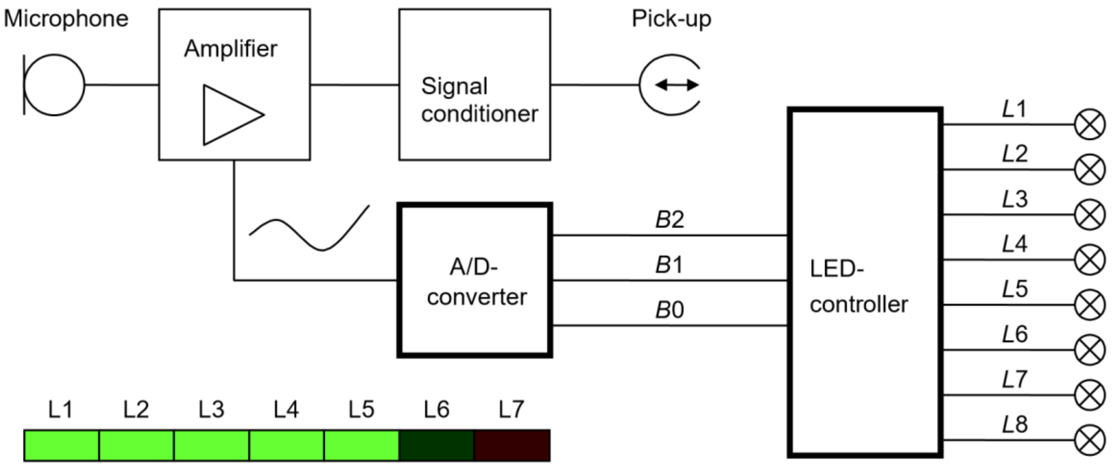
A/D-conversion

1 Principle of A/D-conversion

Following block diagram shows how a sound level indicator of a tape recorder is connected led display bar.

