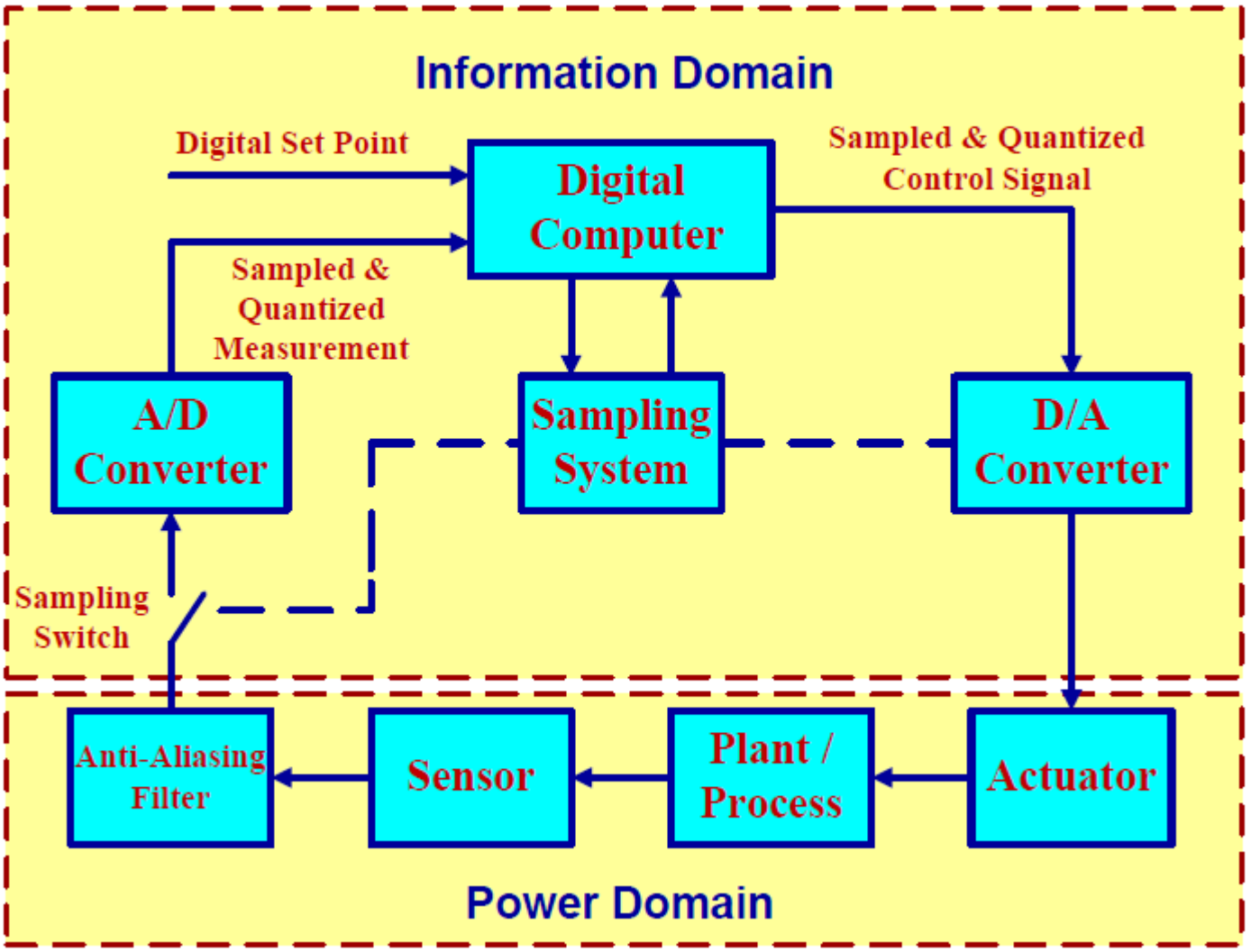
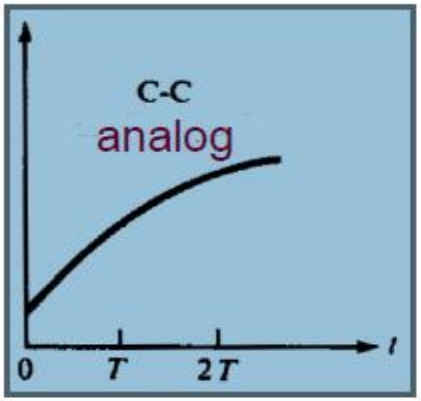
Εισαγωγικές έννοιες Ψηφιακών Συστημάτων Αυτομάτου Ελέγχου

(Introductory concepts to digital control engineering)

