

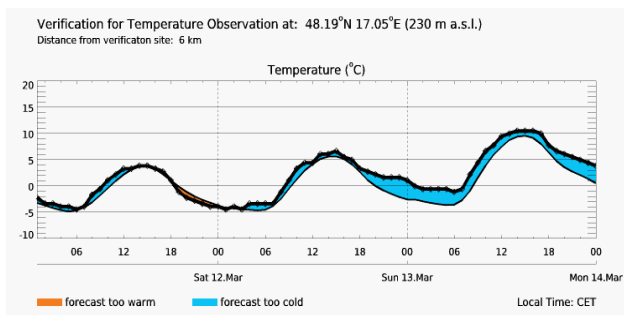
Počítač – analógový / digitálny

analógový (spojitý) – číslicový, digitálny (diskrétny)



Source: <http://morguefile.com/>

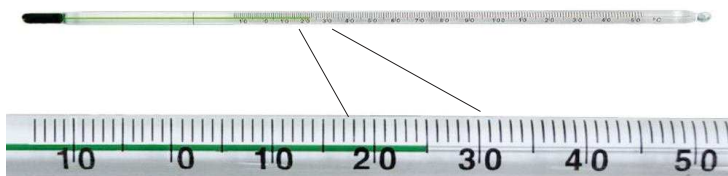
Analógový vs. Digitálny



VZORKOVANIE = SAMPLING

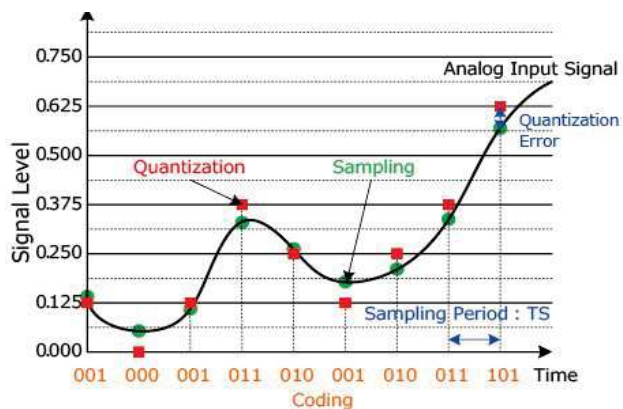
https://www.meteoblue.com/sk/po%C4%8Dasie/historyclimate/verificationshort/bratislava_slovensk%C3%A11-republika_3060972

Analógový vs. Digitálny



KVANTOVANIE = QUANTIZATION

Analógový vs. Digitálny



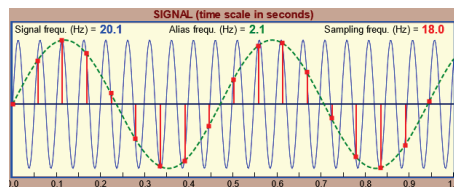
Vzorkovanie

Nyquist -- Shannon -- Kotelnikov

$$x(t) \rightarrow x_0, x_1, x_2, \dots, x_n : x_k = x(kT)$$

kde T je perióda vzorkovania $f_s = \frac{1}{T}$

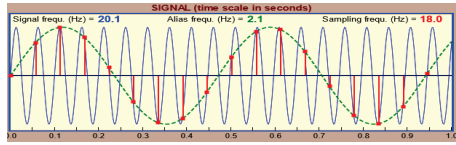
$$f_s > 2 f_{max}$$



<http://195.134.76.37/applets/AppletNyquist/AppletNyquist2.html>

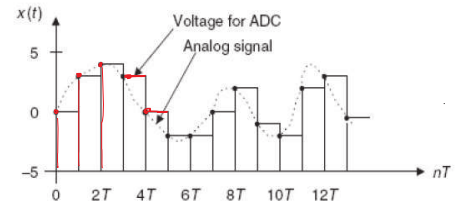
Vyskúšajte:

Aká bude zdanlivá frekvencia, ak signál s $f = 10\text{Hz}$ budeme merať 8x za sekundu?



