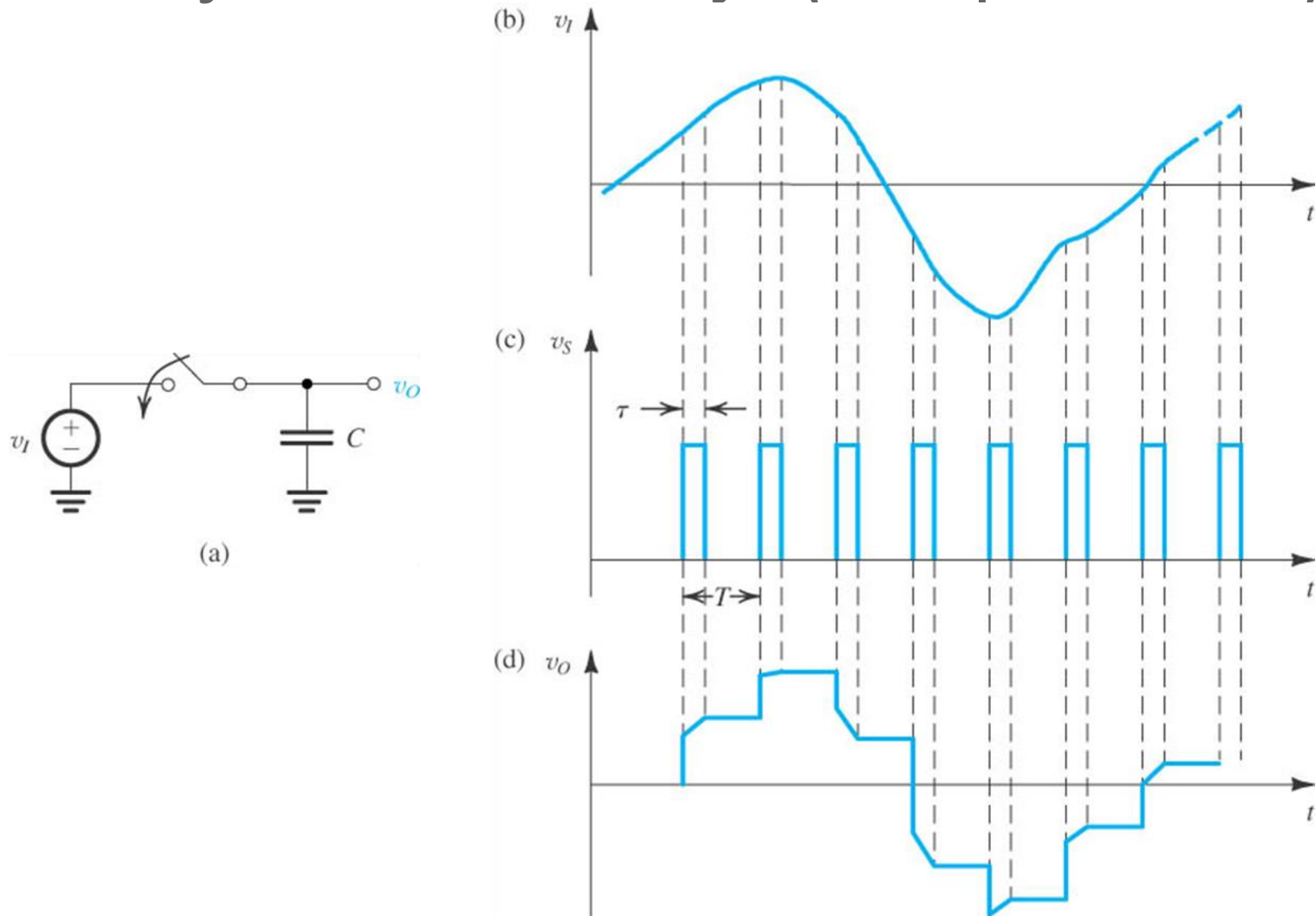


Osnove mikroprocesorske elektronike

doc. dr. Marko Jankovec

A/D pretvorba

Vzorčenje in zadrževanje (Sample&Hold)



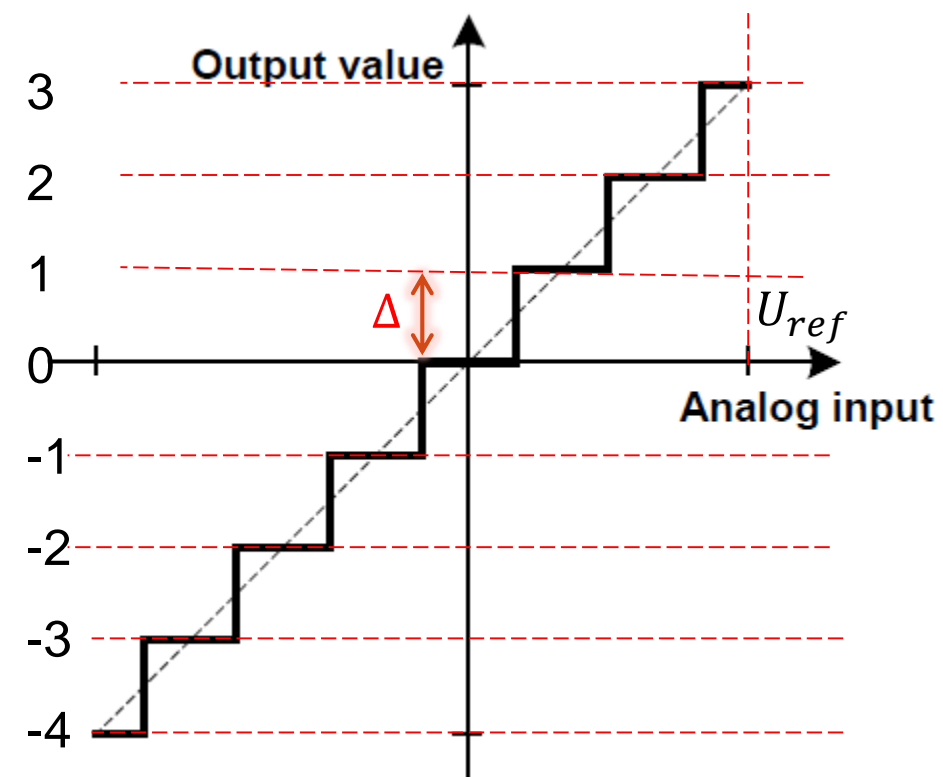
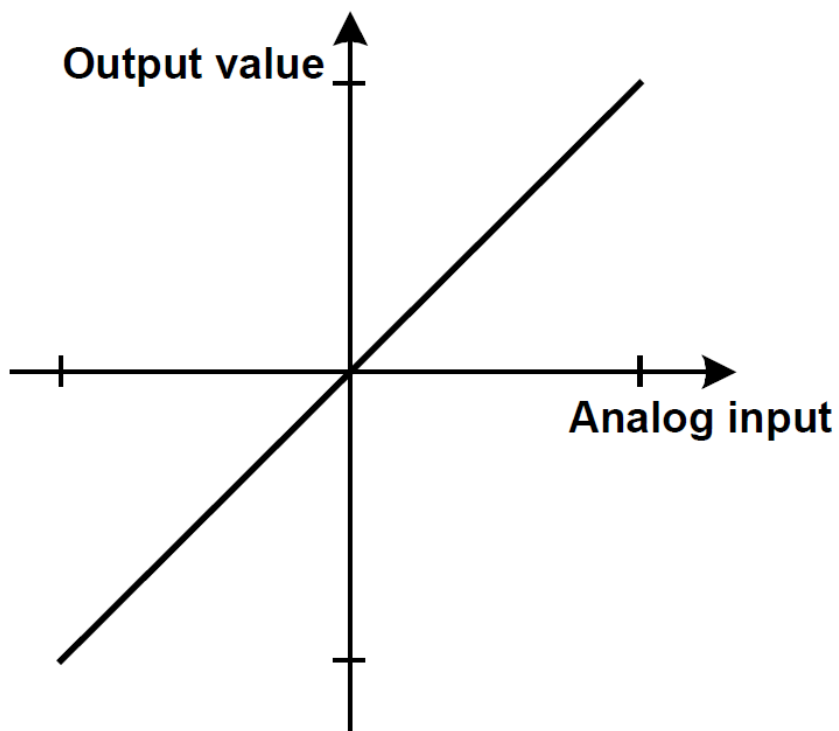
Idealni in realni ADC