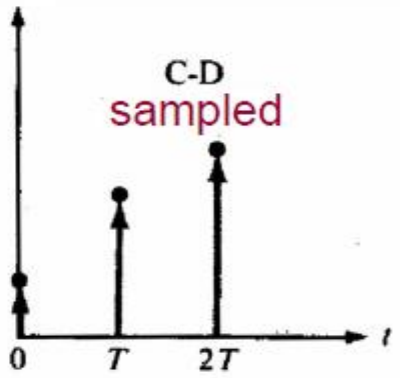
Σύστημα Ψηφιακού Ελέγχου



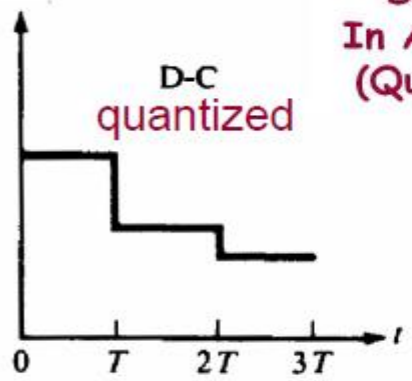
Είδη σημάτων

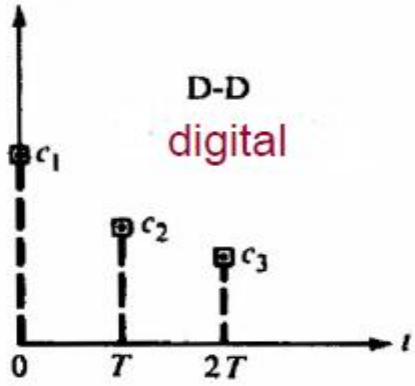


Computer-Controlled System Signals

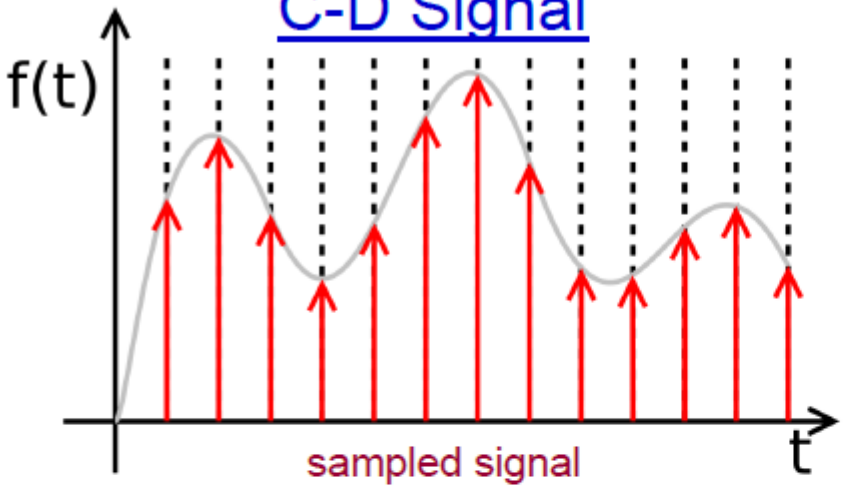


	Continuous In Time	Discrete In Time (Sampled)
Continuous In Amplitude	C-C	C-D
Discrete In Amplitude (Quantized)	D-C	D-D