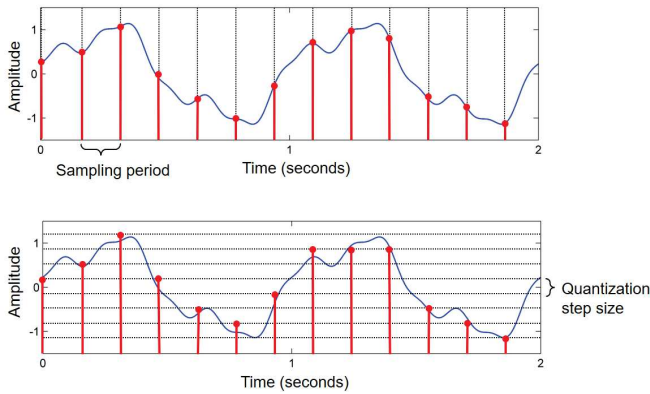
<http://195.134.76.37/applets/AppletNyquist/AppletNyquist2.html>

Rekonštrukcia

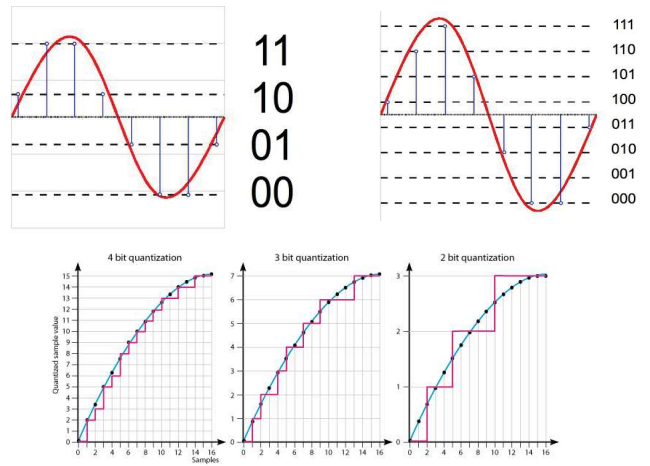


Kvantovanie

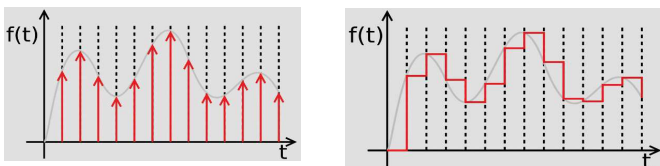
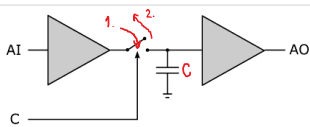
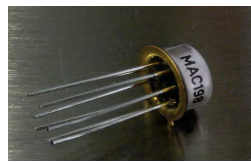
Figure 2.13 from [Müller, FMP, Springer 2015]



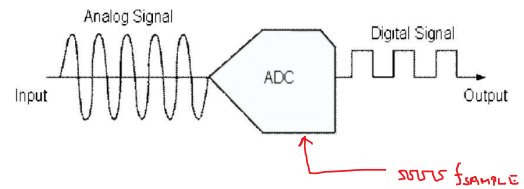
Kvantovanie



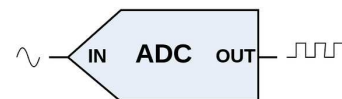
Sample & Hold



A/D prevodník I.

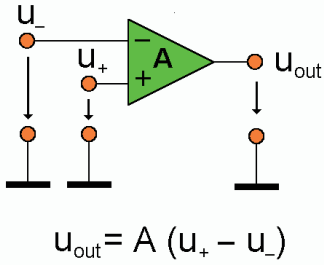


Electrical symbol [edit]



Operačný zosilňovač

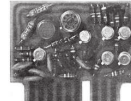
operational amplifier, Op-Amp



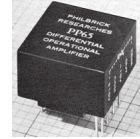
Ideálny zosilňovač:

- 1) $A = \infty$
- 2) $R_{vst} = \infty$
- 3) $R_{vyst} = 0$
- 4) $f_{max} = \infty$
- 5) $U_{out} = 0$ ak $U_{diff} = 0$
- 6) $U_{max} = \infty$