$$U_{ref} = 1V \text{ (ref. napetost)}$$

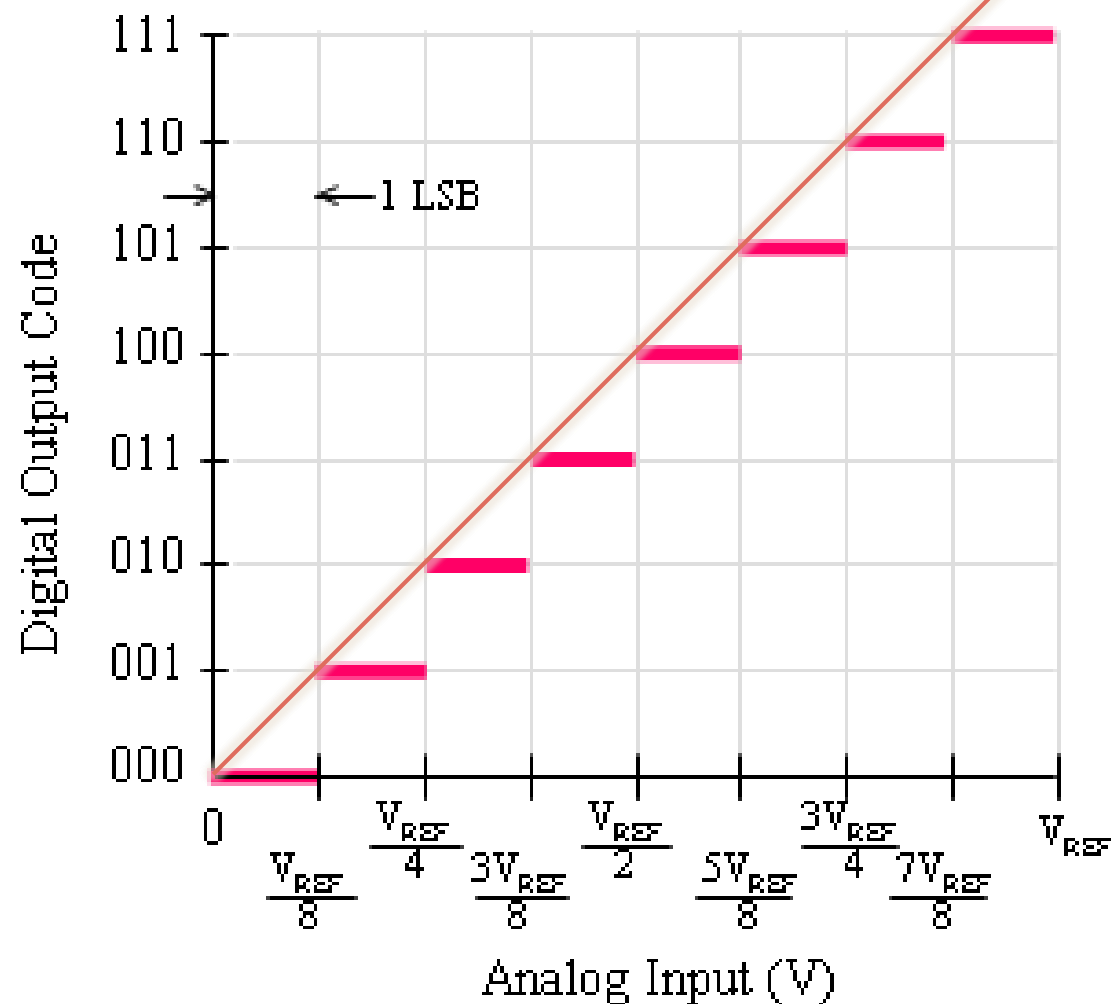
$$Q = 3 \text{ bit (št. bitov)}$$

$$N = 2^3 = 8 \text{ (ločljivost)}$$

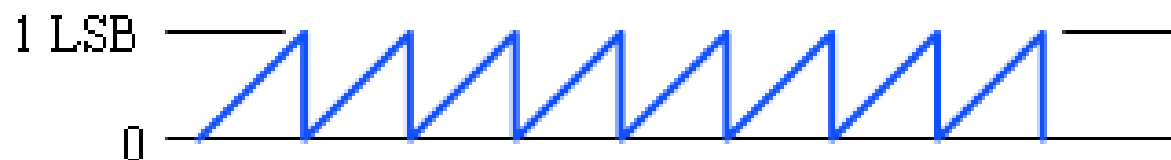
$$\Delta = \frac{U_{ref}}{N} = 125 \text{ mV (LSB)}$$



Kvantizacija

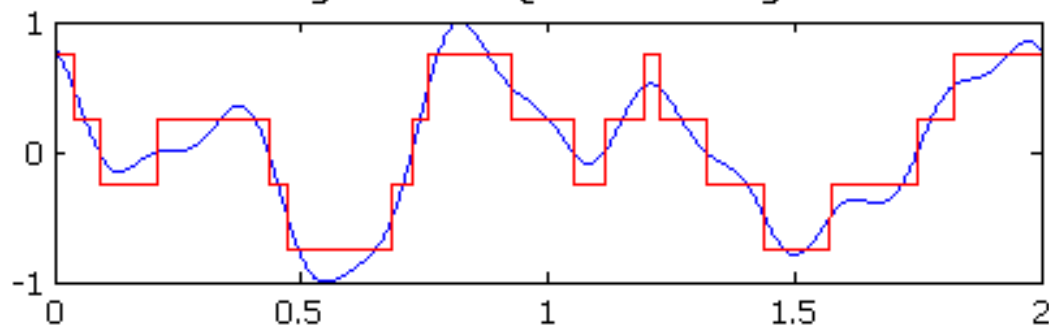


$$Napaka_{maks} = 1 \text{ LSB}$$

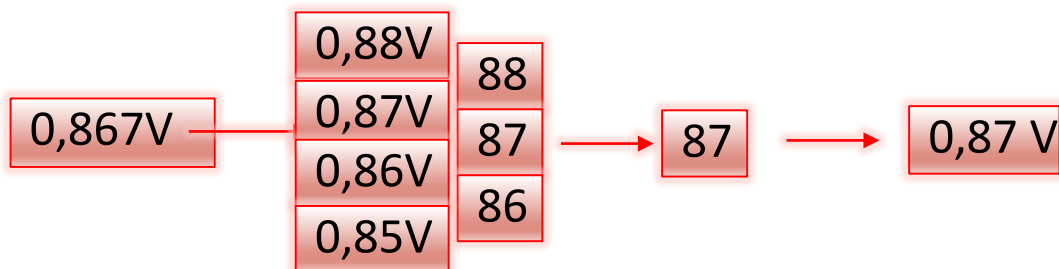
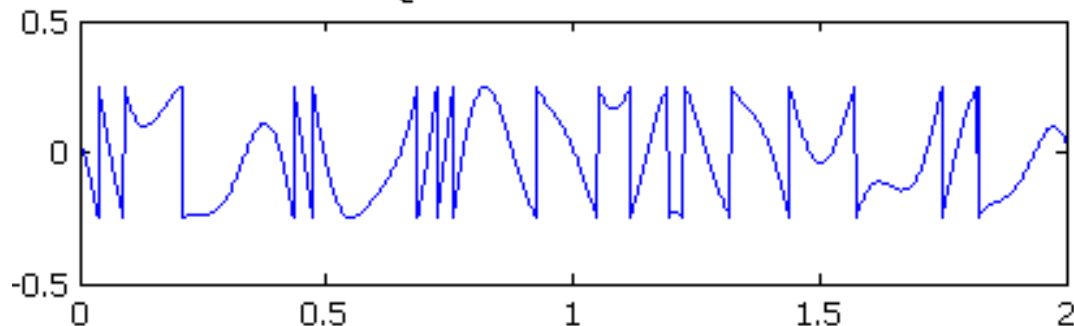


Kvantizacija

Original and Quantized Signal



Quantization Error



$$Napaka_{rms} = \frac{\Delta}{\sqrt{12}}$$

$$SNR = 20 \log(2^Q)$$

$$U_{ref} = 2,56 V \text{ (ref. napetost)}$$

$$Q = 10 \text{ bit (št. bitov)}$$

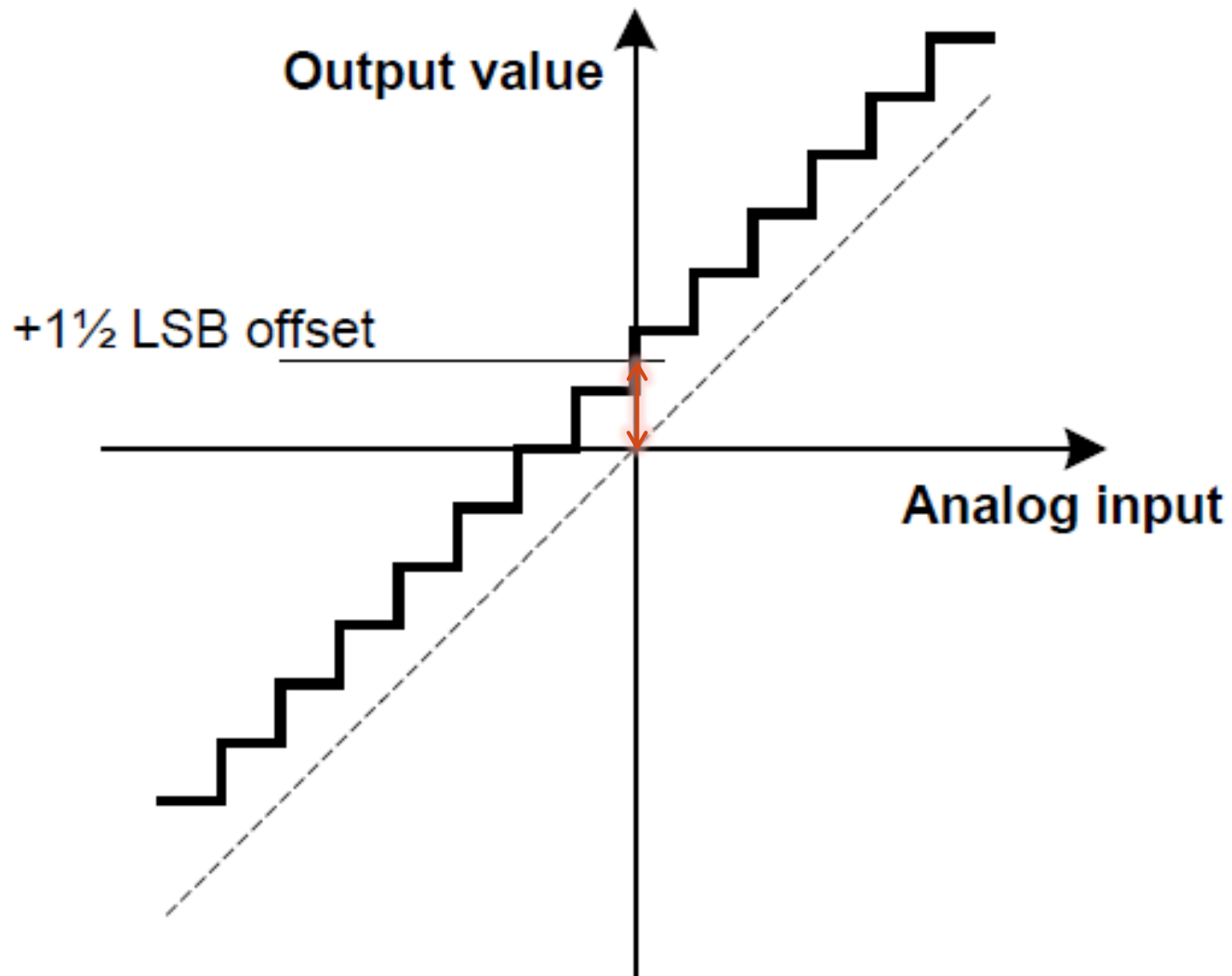
$$N = 2^{10} = 1024 \text{ (ločljivost)}$$