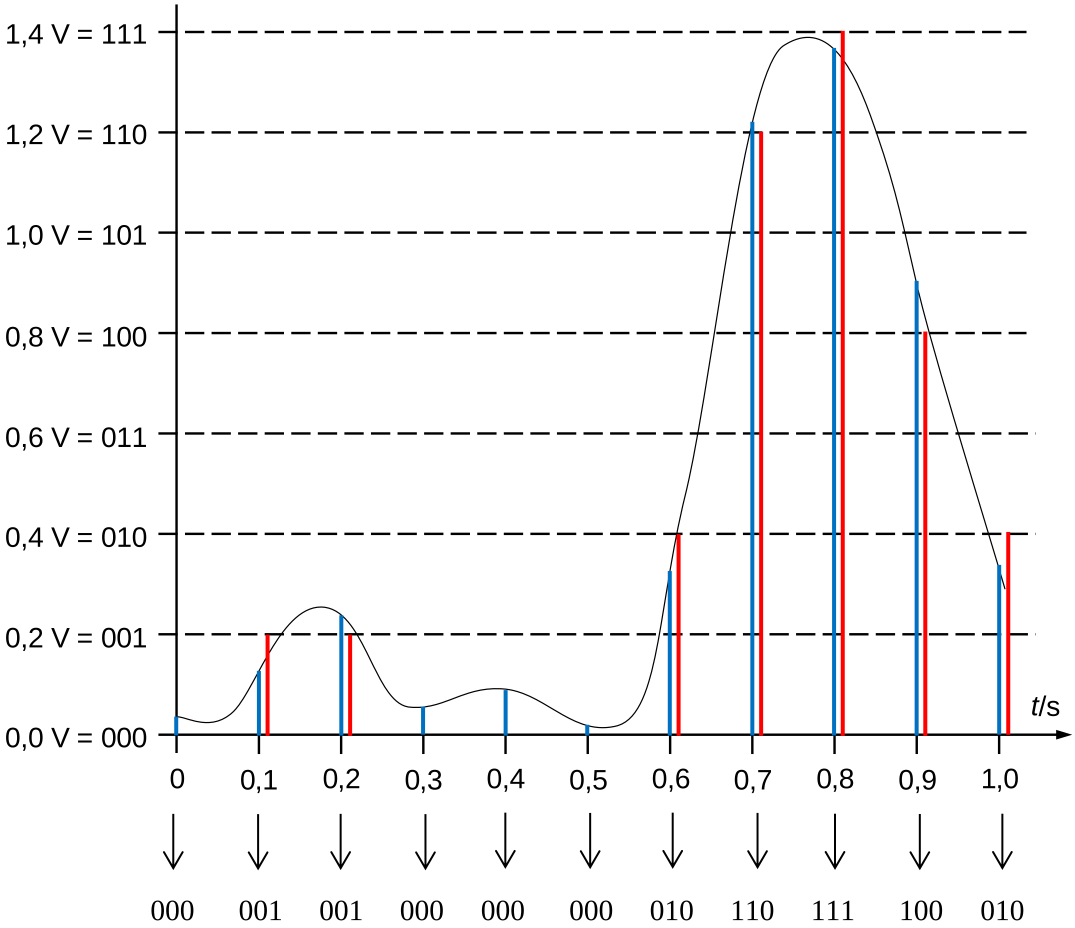


Diodes L1-L7 form a bar display where the length of the bar corresponds to sound level. A louder sound lights a longer part of the bar than a quieter sound. Binary value 000 lights no leds and binary value 111 lights leds L1-L7. In the picture above the binary value of sound level is 5 (101 binary). Led L8 is an indicator that isn't part of the led bar. L8 is on if the sound level is lower than the maximum value. L8 is switched off when 111 is fed into the led controller.

1.1 A/D-conversion, linear quantization

Graph shows a one second audio signal from a microphone. Audio signal is connected to an A/D-converter. It is known that highest possible signal voltage is 1.4 volts. Signal is represented as a three-bit binary number. Binary number 000 corresponds to 0 volts and binary number 111 corresponds to 1.4 volts. Quantization is linear which means that voltage difference is constant between any two successive codes.

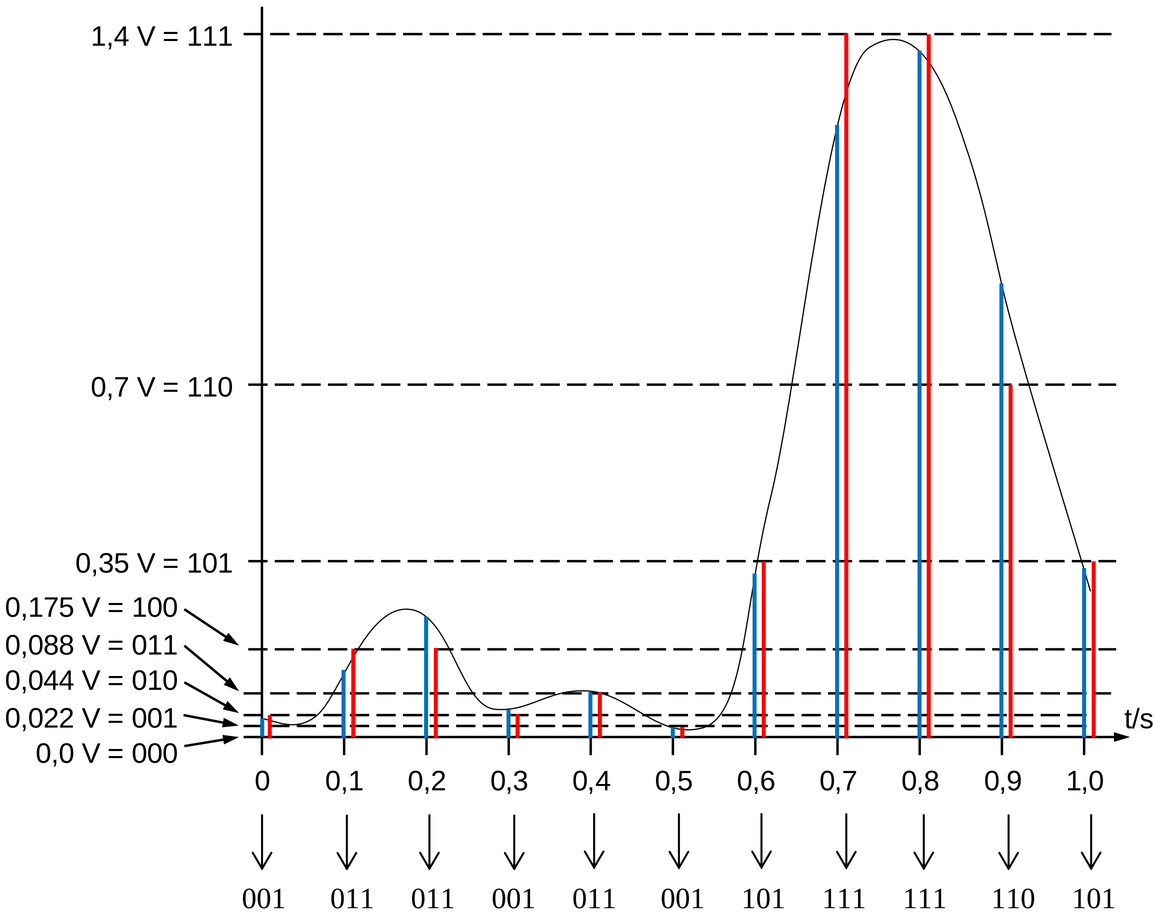
Draw sample value into the picture when first sample is taken at $t = 0$ and successive samples are taken 0,1 second intervals. Draw also quantized sample with different colors and mark corresponding binary values next to the quantized sample.