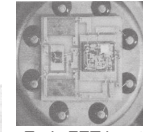
11. História Technology



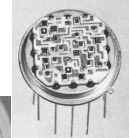
GAP/R's model P45: a solid-state, discrete op-amp (1961)



GAP/R's model PP65: a solid-state op-amp in a potted module (1962)



Early FET input AD op-amp (1970)



ADI's HOS-050: a high speed hybrid IC op-amp (1979)



TI's OPA2188: first zero-drift, 36-V operational amplifier (2012)



Operačné zosilňovače

Základné vlastnosti

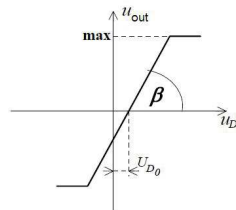
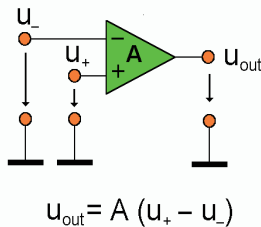
Jednosmerné zosilnenie

- súhlasné (súfázne)
- rozdielové

A je jednosmerné rozdielové zosilnenie naprázdno (ideál $A = \infty$)

$$A = \frac{\Delta u_{out}}{\Delta u_D} = \text{tg } \beta$$

U_{D0} je vstupná napät'ová nesymetria (tiež napät'ový ofset - U_{D0} je potrebné do vstupu na $U_{out} = 0$)



Operačné zosilňovače

Základné vlastnosti

Jednosmerné zosilnenie súhlasné

Reálny OZ zosilňuje i súhlasné u_{CM}

$$u_{CM} = \frac{u_- + u_+}{2}$$

jednosmerné súhlasné zosilnenie B_0

$$u_{out} = A \cdot u_D + B_0 \cdot u_{CM}$$

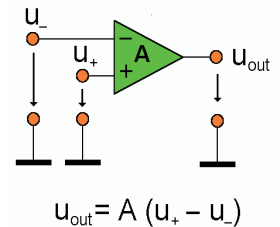
- kvalitný zosilňovač $\rightarrow B_0 \ll A$

činiteľ potlačenia súhlasného napätia CMRR (Common Mode Rejection Ratio)

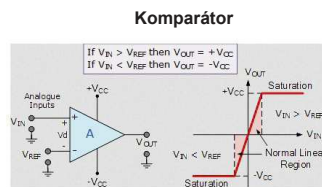
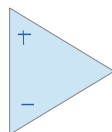
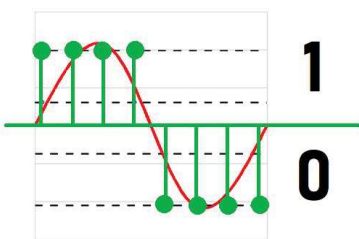
$$CMRR = \frac{A_0}{B_0}$$

Poznámka:

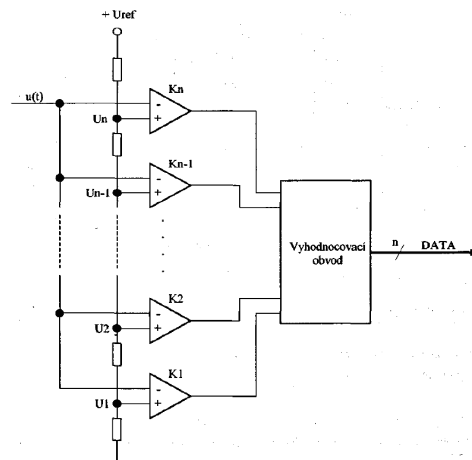
V katalógoch tiež ako diskriminačný súčiniteľ k_d . Reálne býva $10^4 + 10^7$, resp. 80 + 100 dB.