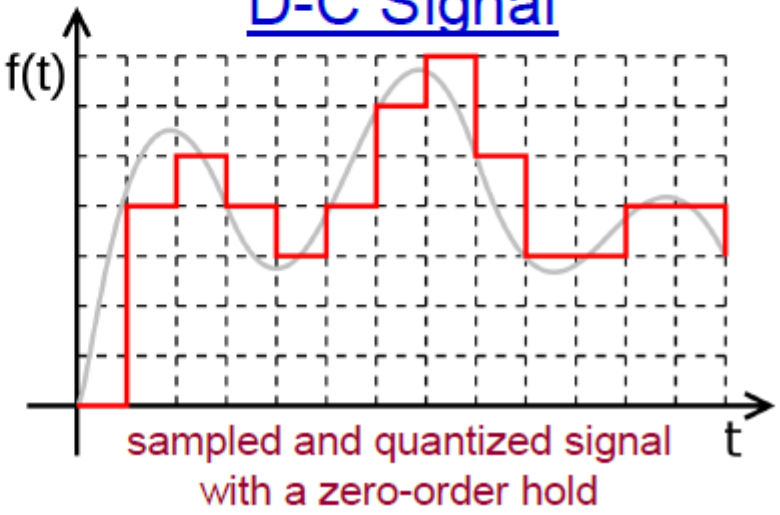
C-D Signal



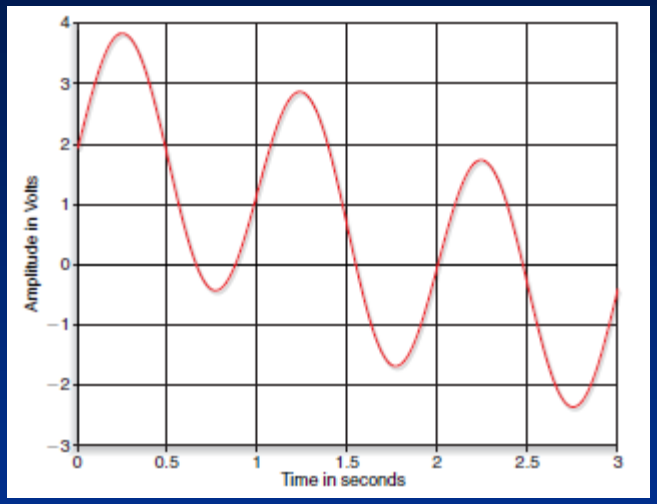
Zero-Order Hold

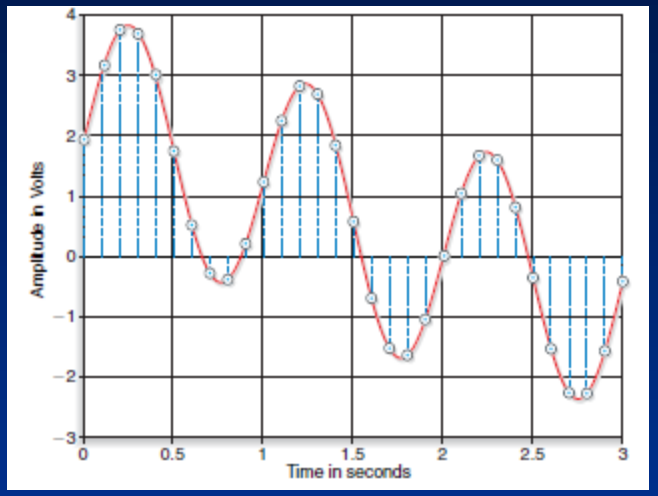
Sampled and quantized values are held constant between sampling instants, which makes the signal discrete in amplitude, but continuous in time.

