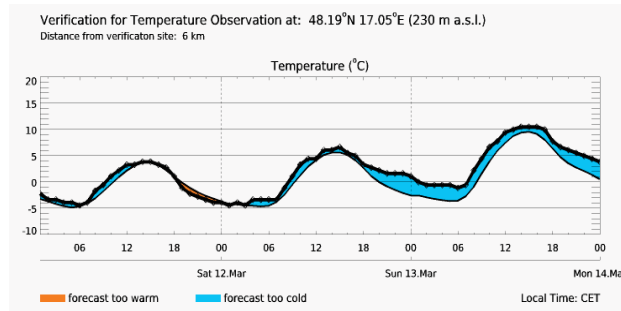


Analógový vs. Digitálny



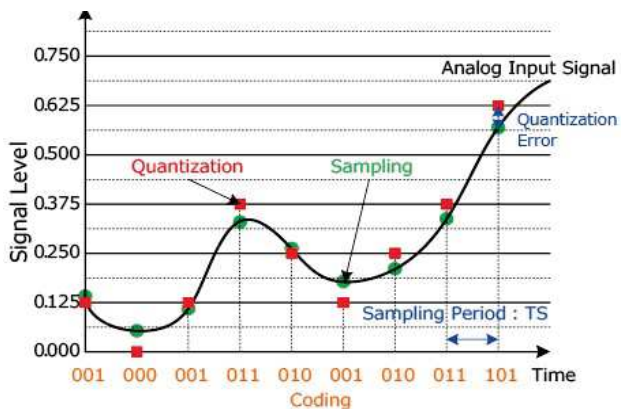
VZORKOVANIE = SAMPLING

https://www.meteoblue.com/sk/po/C4%8Dasie/historyclimate/verificationsshort/bratislava_slovensk%c3%a1-republika_3060972

Analógový vs. Digitálny



Analógový vs. Digitálny

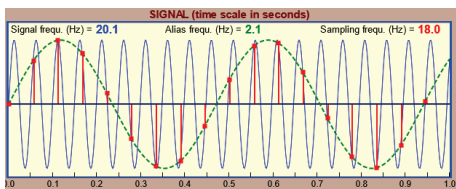


Vzorkovanie

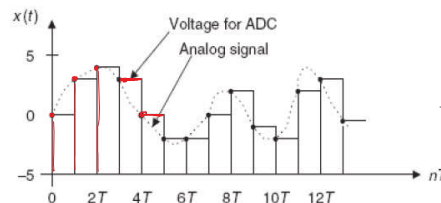
Nyquist -- Shannon -- Kotel'nikov

kde T je perióda vzorkovania

Rekonštrukcia

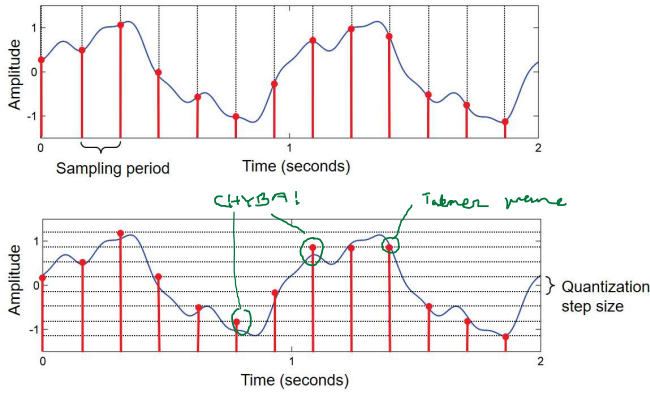


http://195.134.76.37/applets/AppletNyquist/App1_Nyquist2.html

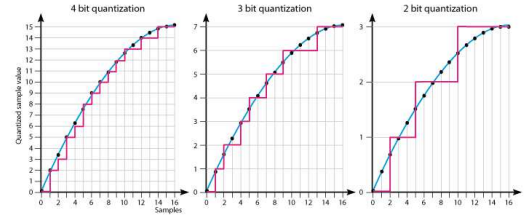
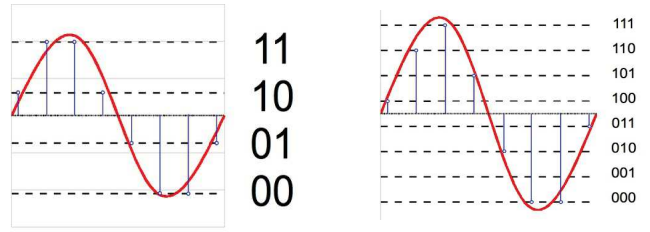