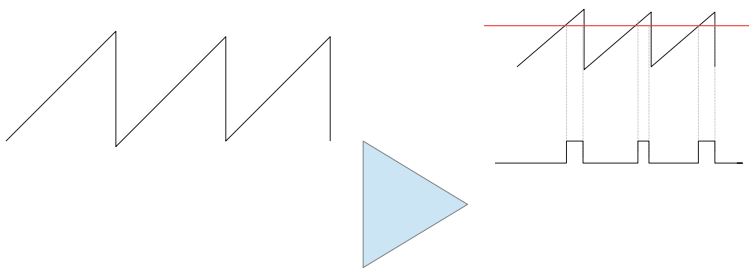
A/D prevodník



Paralelný A/D prevodník

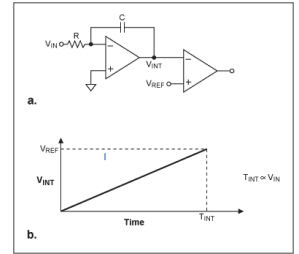
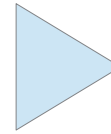


Integračný A/D prevodník



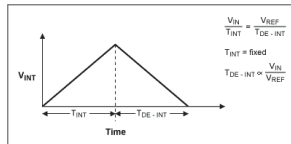
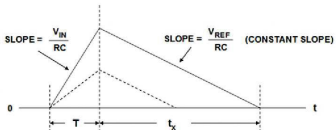
Integračný A/D prevodník

Single-Slope ADC Architecture



Integračný A/D prevodník

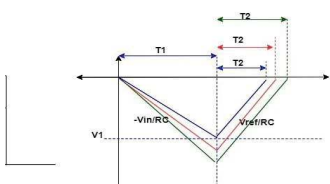
Dual-Slope ADC Architecture



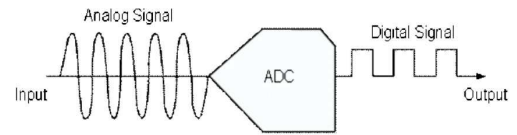
$$\frac{V_{IN}}{RC} T = \frac{V_{REF}}{RC} t_x$$

$$t_x = \frac{V_{IN}}{V_{REF}} T$$

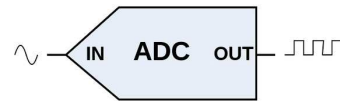
HIGH NORMAL MODE REJECTION AT MULTIPLES OF $\frac{1}{T}$



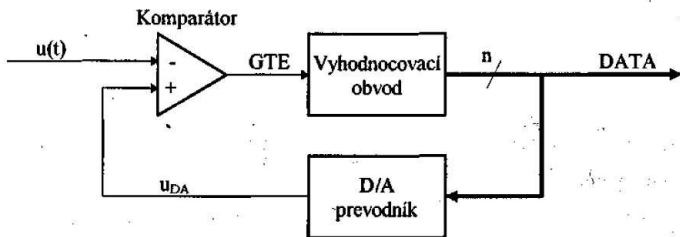
A/D prevodník II.



Electrical symbol [edit]