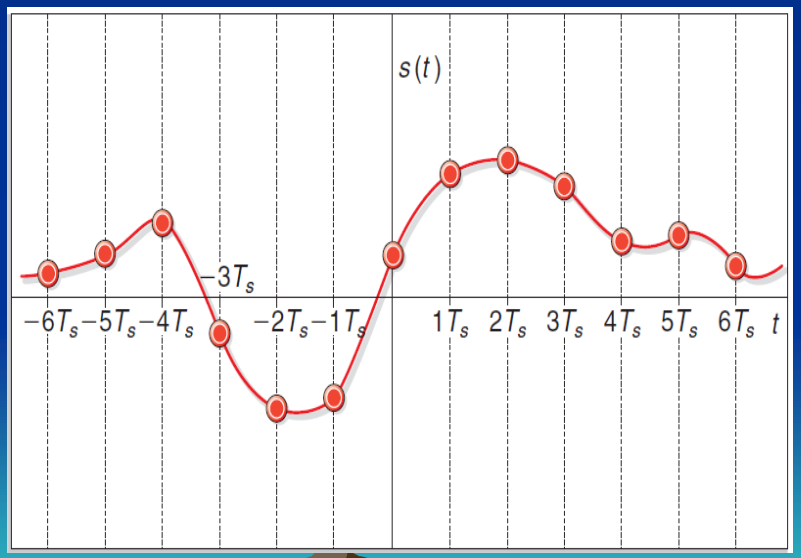
D-C Signal

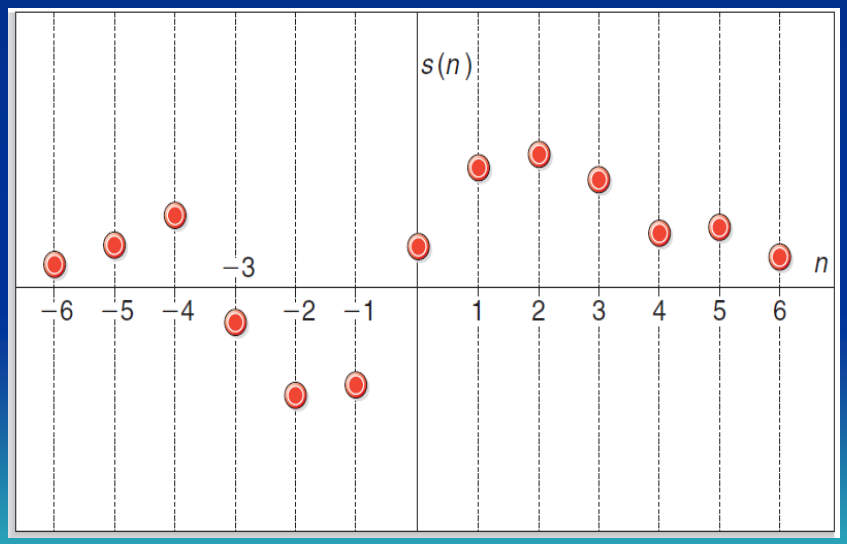


Δειγματοληψία σήματος



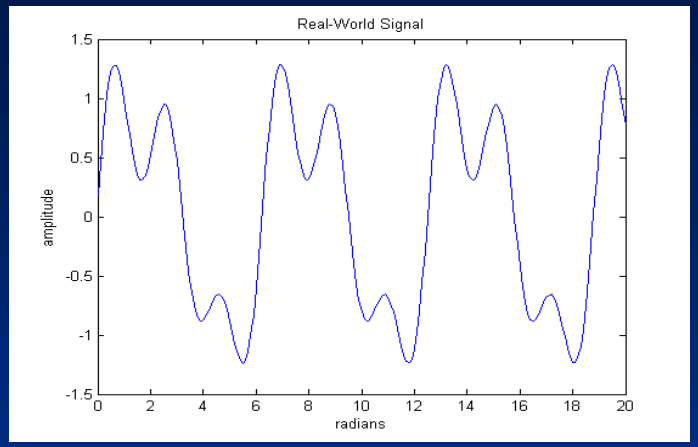


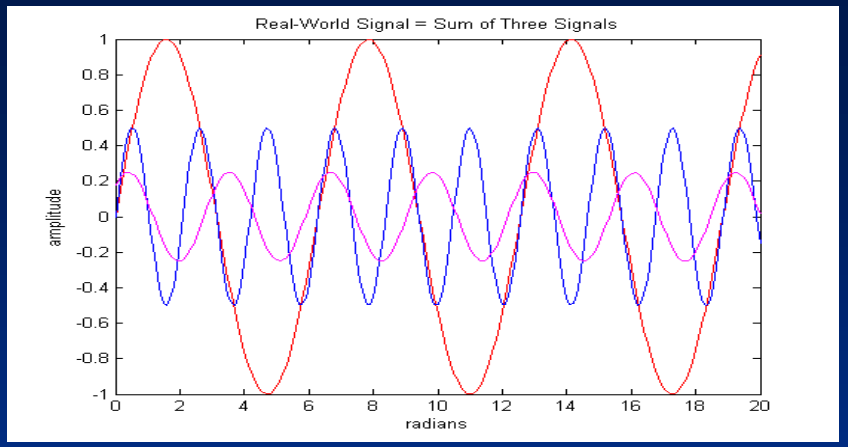




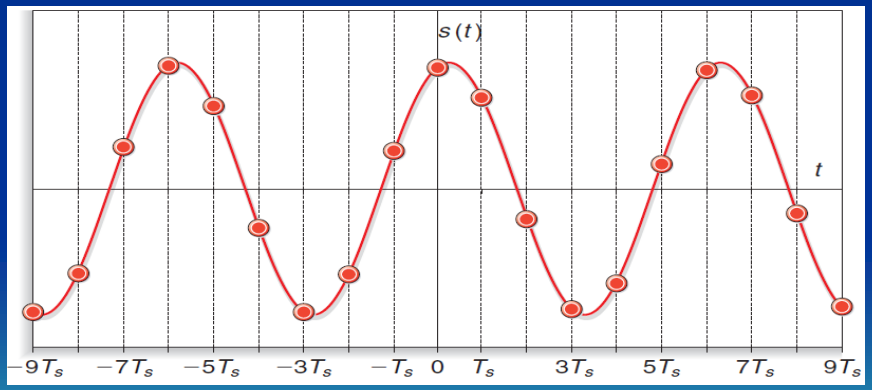
συχνότητα δειγματοληψίας $f_s = 1/T_s$ ακολουθία αριθμών $s[n]=s[nT_s]$ με $n=0, \pm1, \pm2....$

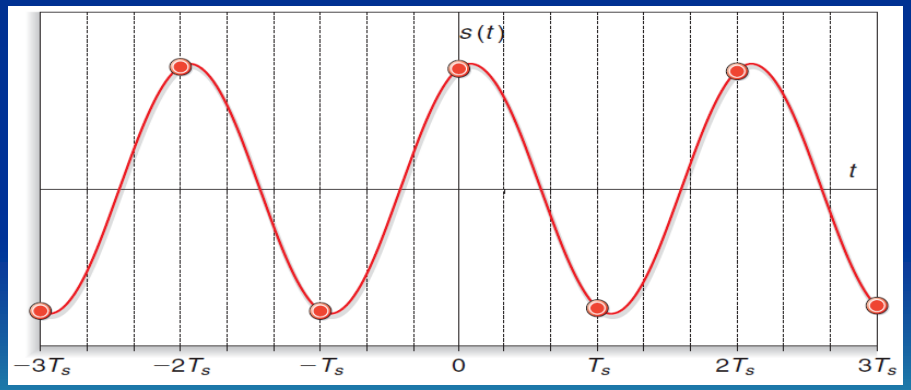
Θεώρημα Δειγματοληψίας Nyquist





Ένα σήμα μπορεί να διασπαστεί σ' ένα άθροισμα ημιτονοειδών σημάτων και αυτός ο συνδυασμός είναι μοναδικός





Ένα σήμα δειγματοληψίας μπορεί να μετατραπεί στο αρχικό αναλογικό σήμα εάν η $f_s > 2f_{highest}$

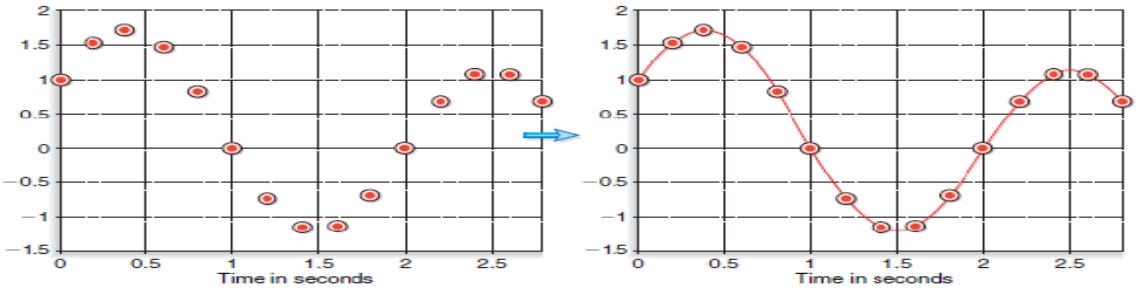
Θεώρημα Δειγματοληψίας Nyquist

Το εύρος ζώνης σήματος αναφέρεται στη διαφορά μεταξύ της $f_{highest}$ από την $f_{minimum}$. Γενικά πρέπει $f_s > 2f_{BW}$.