$$\Delta = \frac{U_{ref}}{N} = 2,5 \text{ mV (LSB)}$$

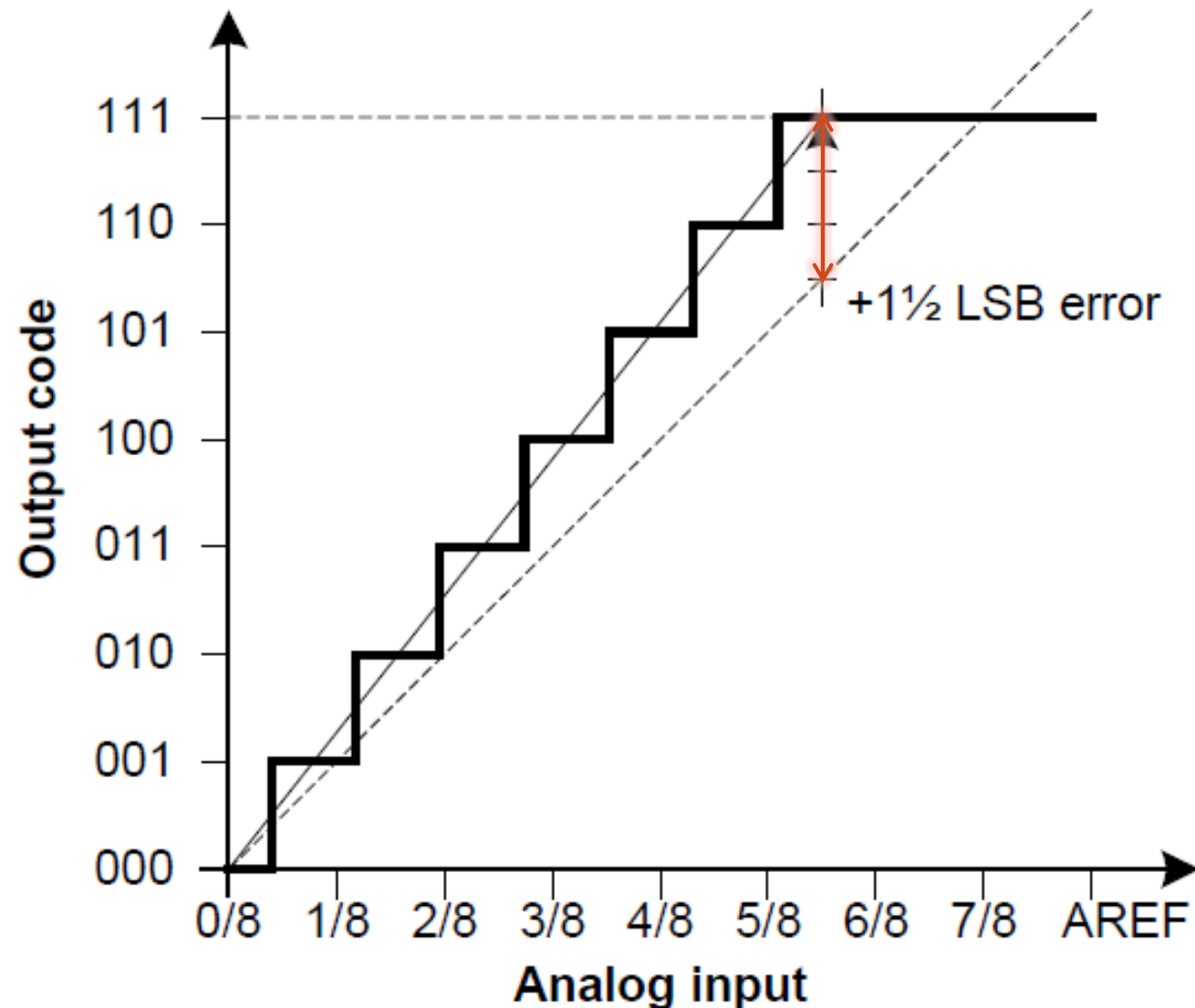
$$Napaka_{rms} = \frac{2,5 \text{ mV}}{\sqrt{12}} = 0,7 \text{ mV}$$