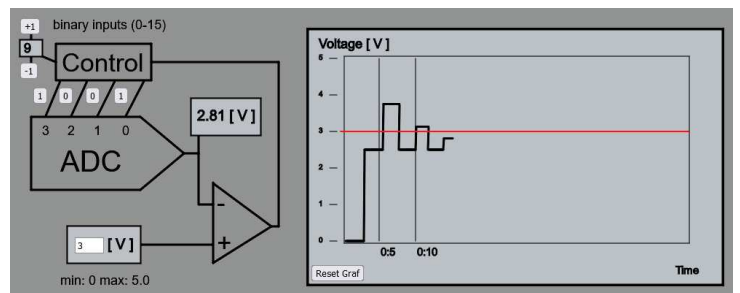


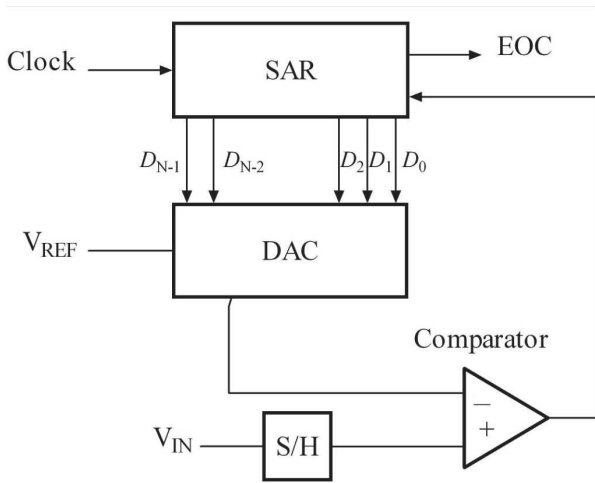
A/D prevodník



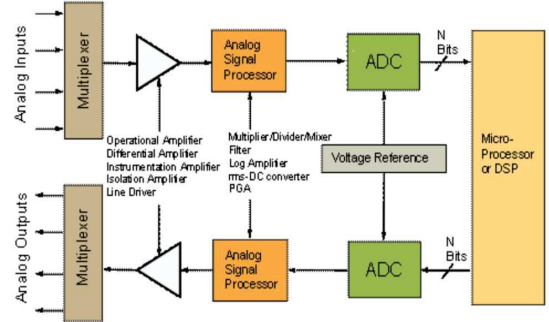
OBR. 49. A/D prevodník s postupným prevodom

A/D prevodník





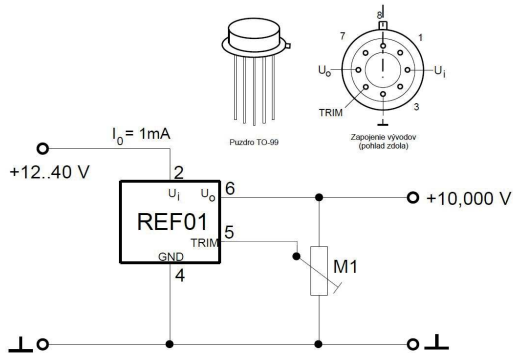
A/D prevodník



Referenčné napätie

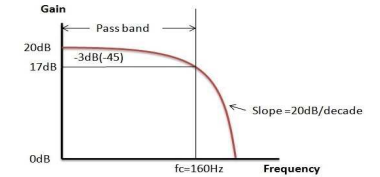
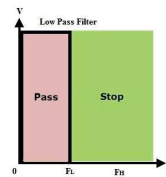
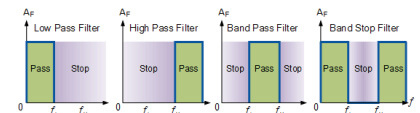
2.1.2 Trojsvorkový zdroj referenčného napätia REF-01