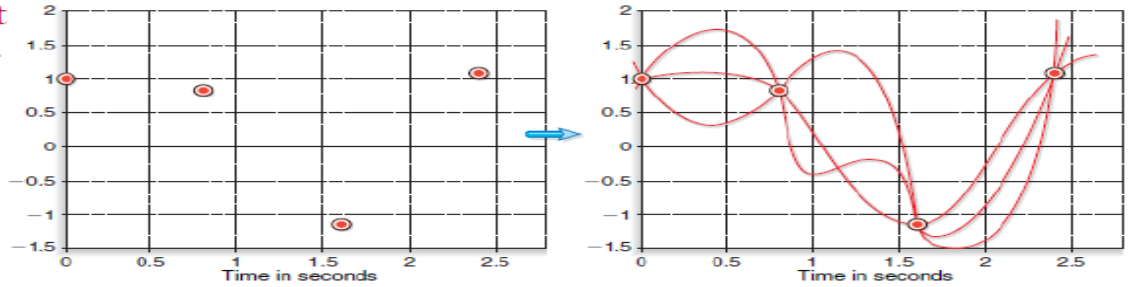
Signal Type	Signal Bandwidth	Minimum Sampling Rate	Rate Actually Used
Telephone-quality speech	3.5 kHz	7000 samples/s	8000 samples/s
Music	20 kHz	40,000 samples/s	44,100 samples/s
FM radio	200 kHz	400,000 samples/s	500,000 samples/s
Standard-definition television	6 MHz	12,000,000 samples/s	14,400,000 samples/s

Nyquist Rate

Signal sampled above the Nyquist rate and reconstructed.

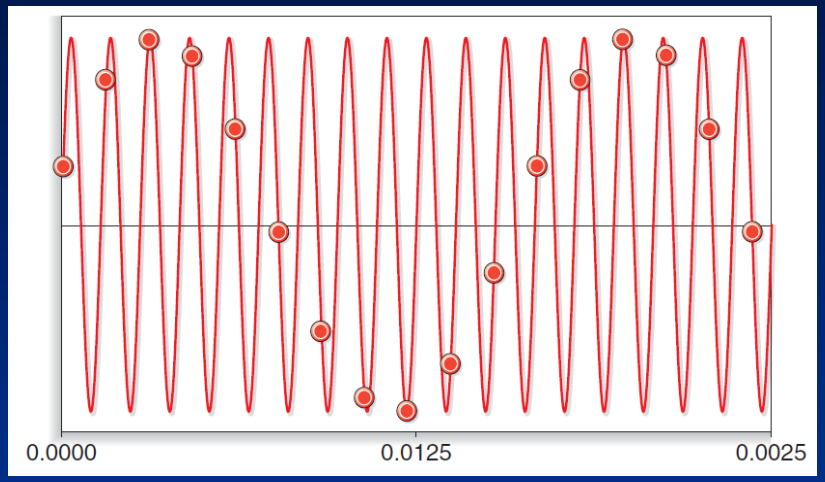


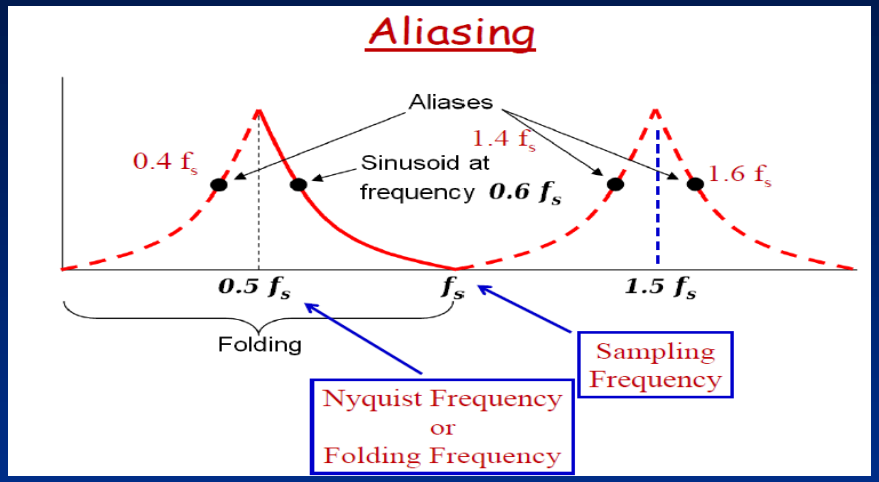
Signal sampled below the Nyquist rate. Many band-limited signals with bandwidth $> f_s/2$ that pass through the samples can be reconstructed.