$$SNR = 20 \log(2^Q) = 60 \text{ dB}$$

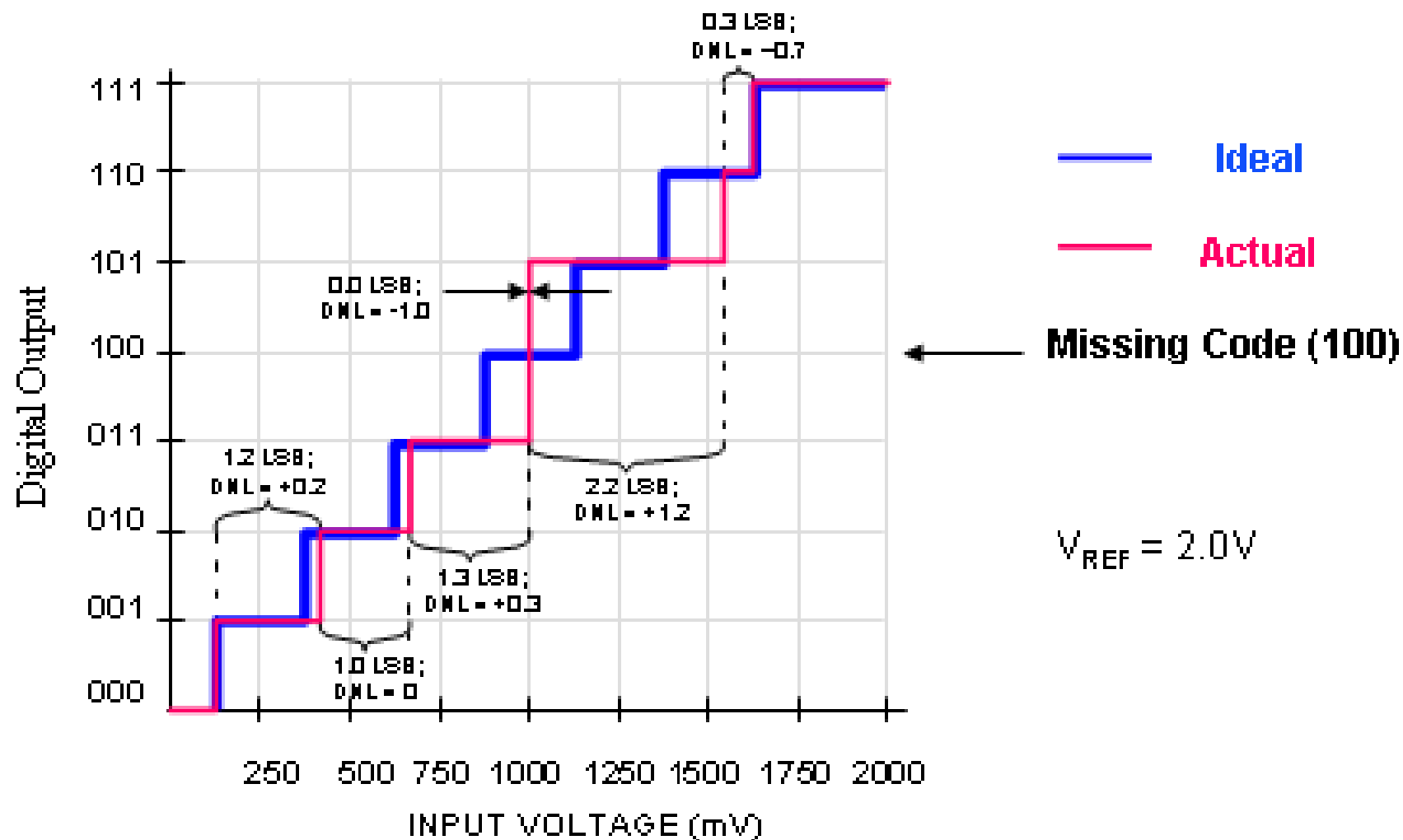
Napaka ničelne vrednosti



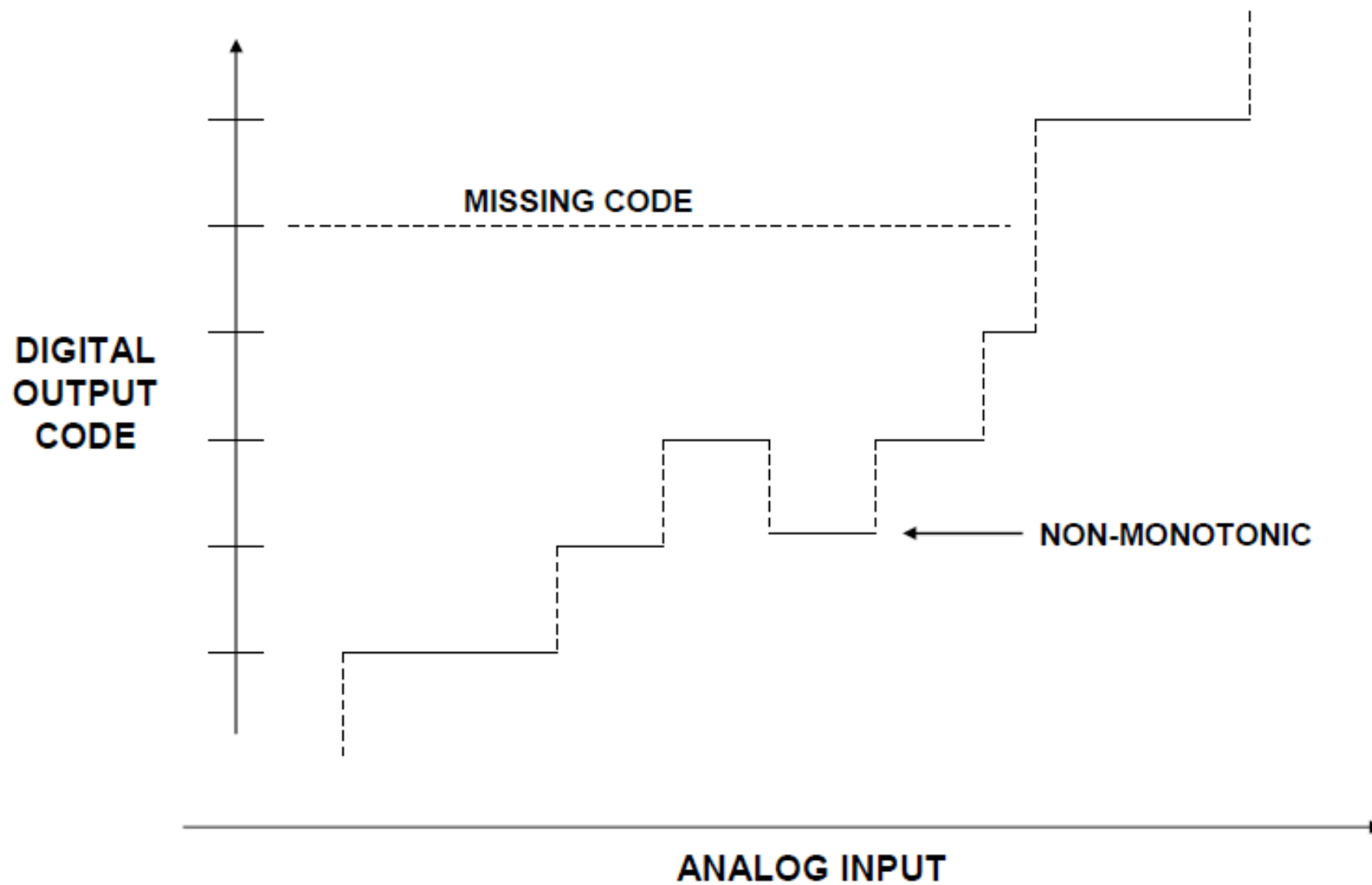
Napaka ojačenja



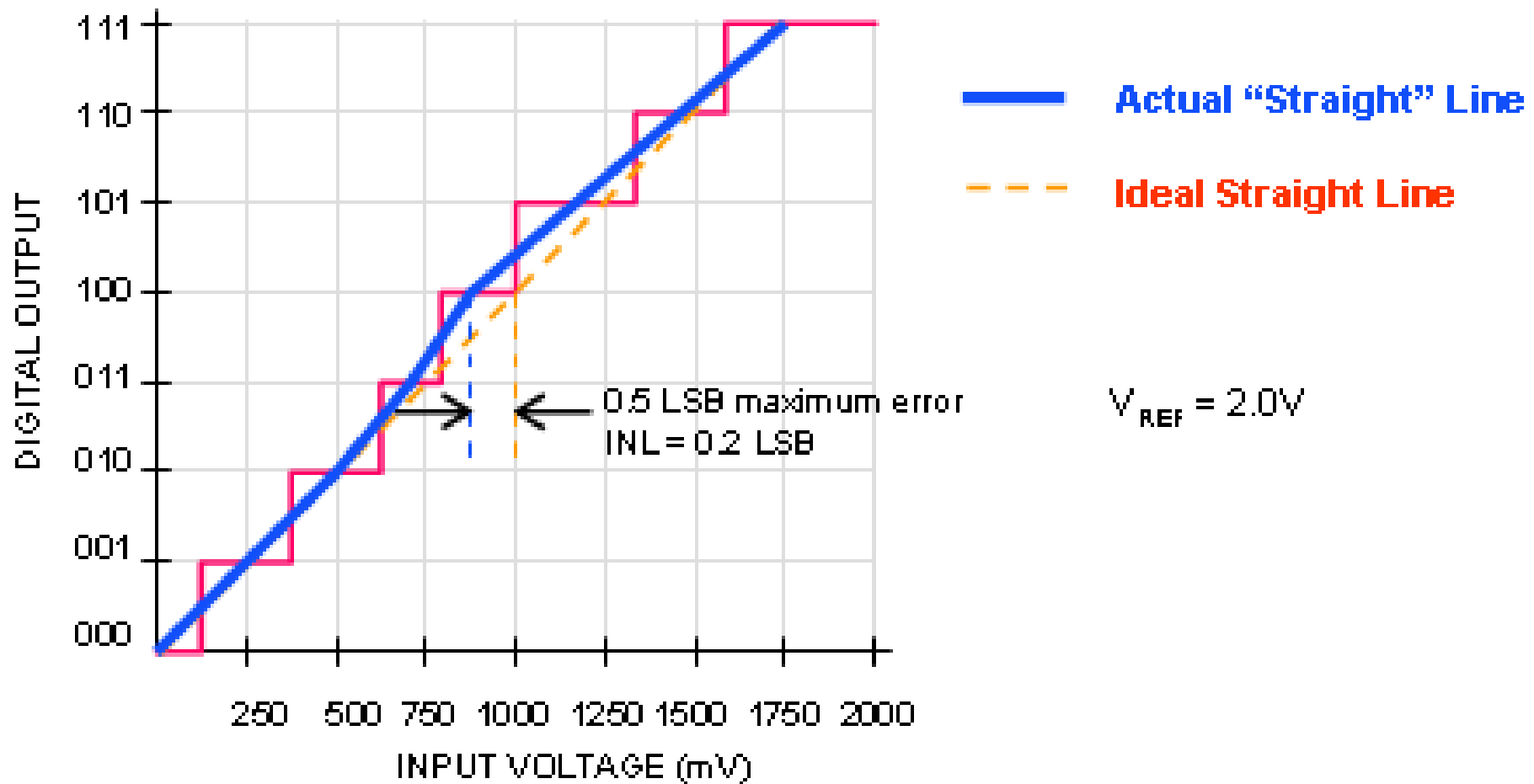
Diferencialna nelinearnost