Kvantovanie

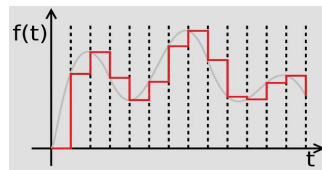
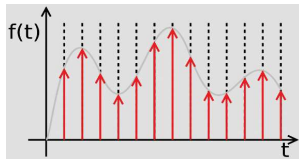
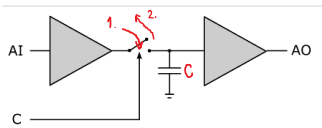
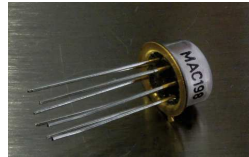
Figure 2.13 from [Müller, FMP, Springer 2015]



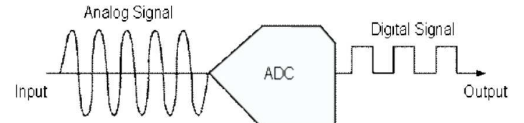
Kvantovanie



Sample & Hold



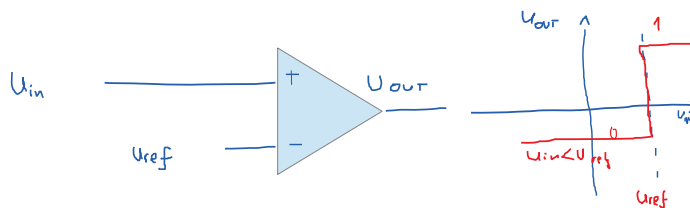
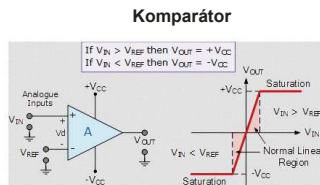
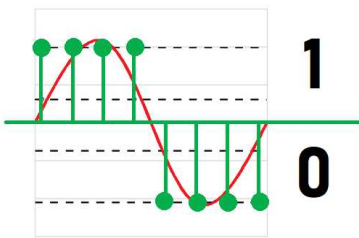
A/D prevodník I.



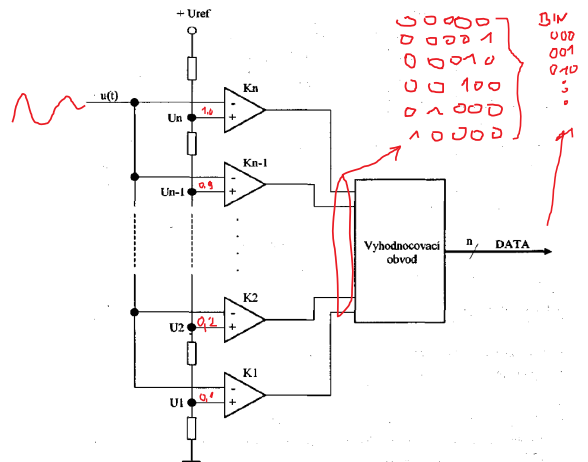
Electrical symbol [edit]