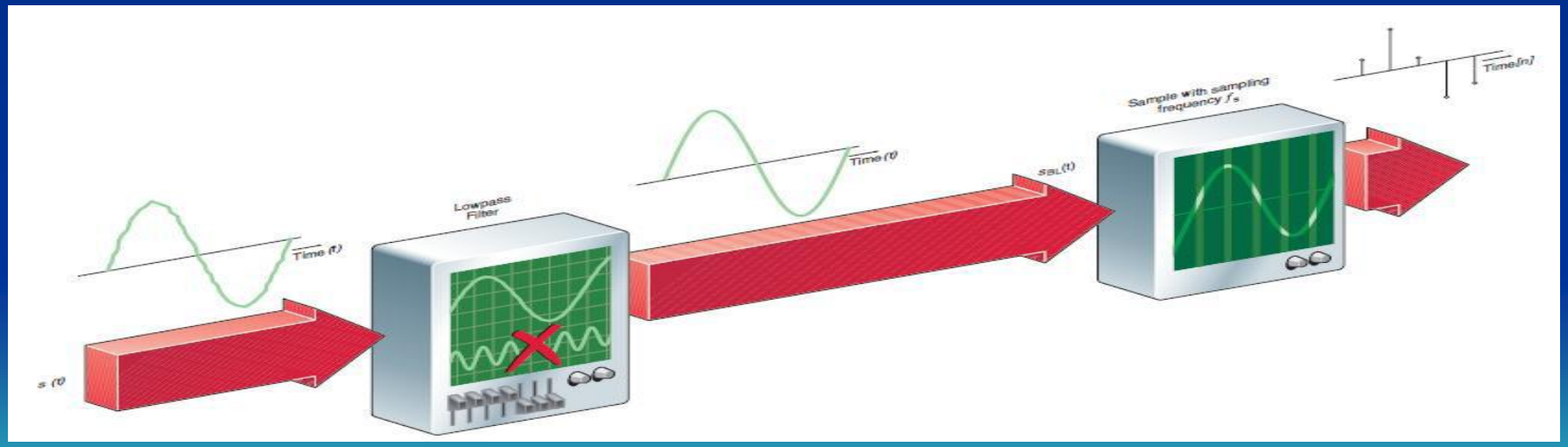
Which signal is correct?

Ψευδοαναδόμιση (aliasing)