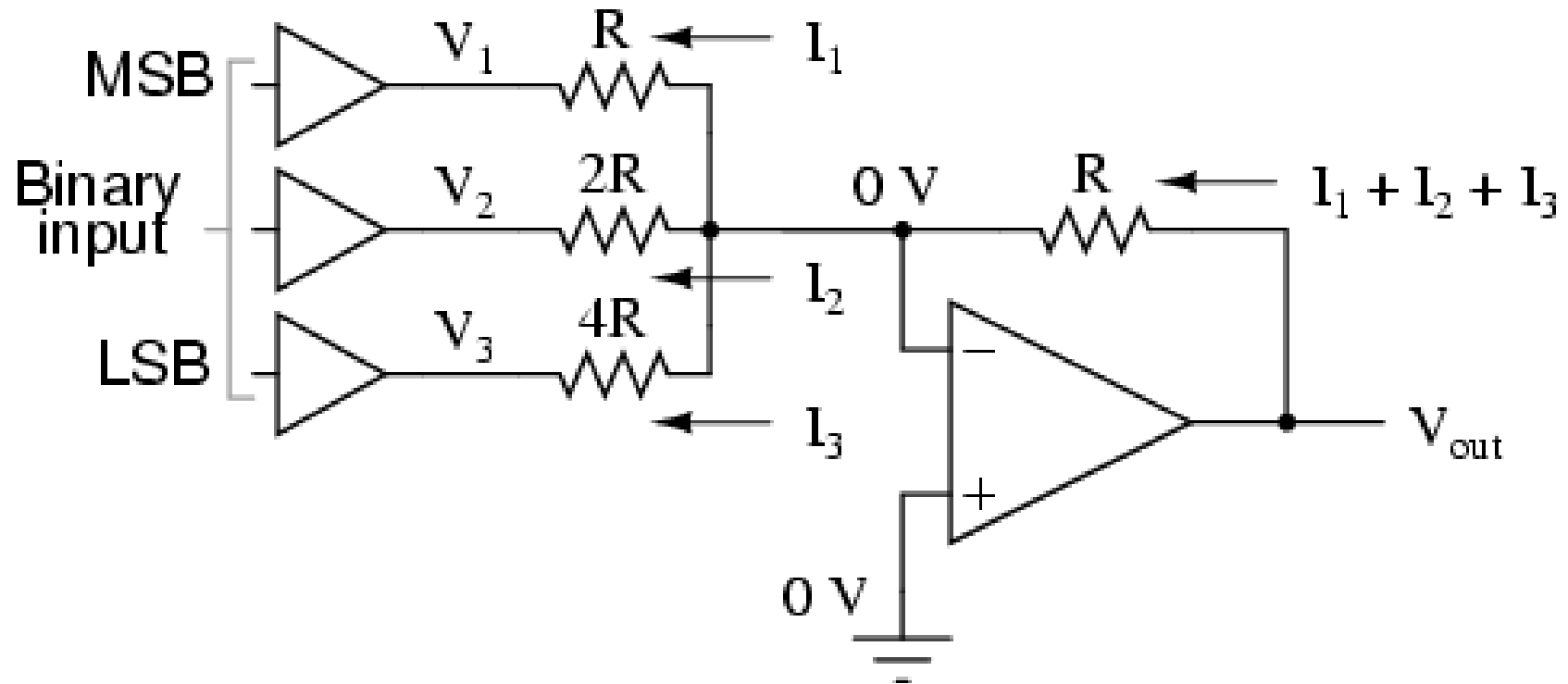
Monotonost



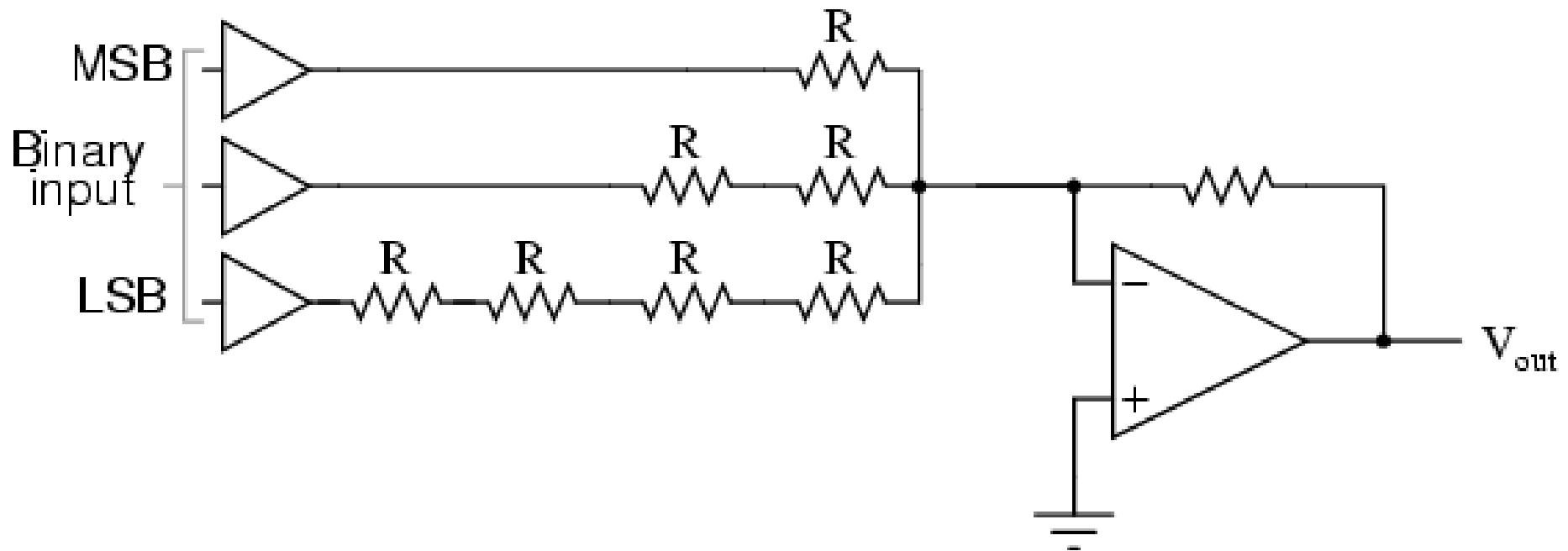
Integralna nelinearnost



DA pretvornik

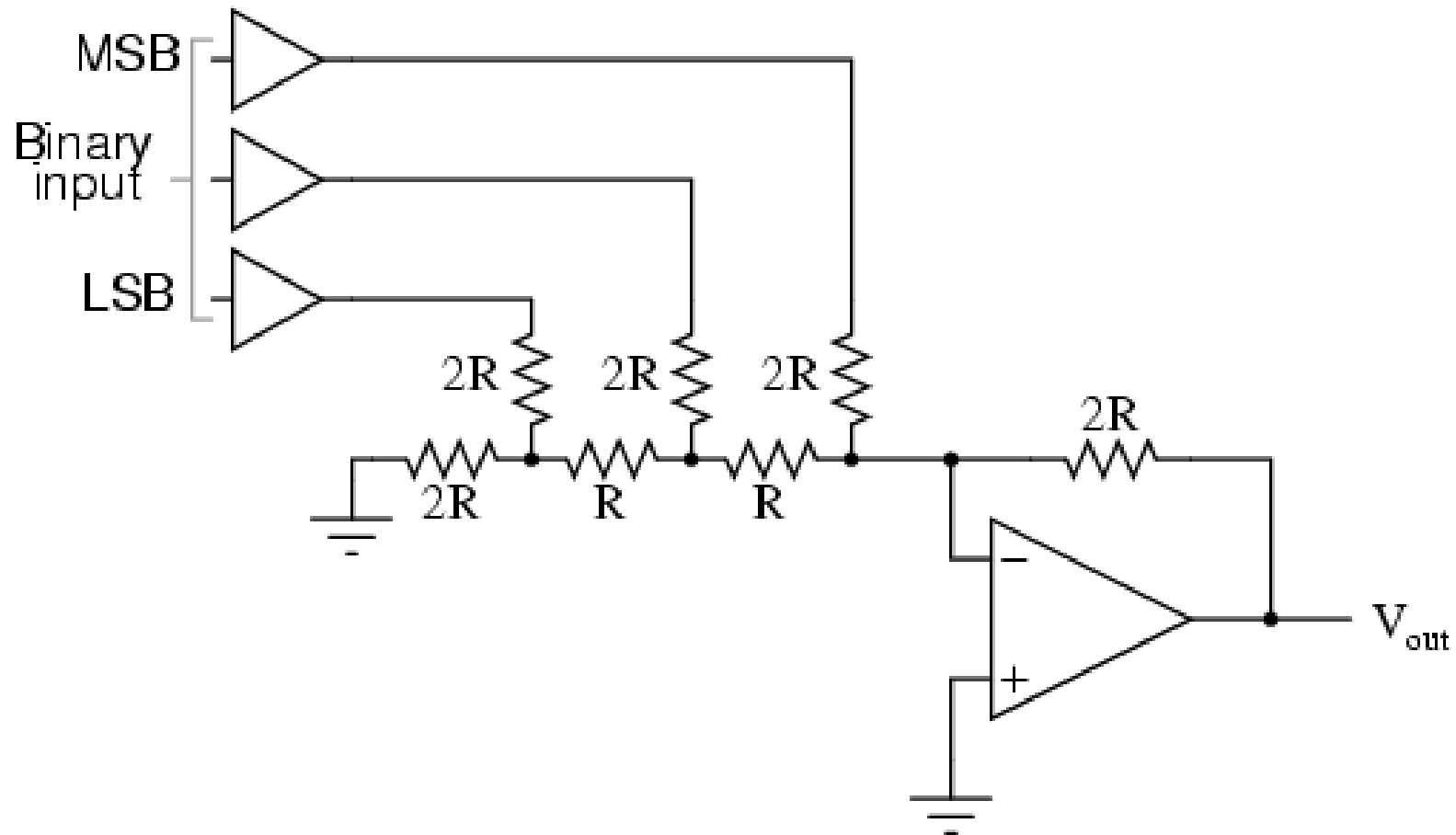


DA pretvornik

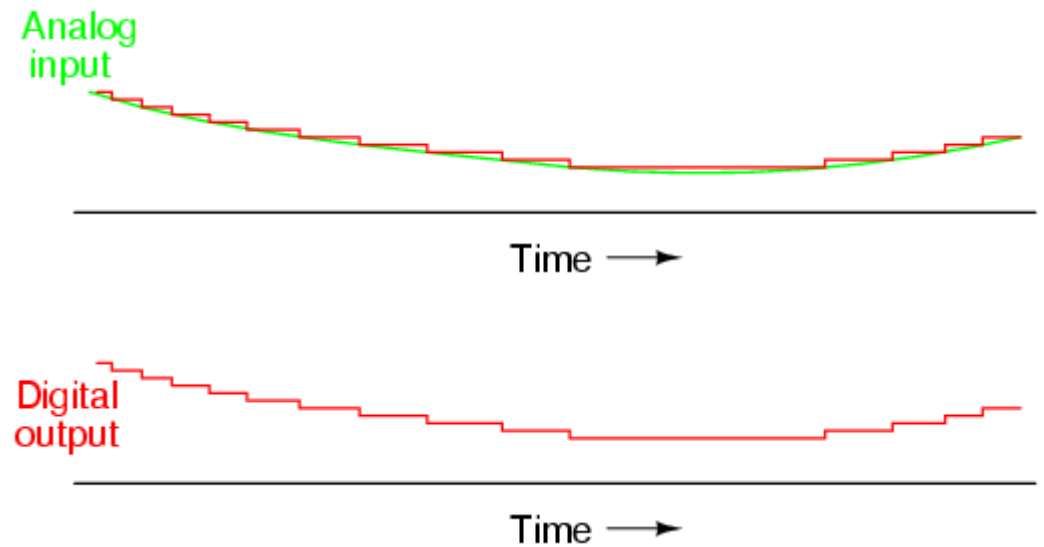
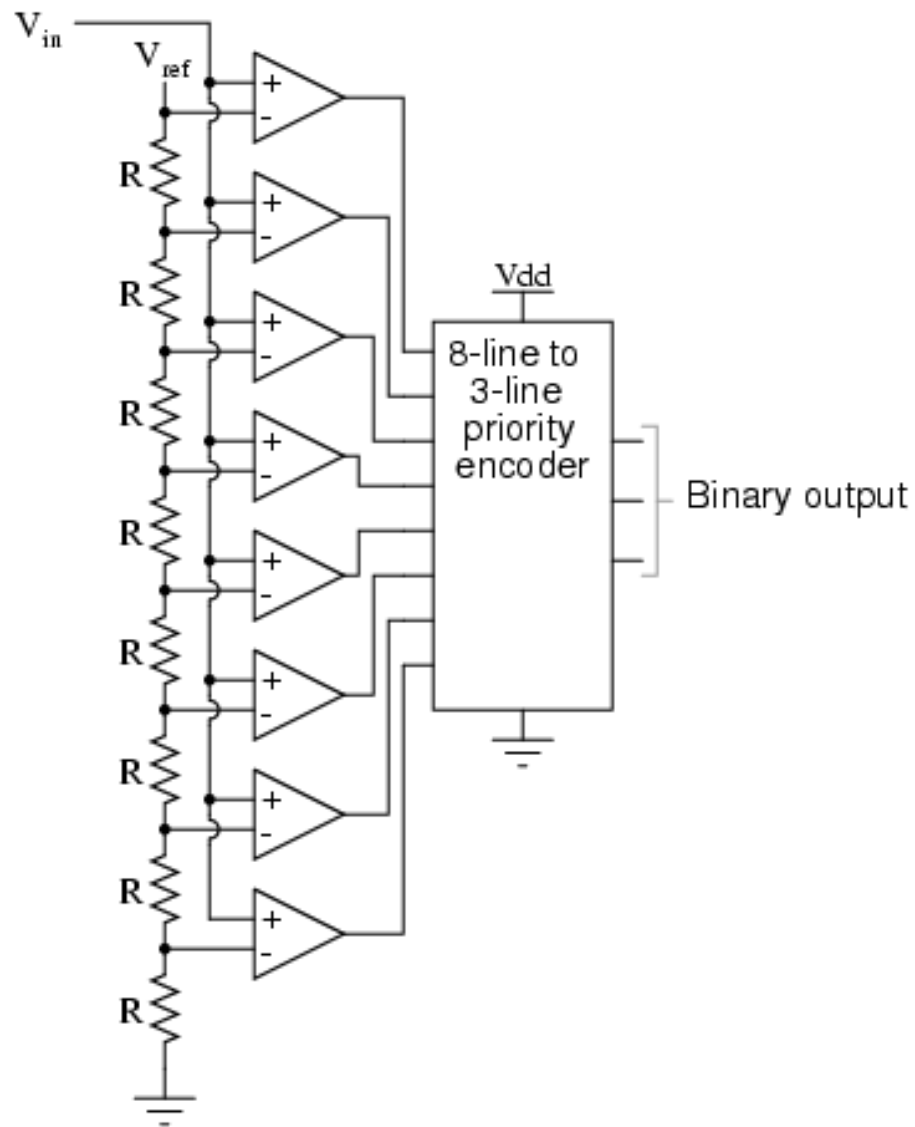


