-bit D/A converter produce? What is the smallest voltage increment (resolution)?

levels: __$2^N = 2^{12} = 4096$__

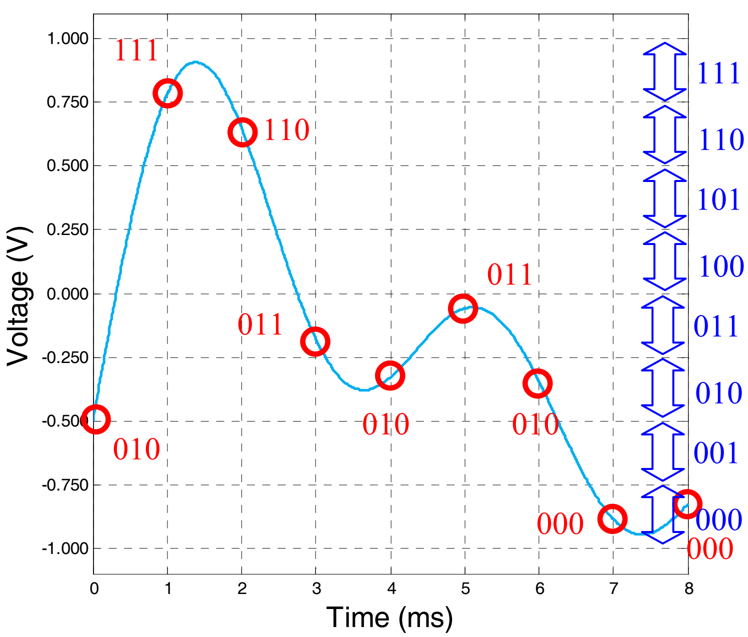
resolution: _$q = \frac{v_{max} - v_{min}}{2^N} = \frac{5-0}{4096} = 1.22 \text{ mV}$_

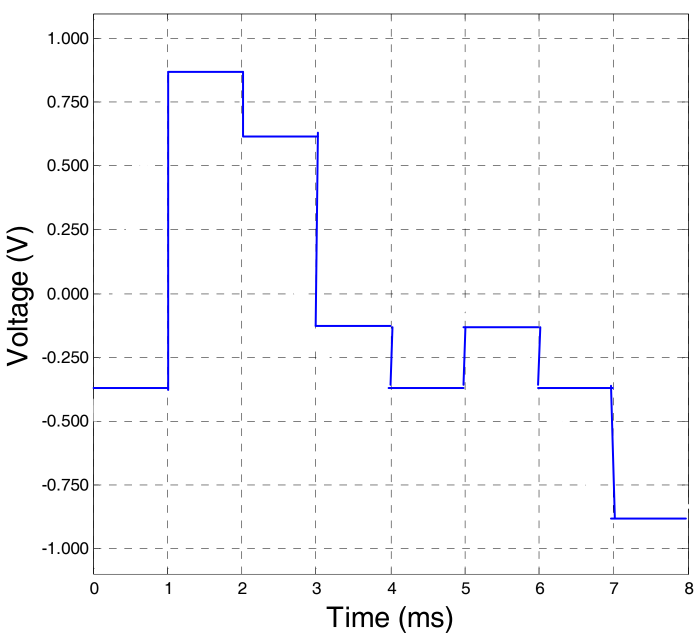
2. What is the dynamic range (DR) of a 12-bit converter (in dB) ? _$DR = 6.02 \cdot N = 72.74 \text{ dB}$_

2. Consider the following analog waveform. This waveform is to be sampled at a 1-kHz rate and quantized with a 3-bit quantizer (input range -1.0 to +1.0 V).

a. What is the resolution (q) of this quantizer? $q =$ __$\frac{v_{max} - v_{min}}{2^N} = \frac{1-(-1)}{8} = 0.25 \text{ V}$___

b. Circle the sample points on the analog waveform below.
c. Indicate the quantization intervals and corresponding binary values.
d. Indicate the binary number assigned to each sample point.
e. Sketch the reconstructed waveform at the D/A.





f. Consider the bit stream below representing the digitally encoded previous waveform where each sampled point is represented by 3 bits.

010 111 110 011 010 011 010 000 000

The bit sequence "000"corresponding to the sample point at time $t = 7$ ms. The D/A converter produces an output of -0.875 V for an input of "000." Consider the effect of a bit error in transmission. The following three sequence represent the 3 possible single bit errors. Determine the output voltage that would be produced by the D/A converter for each of these 3-bit sequences.

D/A input	bit sequence	D/A output voltage
received code with no error	000	-0.875 V
received code with single bit error (3 possibilities)	001	-0.625 V
	010	-0.375 V
	100	0.125 V

Which bit error sequence produces the most error from the correct output? ___100_________

g. In to order transmit this signal in real time, 3 bits must be transmitted every sampling interval.

010 111 110 011 010 011 010 000 000

What is the required data rate (bits/sec) to transmit this digital signal (recall the sampling rate is 1 kHz)?

$$rate = \left(\frac{1000 \text{ samples}}{1 \text{ s}}\right)\left(\frac{3 \text{ bits}}{1 \text{ sample}}\right) = 3000 \text{ bits/s}$$

g. Now consider a CD-quality recording with a sampling rate of 44.1 kHz with a 16-bit quantizer.

What is the data rate (bits/second) for this case? data rate (mono): ____________

$$rate_{mono} = \left(\frac{44{,}100 \text{ samples}}{1 \text{ s}}\right)\left(\frac{16 \text{ bits}}{1 \text{ sample}}\right) = 705{,}600 \text{ bits/s}$$

Recall that CDs are stereo, so we have to double this data rate because both the right and left channels are encoded. What is the data rate for stereo?

data rate (stereo):

$$rate_{stereo} = 2 \cdot rate_{mono} = 1{,}411{,}200 \text{ bits/s}$$

Using this information we can estimate the capacity (in minutes) of a compact disk. If a CD contains 700 MB (1 megabyte = 8 388 608 bits), how many minutes of music can it contain?

capacity (minutes): $\left(\frac{700 \text{ MB}}{1}\right)\left(\frac{8{,}388{,}608 \text{ bits}}{1 \text{ MB}}\right)\left(\frac{1 \text{ s}}{1{,}411{,}200 \text{ bits}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right) = 69.35 \text{ min}$

In reality, the actual number of bits on the CD is far higher than what the 700 MB would indicate due to administrative data and error correcting coding used to protect against bit errors caused by physical defects in the CD surface.