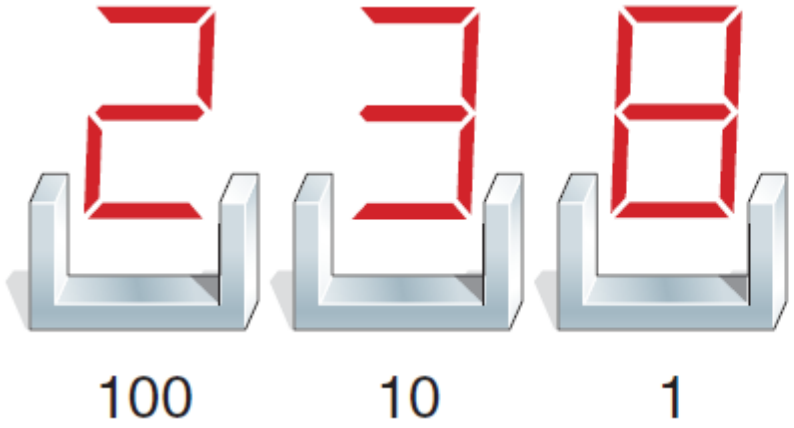


σήμα 720 Hz εμφανίζεται σαν 60 Hz αν $f_s = 660\text{Hz}$

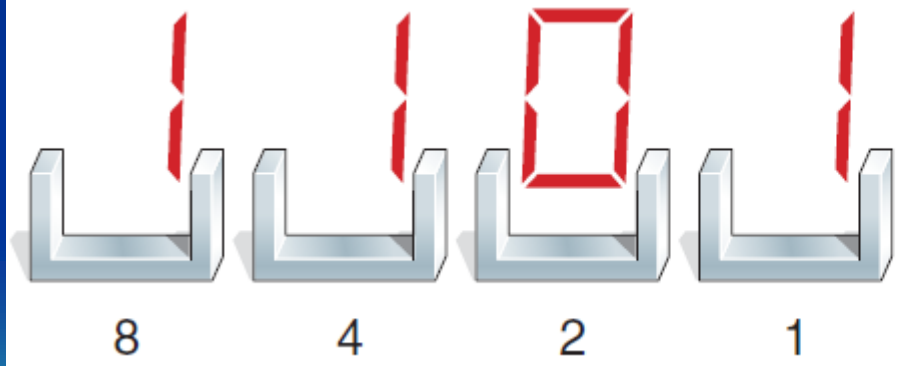


Χαμηλοπερατό φίλτρο antialiasing προσθέτει χρονική καθυστέρηση- Απόδοση

Δυαδικοί αριθμοί - Η ψηφιακή επιλογή



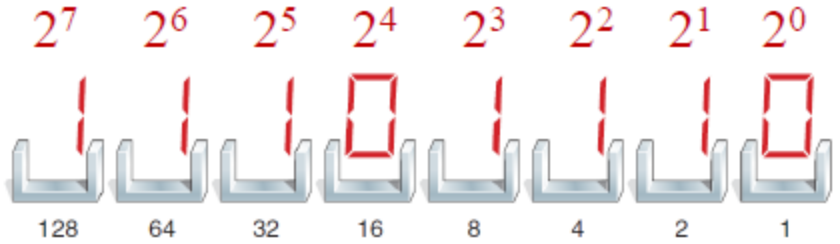
$$238 = 2(100) + 3(10) + 8(1)$$



$$13 = 1(8) + 1(4) + 0(2) + 1(1)$$

Μετατροπή από δυαδική σε δεκαδική μορφή και αντίστροφα

$11101110_2 = 238_{10}$ ⟶

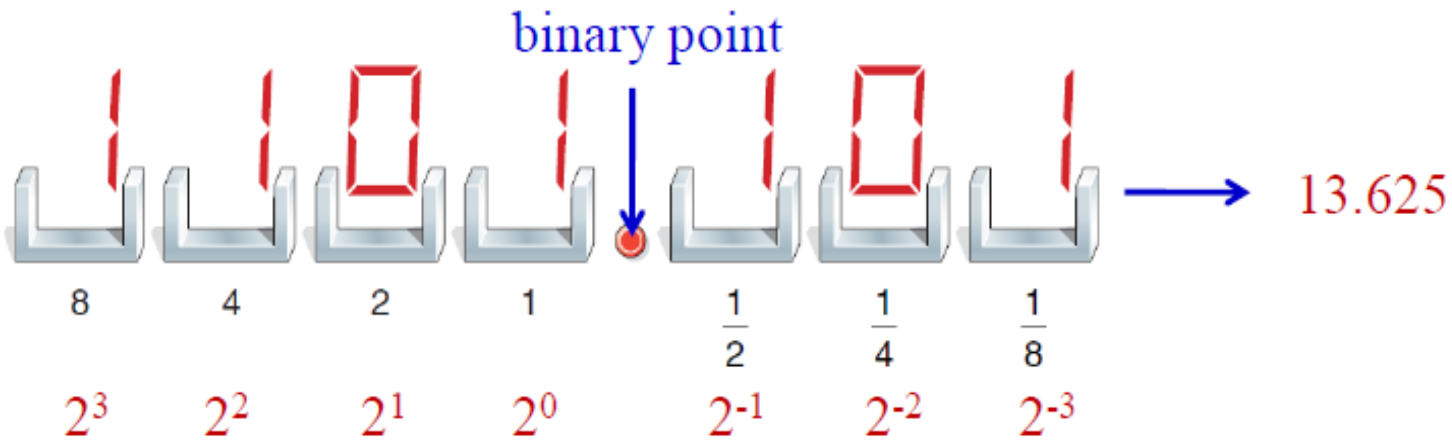


$$B_7(2^7)+B_6(2^6)+B_5(2^5)+B_4(2^4)+B_3(2^3)+$$
$$B_2(2^2)+B_1(2^1)+B_0(2^0)=213$$
$$B_7(128)+B_6(64)+B_5(32)+B_4(16)+B_3(8)+$$
$$B_2(4)+B_1(2)+B_0(1)=213$$

$11010101_2 = 213_{10}$

213
−128 ⟶ $B_7=1$
85
−64 ⟶ $B_6=1$
21
32 ⟶ $B_5=0$
−16 ⟶ $B_4=1$
5
8 ⟶ $B_3=0$
−4 ⟶ $B_2=1$
1
2 ⟶ $B_1=0$
−1 ⟶ $B_0=1$

Μετατροπή από δυαδική σε δεκαδική μορφή και αντίστροφα

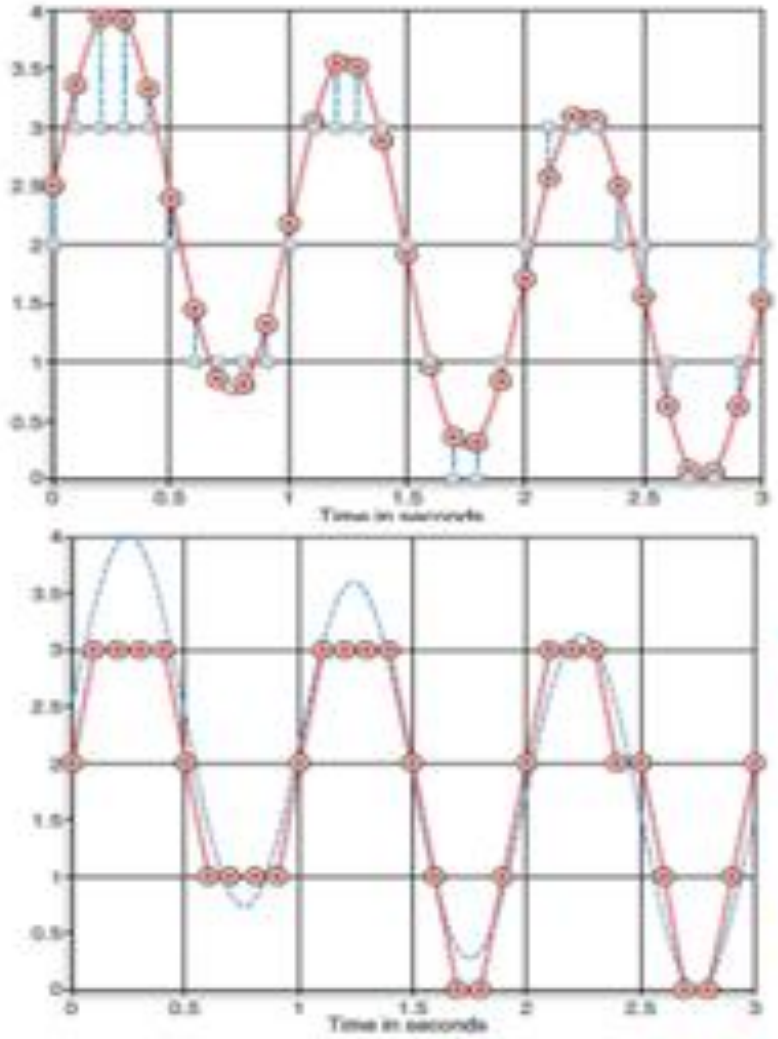


$$1101.101_2 = (1\times 2^3)+(1\times 2^2)+(0\times 2^1)+(1\times 2^0)+(1\times 2^{-1})+(0\times 2^{-2})+(1\times 2^{-3})$$

$$13.625_{10} = (1\times 10^1)+(3\times 10^0)+(6\times 10^{-1})+(2\times 10^{-2})+(5\times 10^{-3})$$