1.2 A/D-conversion, logarithmic quantization

Audio signal is often converted to digital form using logarithmic quantization. Quantization levels of logarithmic quantization are smaller closer to zero and larger at higher voltages.

Following graph shown logarithmic quantization levels and same audio signal as previous graph. Perform quantization and coding the same ways as with previous graph and mark binary values next to each quantized signal.



1.3 Comparison of quantization methods

Compare quantization methods by coloring the number of leds corresponding to each quantized sample.

Linear quantization							
Time	L1	L2	L3	L4	L5	L6	L7
0,0 s							
0,1 s							
0,2 s							
0,3 s							
0,4 s							
0,5 s							
0,6 s							
0,7 s							
0,8 s							
0,9 s							
1,0 s							

Logarithmic quantization							
Time	L1	L2	L3	L4	L5	L6	L7
0,0 s							
0,1 s							
0,2 s							
0,3 s							
0,4 s							
0,5 s							
0,6 s							
0,7 s							
0,8 s							
0,9 s							
1,0 s							

Which of the quantization methods is better for a sound level display? Why?

Logarithmic quantization is better for a sound level display since it is more sensitive to the changes in sound signal at low levels.

On the other hand, with linear quantization, it can only be detected when there is a significant change in sound signal. Therefore at 0,3s - 0,5s interval no led is lightened up.

2 AD-conversion and physical values

2.1 AD-conversion

Consider a 12-bit linear AD-converter with reference voltage of 3.3 V. What was the ADC input voltage if the ADC value was:

1. 2734

$$Voltage = 2734 \times \frac{3.3}{2^{12}-1} \approx 2.2\,V$$

2. 3999

$$Voltage = 3999 \times \frac{3.3}{2^{12}-1} \approx 3.22\,V$$

3. 137

$$Voltage = 137 \times \frac{3.3}{2^{12}-1} \approx 0.11\,V$$

4. 512

$$Voltage = 512 \times \frac{3.3}{2^{12}-1} \approx 0.4126\, V$$

2.2 AD-conversion

Consider a 14-bit linear AD-converter with reference voltage of 5.0 V. What is ADC output value if the ADC input voltage is:

1. 3.3 V

$$ADC\ value = \frac{3.3}{\frac{5.0}{2^{14}-1}} = 10812.78$$

2. 0.65 V

$$ADC\ value = \frac{0.65}{\frac{5.0}{2^{14}-1}} = 2129.79$$

3. 5.0 V

$$ADC\ value = \frac{5.0}{\frac{5.0}{2^{14}-1}} = 16383$$

4. 2.1 V

$$ADC\ value = \frac{2.1}{\frac{5.0}{2^{14}-1}} = 6880.86$$