DA pretvornik – R-2R

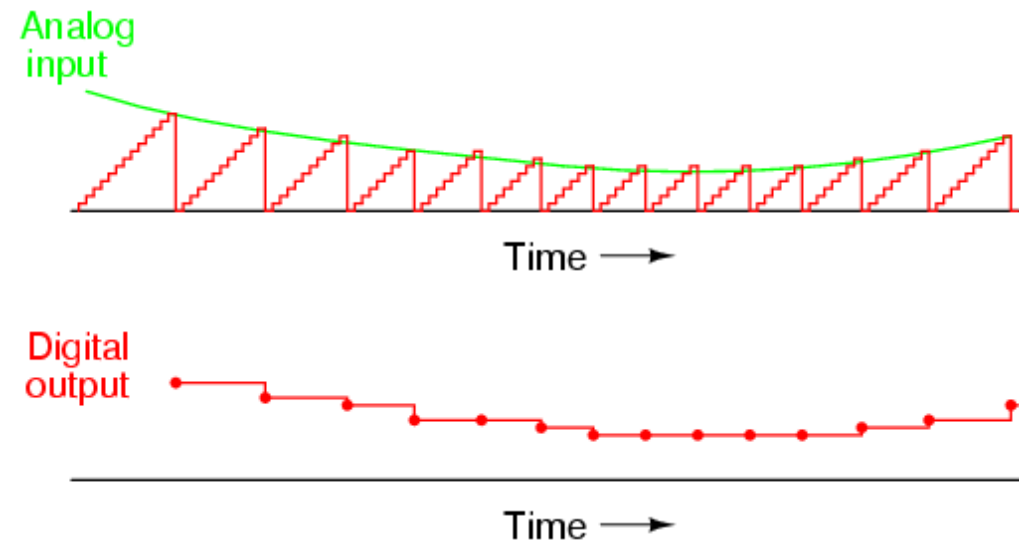
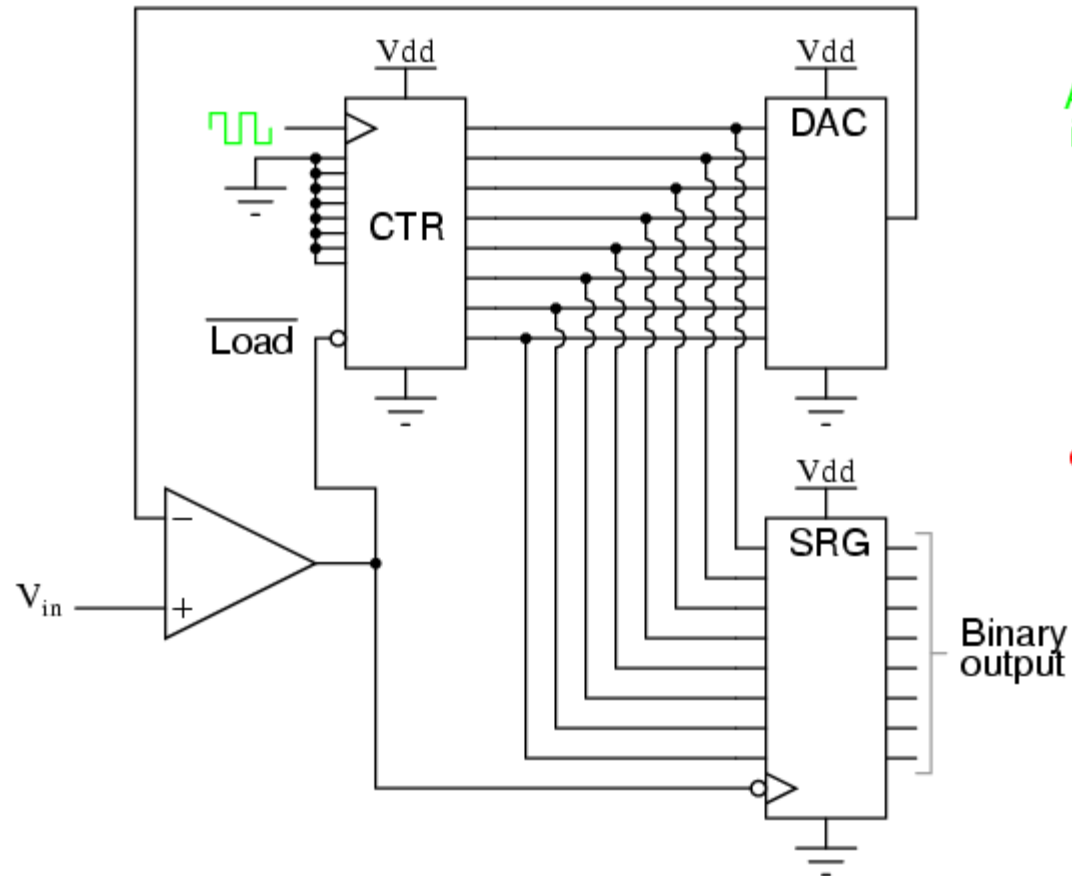
R/2R "ladder" DAC



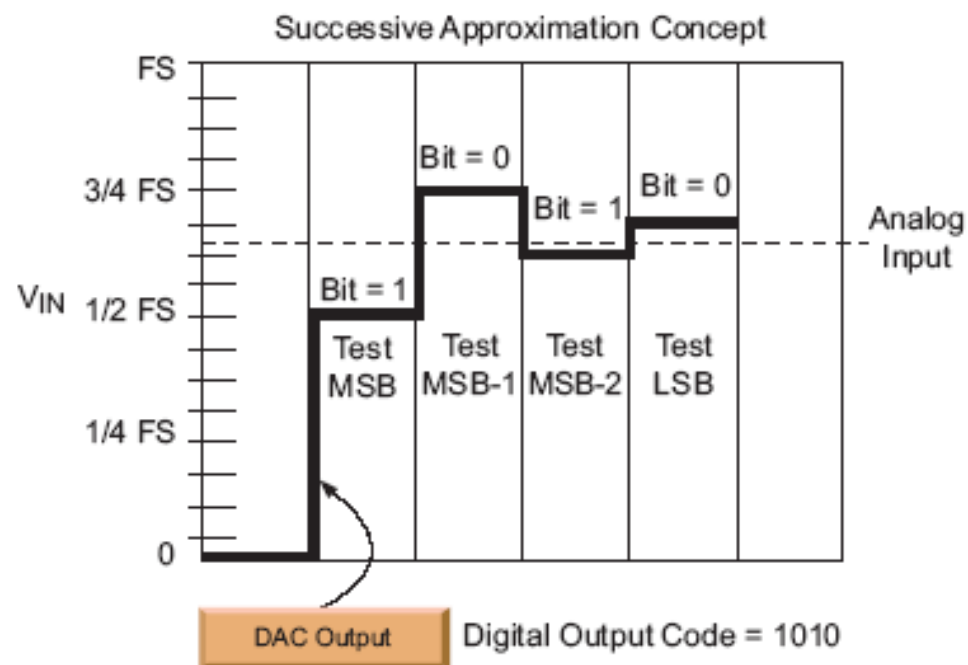
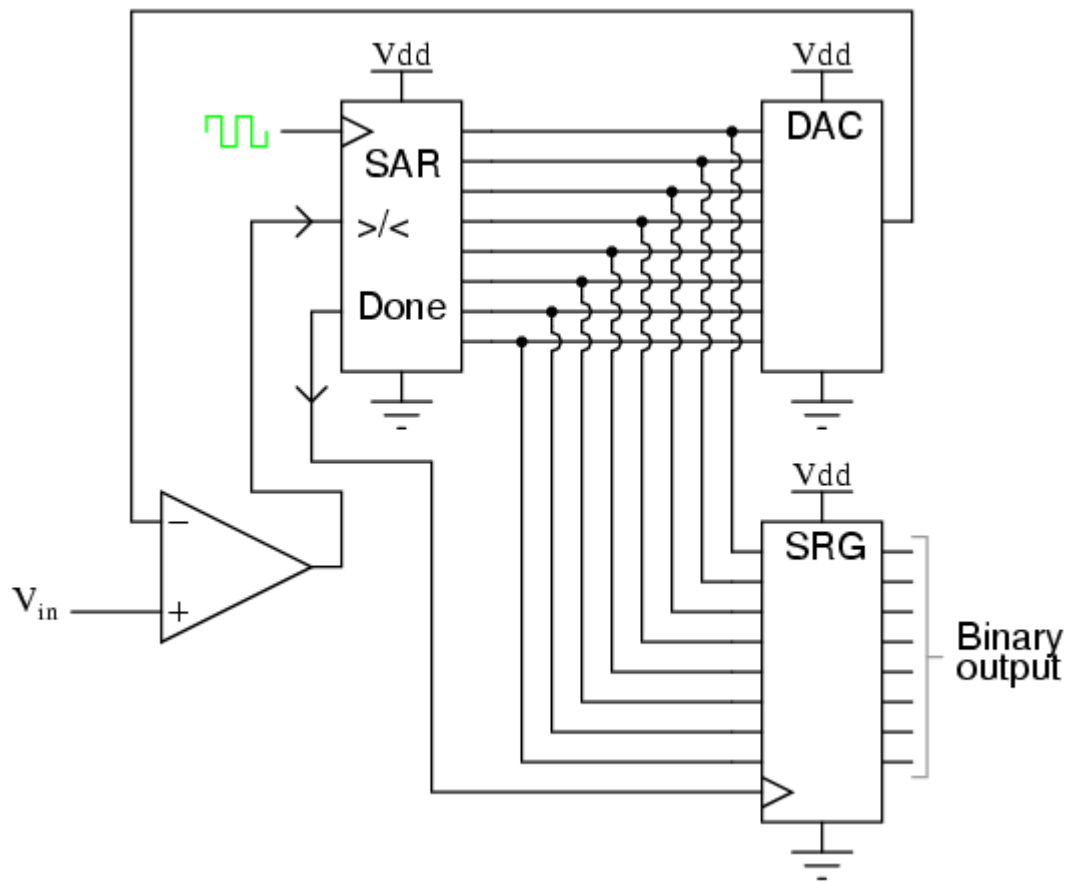
A/D pretvornik – FLASH