REF 01



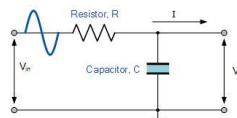
Filter

Ideal Filter Response Curves

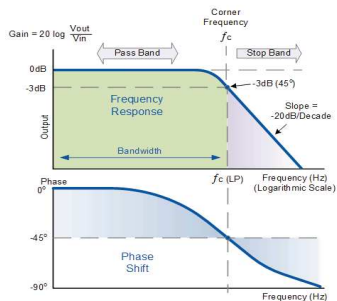


Filter

RC Low Pass Filter Circuit

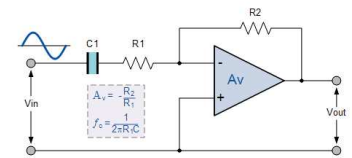


Frequency Response of a 1st-order Low Pass Filter

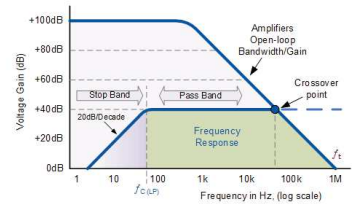


Filter

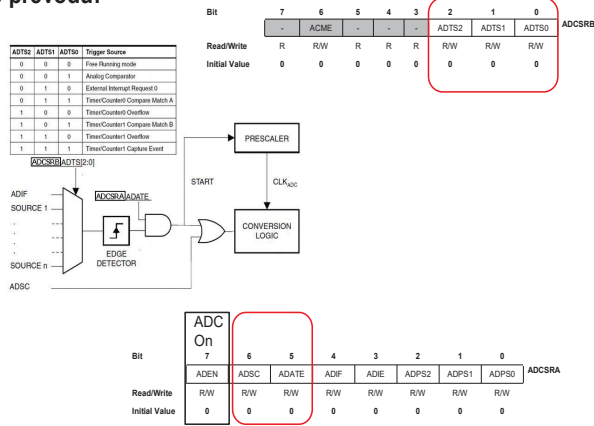
Inverting Operational Amplifier Circuit



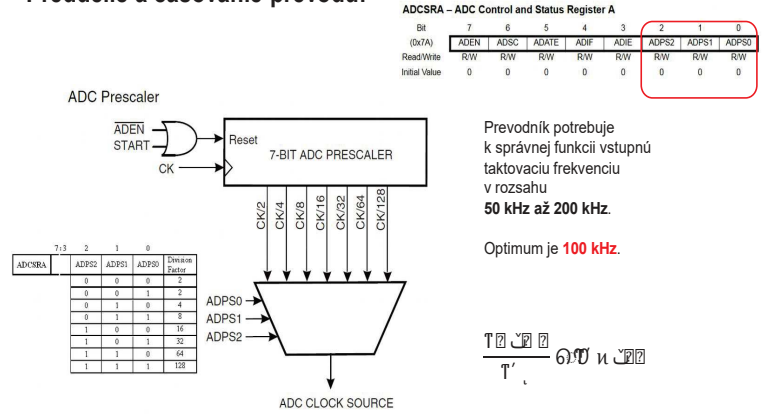
Frequency Response Curve



Spustenie prevodu:



Preddelič a časovanie prevodu:



Časovanie prevodu:

Figure 23-5. ADC Timing Diagram, Single Conversion

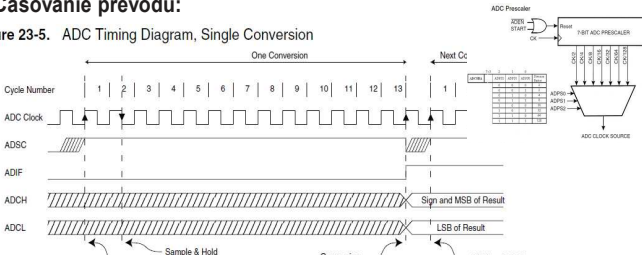


Table 23-1. ADC Conversion Time

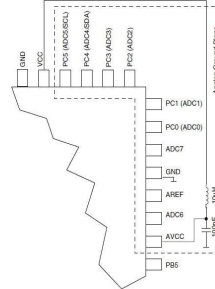
Condition	Sample & Hold (Cycles from Start of Conversion)	Conversion Time (Cycles)
First conversion	13.5	25
Normal conversions, single ended	1.5	13
Auto Triggered conversions	2	13.5

Prevodník potrebuje k správnej funkcii vstupnú taktovaciu frekvenciu v rozsahu **50 kHz až 200 kHz**.

Optimum je **100 kHz**.

Napájanie:

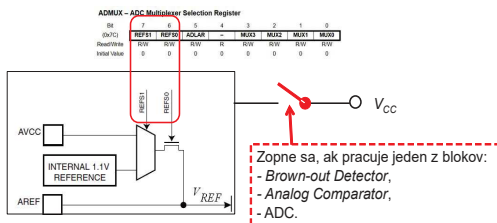
Figure 23-9. ADC Power Connections



AV_{CC} - je pin pre napájacie napätie pinov Portu C a napájanie ADC. Napätie tohto pinu sa nesmie líšiť od V_{CC} o viac ako ±0.3V.

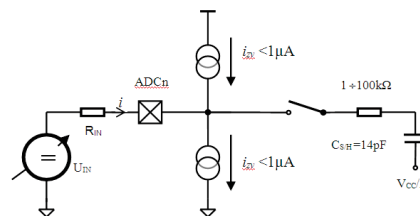
AREF - je pin analógového referenčného napätia pre A/D prevodník.