Χρησιμοποίηση Bits για αποθήκευση δειγμάτων: Κβαντοποίηση

True value	Quantized value	Binary number
2.5000	2	10
3.3783	3	11
3.9132	3	11
3.8966	3	11
3.3288	3	11
2.4183	2	10
1.4997	1	01
0.9179	1	01
0.8748	1	01
1.3712	1	01
2.2020	2	10
3.0304	3	11
3.5303	3	11
3.4644	3	11
2.8633	3	11
1.9261	2	10



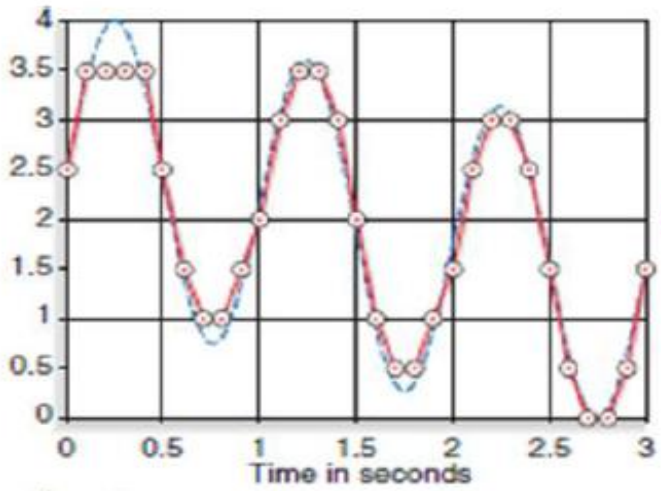
True value	Quantized value	Binary number
0.9901	1	01
0.3938	0	00
0.3430	0	00
0.8413	1	01
1.6800	2	10
2.5228	3	11
3.0333	3	11
3.0835	3	11
2.4338	2	10
1.5323	2	10
0.6359	1	01
0.0811	0	00
0.0761	0	00
0.6295	1	01
1.5060	2	10

Here we are storing each sample with only two bits (4 possible stored states: 0, 1, 2, 3).

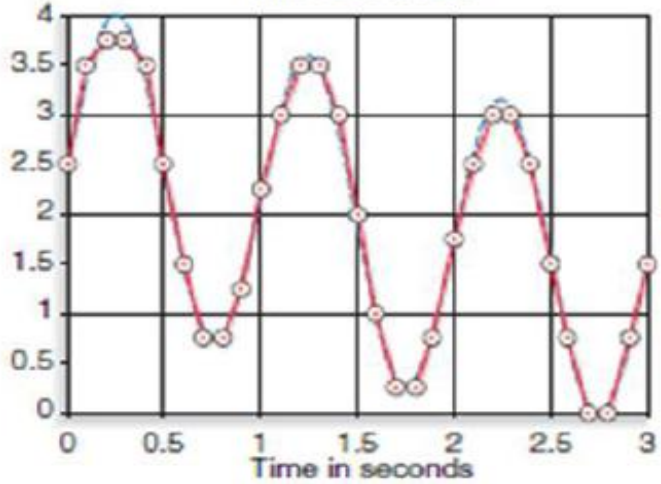
For each signal value s[n], we then round the true value to the nearest of the four levels. This process of signal rounding is a form of quantization.

Digitization: Sampling & Quantization

Χρησιμοποίηση Bits για αποθήκευση δειγμάτων: Κβαντοποίηση

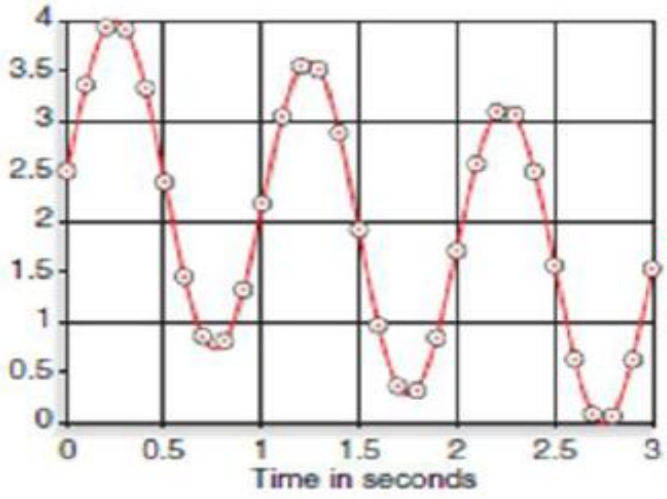


3 Bits



4 Bits

Shown is an analog signal quantized using 3 bits, 4 bits, and 16 bits. Notice how accurate the samples are when stored using 16 bits.



16 Bits

ΒΙΒΛΙΟΓΡΑΦΙΑ

- K. Craig, *Electromechanical Engineering Systems*, Classroom notes, 2011.