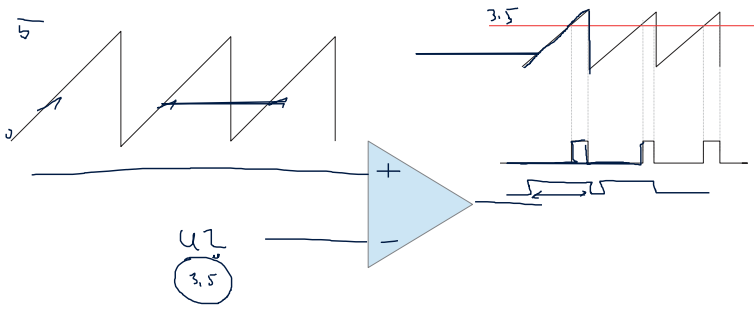
A/D prevodník



Paralelný A/D prevodník

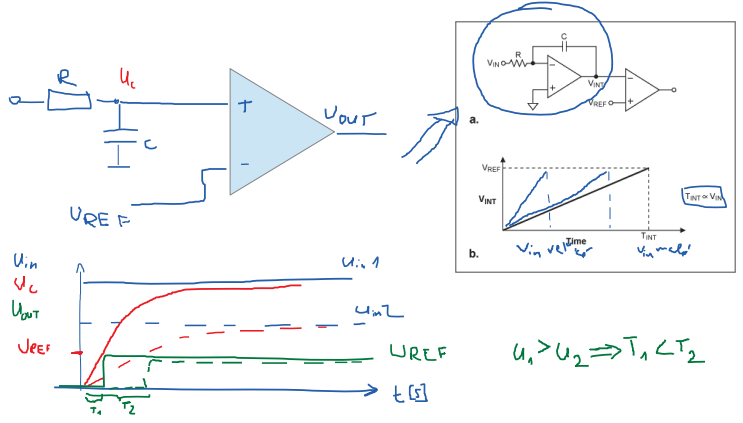


Integračný A/D prevodník



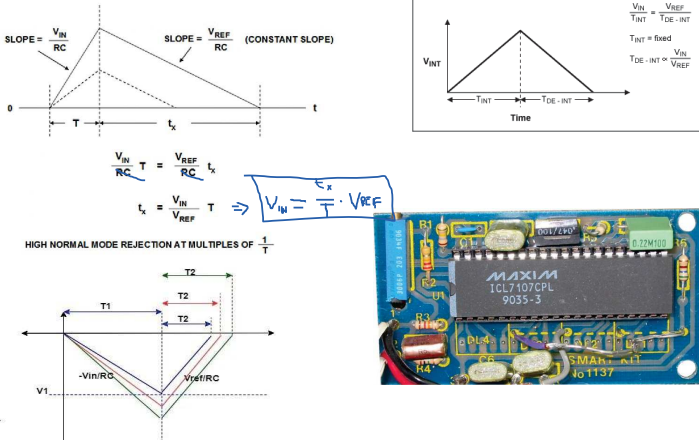
Integračný A/D prevodník

Single-Slope ADC Architecture

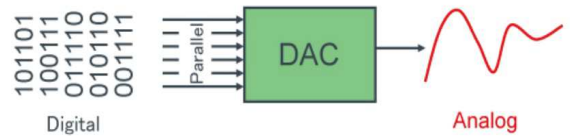


Integračný A/D prevodník

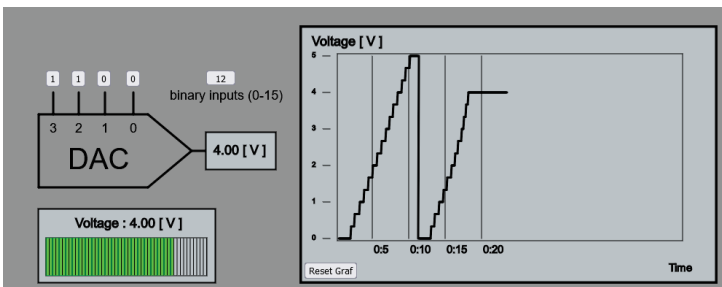
Dual-Slope ADC Architecture



D/A prevodník

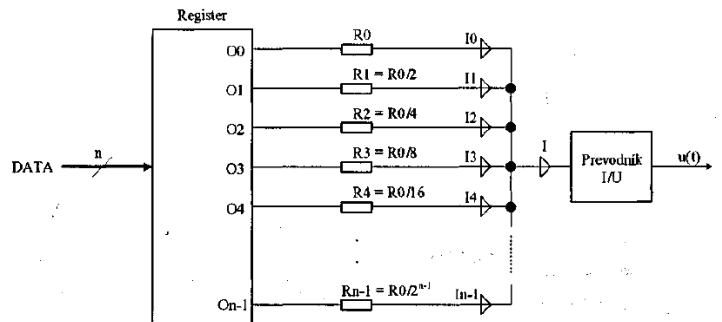


D/A prevodník

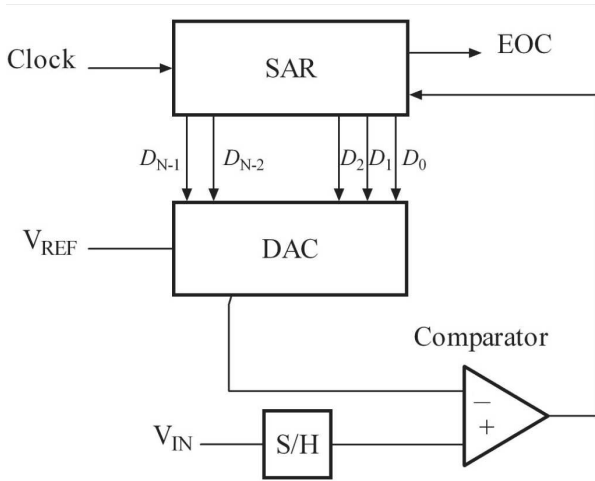


<https://senzor.robotika.sk/mmp/anim/dac.html>

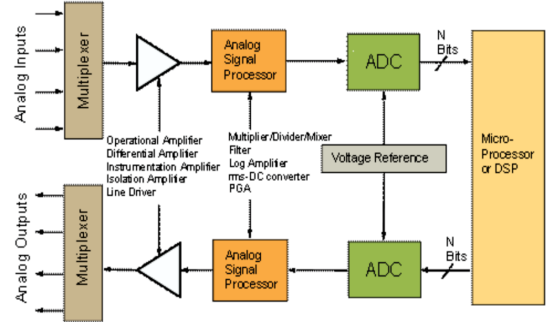
D/A prevodník



OBR. 51. D/A prevodník s váhovými odporami



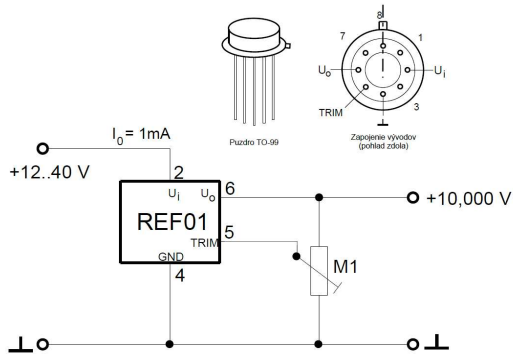