A/D pretvornik z digitalno rampo

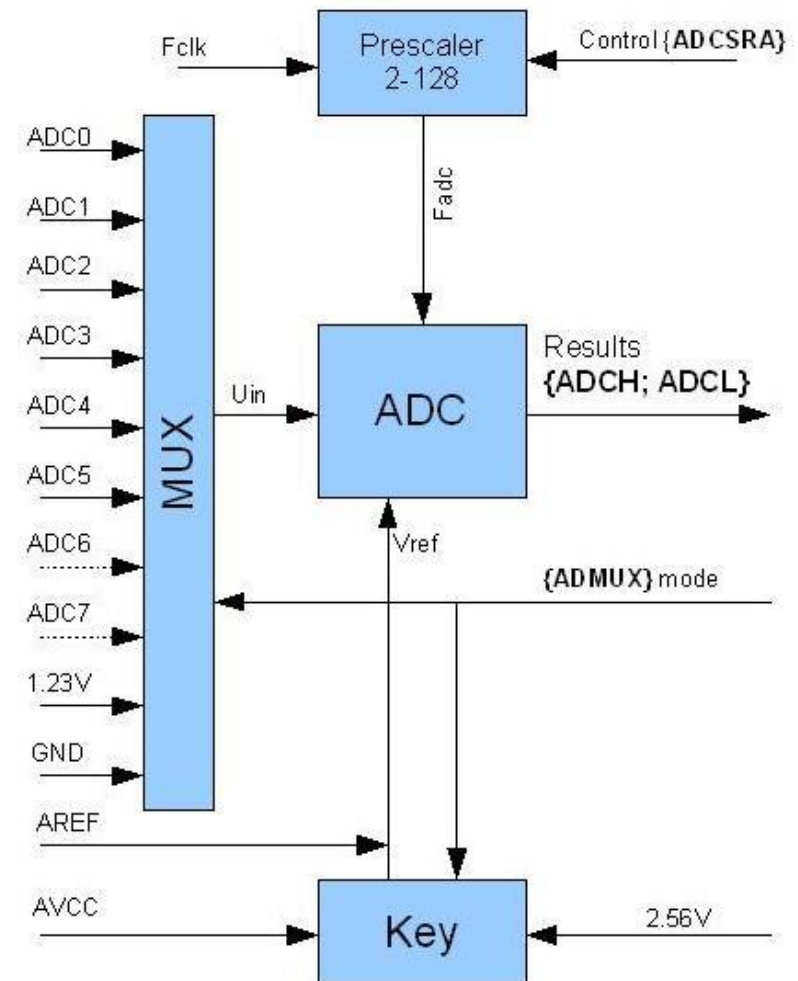


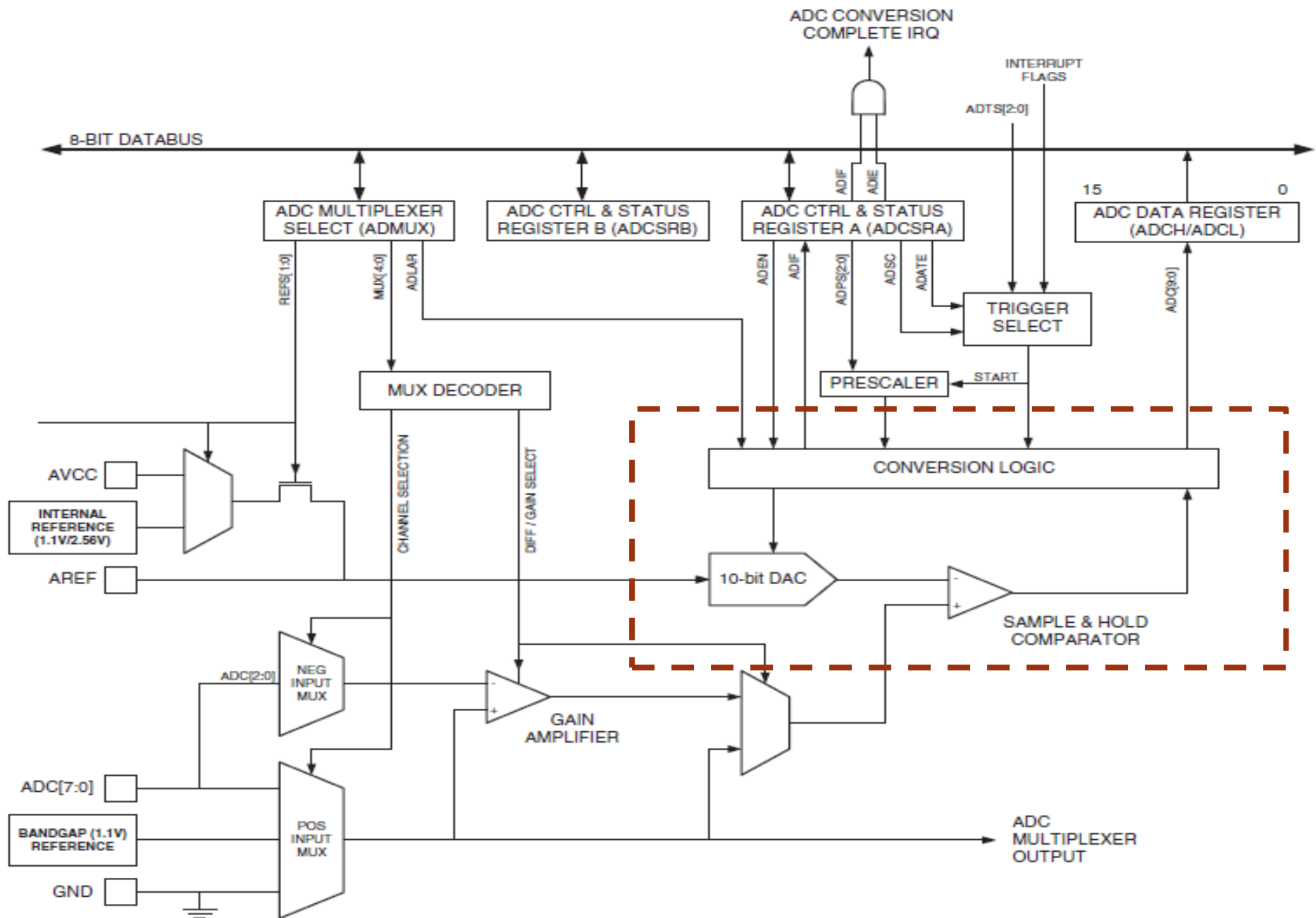
A/D pretvornik s postopnim približevanjem



A/D pretvornik pri ATmega 324 (ADC)

- Resolucija 10 bit
- Integralna nelinearnost 0,5 LSB
- Absolutna napaka ± 2 LSB
- Čas pretvorbe 13 – 260 μ s
- Hitrost pretvorbe do 15 000 vzorcev/s
- 8 multipleksiranih vhodov
- diferencialni ojačevalnik (1x, 10x, 100x)
- Različni viri referenčne napetosti
 - Notranja referenca 1.1 V ali 2.56 V
 - Zunanji vir
 - Napajalna napetost Vcc
- Avtomatsko proženje iz različnih virov prekinitvev





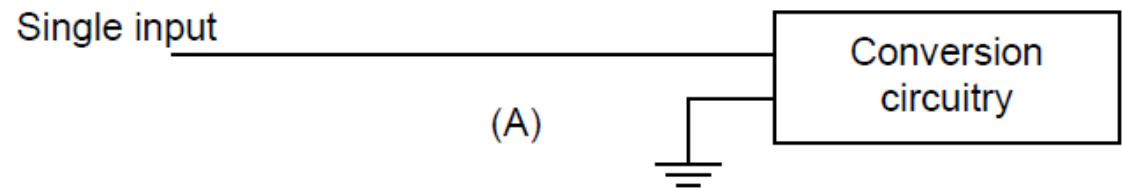
Kdaj lahko zamenjamo vir vhodnega signala oz. reference?

- Kadar je ADC onemogočen (ADEN = 0)
- Kadar je onemogočeno samoproženje (ADATE = 0)
- Med pretvorbo, ampak šele 1 cikel po proženju
 - double buffering registra ADMUX omogoča, da se vsebina spremeni šele po končani pretvorbi
 - največkrat spreminjamo v prekinitveni rutini
 - ampak šele za naslednjo konverzijo
- Po končani pretvorbi
 - ampak preden se zbriše zastavica ADIF
- Pri diferencialnih vhidih
 - ojačevalnik potrebuje vsaj 125 us, da se ustali na novi vrednosti