Zdroje napät'ovej referencie:

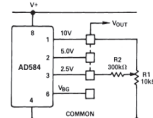


AD584 Cena cca 20Eur
4 referenčné napätia:
10.000 V, 7.500 V, 5.000 V, 2.500 V

Vstup analógového kanála:



Symbol	Parameter	Min.	Typ	Max	Units	
V _{REF}	Bandgap reference voltage	V _{CC} =2.7 T _A =25°C	1.0	1.1	1.2	V
t _{SD}	Bandgap reference start-up time	V _{CC} =2.7 T _A =25°C		40	70	µs
I _{SD}	Bandgap reference current consumption	V _{CC} =2.7 T _A =25°C		10		µA



Vzorkovacia frekvencia A/D prevodníka

Pr.: (Opakovanie; Procesory AVR $f_{ADC} = 200kHz$):

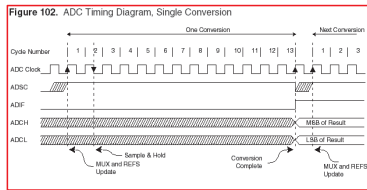
$200\ 000/13 = 15\ 000$
 $15\ 000/2 = 7500$
 $(1/200\ 000) * 13 = 65\ E-6$

A/D prevodník s postupnou aproximáciou má max. frekvenciu vzorkovania. 15 kSPS. Môžeme tvrdiť, že Nyquist-ova frekvencia je cca 7.5kHz? $f = 7.5kHz \approx T = 133.3\ \mu s$

Odpoveď: NIE!

Čas jedného prevodu pozostáva z:

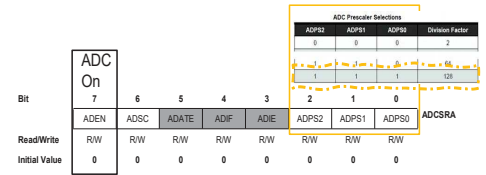
a trvá: cca 70 μs ; (200kHz)



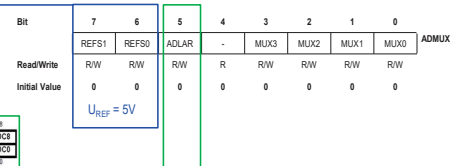
13

Pr. ADC: - inicializácia

```
void adc_init(void){
  ADMUX = (1<<REFS0); // AVCC - nastavenie zdroja ref. napatia
  ADCSRA = (1<<ADEN) // "zapnutie" ADC
           | (1<<ADPS2)|(1<<ADPS1)|(1<<ADPS0); // nastavenie preddelica
}
```



REFS1	REFS0	ADLAR	MUX3	MUX2	MUX1	MUX0
0	1	0	0	0	0	0
1	0	0	0	0	0	0
1	1	0	0	0	0	0

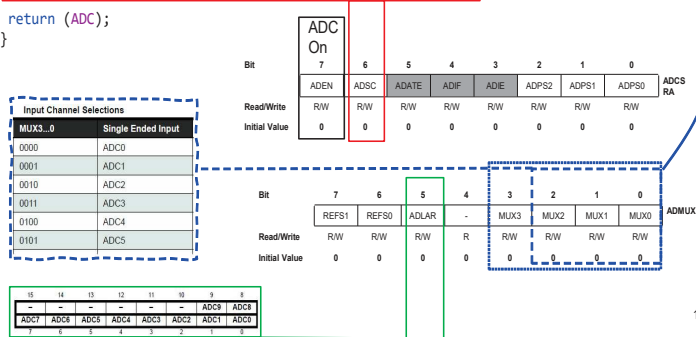


15	14	13	12	11	10	9	8
-	-	-	-	-	-	ADCF	ADCF
ADCF	ADCF	ADCF	ADCF	ADCF	ADCF	ADCF	ADCF
7	6	5	4	3	2	1	0

14

Pr. ADC: - read

```
unsigned int adc_read(char a_pin){
  a_pin &= 0x07;
  ADMUX = (ADMUX & 0xF8) | a_pin;
  ADCSRA |= (1<<ADSC); // spustenie prevodu
  while(ADCSRA & (1<<ADSC)); // pockam na dokoncenie prevodu
  return (ADC);
}
```



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