Rezultat pretvorbe

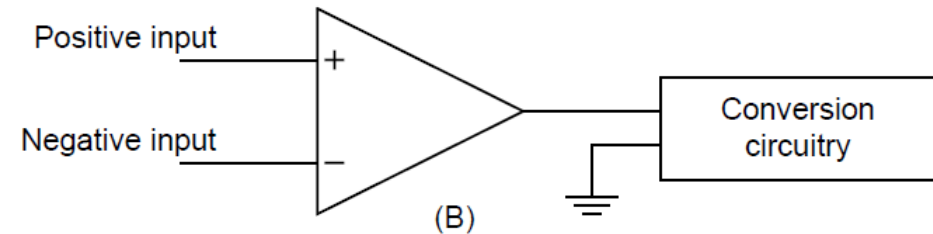
- Merjenje proti masi

$$ADC = \frac{U_{IN}}{U_{REF}} 1024$$



- Diferencialno merjenje

$$ADC = \frac{U_{INp} - U_{INn}}{U_{REF}} GAIN 512$$



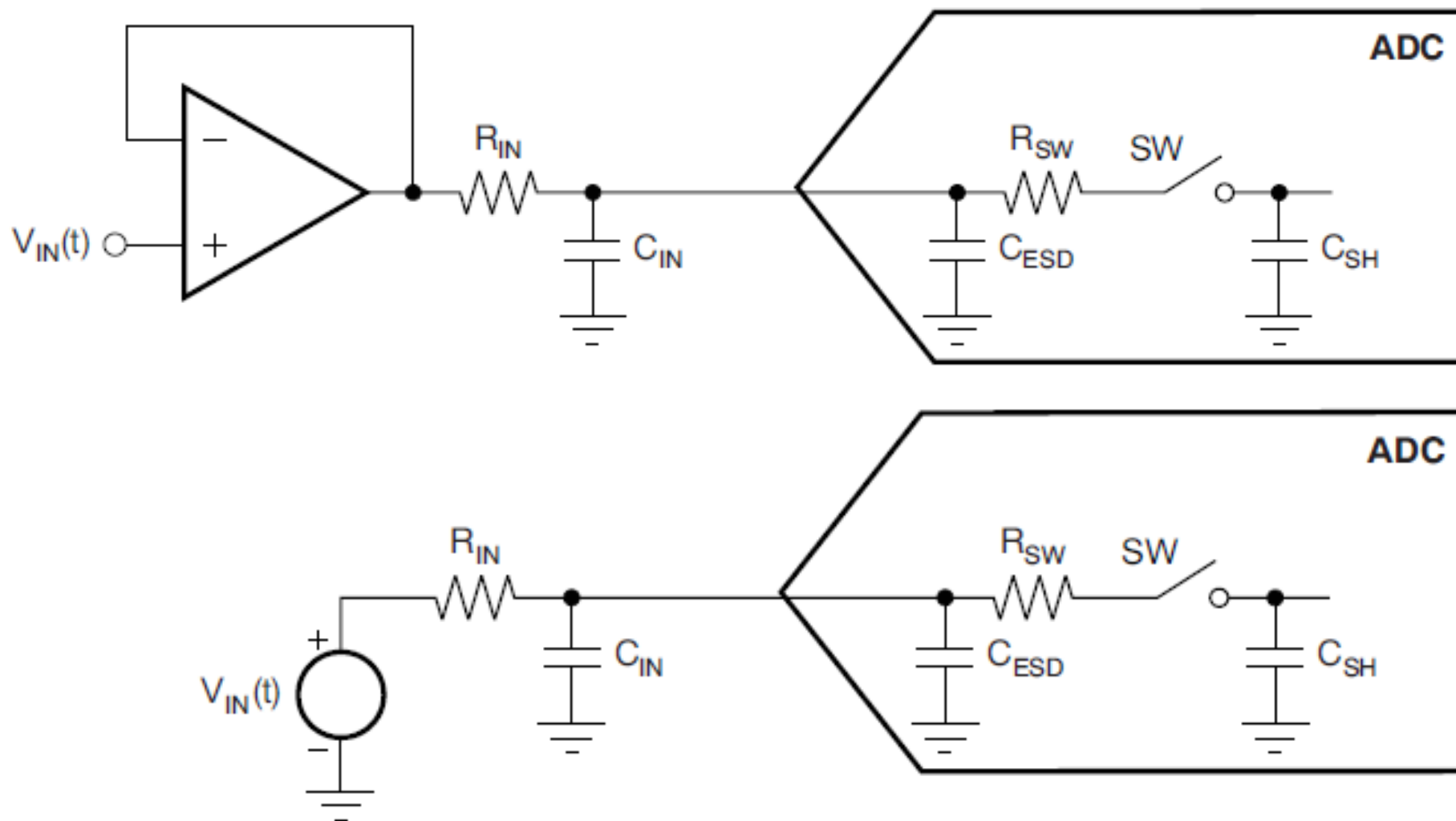
ADLAR = 1

Bit	15	14	13	12	11	10	9	8	
(0x79)	ADC9	ADC8	ADC7	ADC6	ADC5	ADC4	ADC3	ADC2	ADCH
(0x78)	ADC1	ADC0	-	-	-	-	-	-	ADCL

ADLAR = 0

Bit	15	14	13	12	11	10	9	8	
(0x79)	-	-	-	-	-	-	ADC9	ADC8	ADCH
(0x78)	ADC7	ADC6	ADC5	ADC4	ADC3	ADC2	ADC1	ADC0	ADCL
	7	6	5	4	3	2	1	0	

Ekvivalentno vezje vhoda AD pretvonika



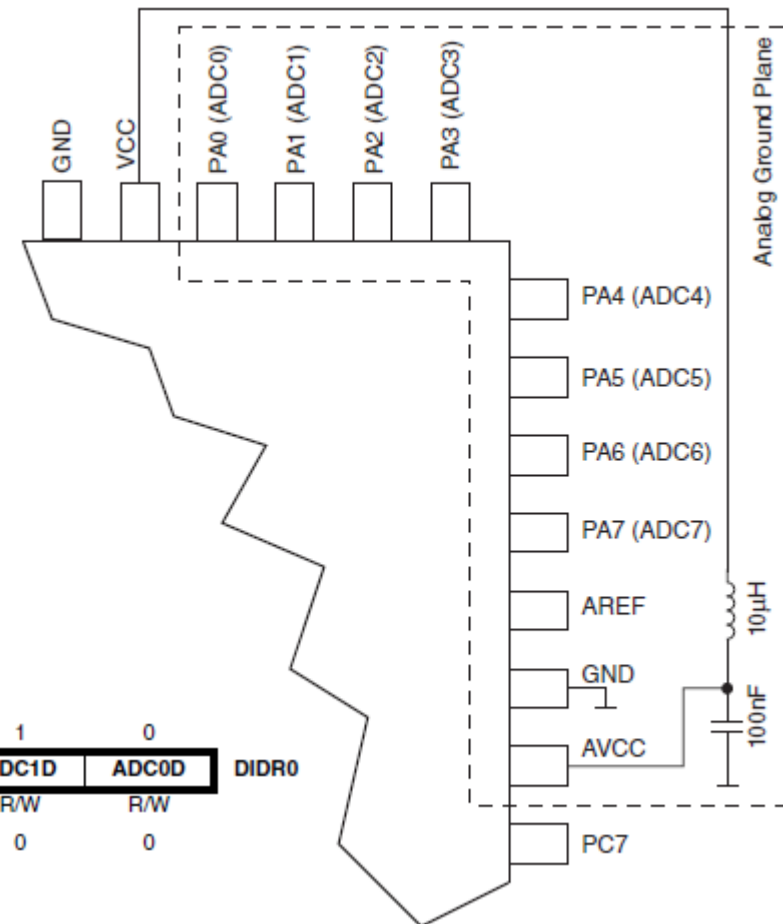
Zmanjšanje šuma ADC

- ADC noise reduction mode
- Pogoji
 - omogočen ADC noise reduction način (SM2..0 = 001)
 - ročno proženje pretvorbe (ADATE = 0)
 - omogočena prekinitev ob končani pretvorbi (ADIE = 1)
- Sprožitev AD pretvorbe
 - ADC mora biti omogočen (ADEN = 1)
 - pretvorbo sproži ASM ukaz „sleep“
 - procesor gre v stanje nizke porabe (koda se ne izvaja)
 - zbudi ga prekinitev ob končani pretvorbu

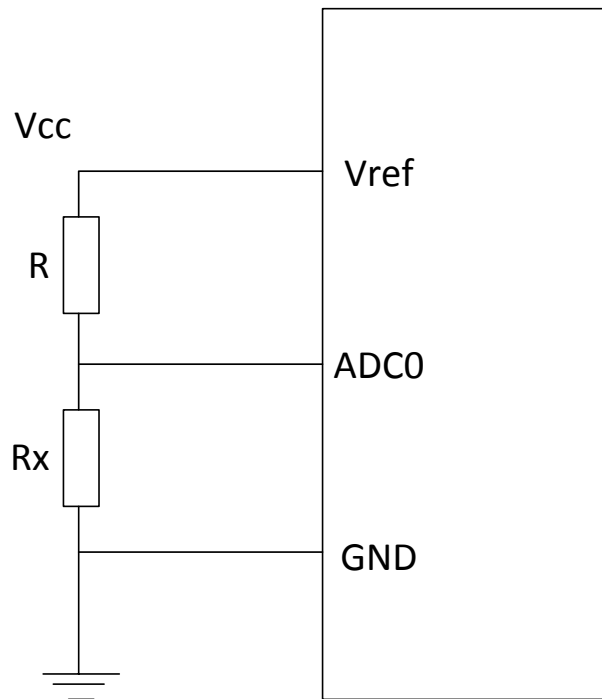
Zmanjšanje šuma ADC

- Analogne povezave naj bodo čim krajše
- AVCC povezan na VCC preko LC filtra
- Uporaba ADC noise canceller načina
- Če so vhodi ADC uporabljeni hkrati kot I/O pini, jih ne preklapljati v času pretvorbe
- Onemogočitev vhodnih digitalnih ojačevalnikov I/O pinov

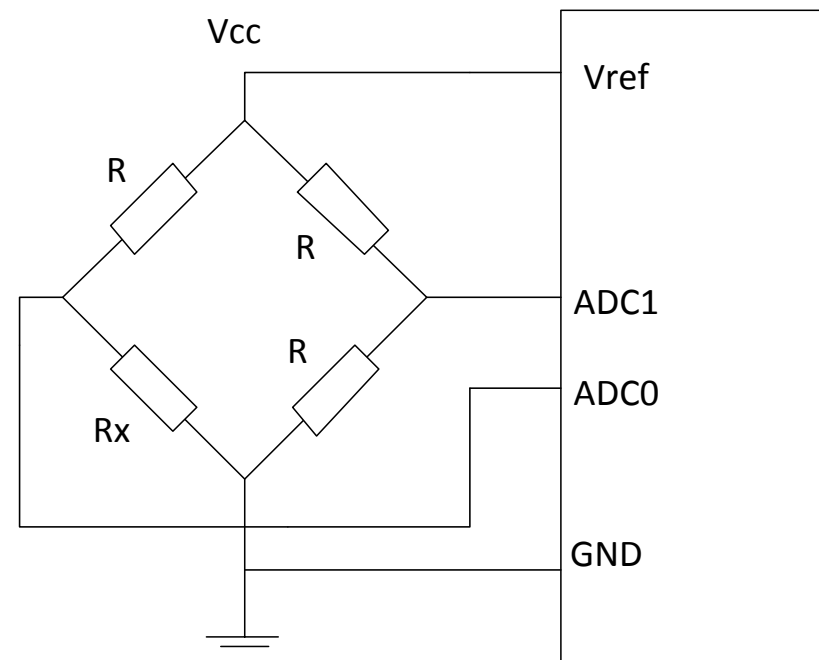
Bit (0x7E)	7	6	5	4	3	2	1	0	
	ADC7D	ADC6D	ADC5D	ADC4D	ADC3D	ADC2D	ADC1D	ADC0D	DIDR0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	



Raciometrična pretvorba



$$ADC = \frac{R_x}{(R + R_x)} 1024$$



$$ADC = \frac{R - R_x}{R + R_x} 1024 = k * \frac{F}{FS} 1024$$

Povečanje ločljivosti (oversampling & dithering)

- Podvojitvev frekvence vzorčenja x4 (povprečenje 4 vzorcev) doda 1 bit ločljivosti
- Dodatek šuma vsaj 1 LSB