A/D prevodník



Referenčné napätie

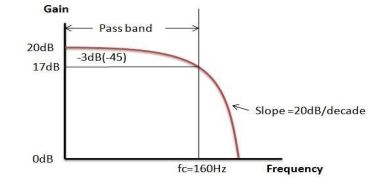
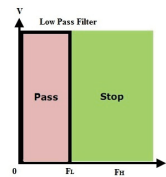
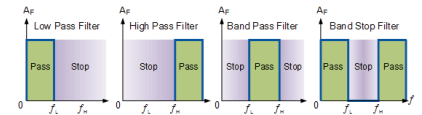
2.1.2 Trojsvorkový zdroj referenčného napätia REF-01

REF 01



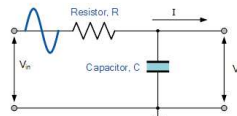
Filter

Ideal Filter Response Curves

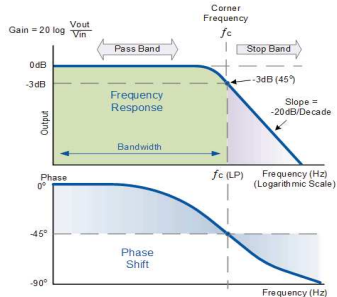


Filter

RC Low Pass Filter Circuit

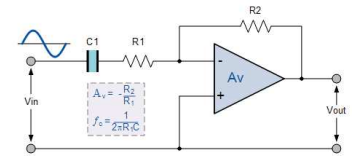


Frequency Response of a 1st-order Low Pass Filter

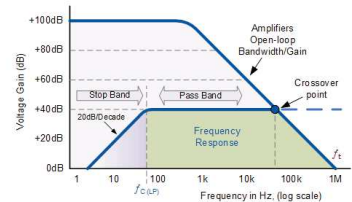


Filter

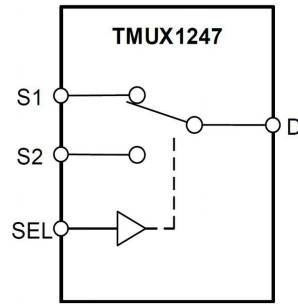
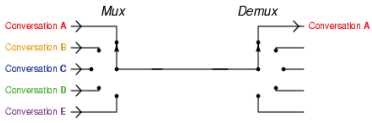
Inverting Operational Amplifier Circuit



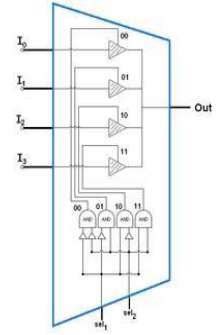
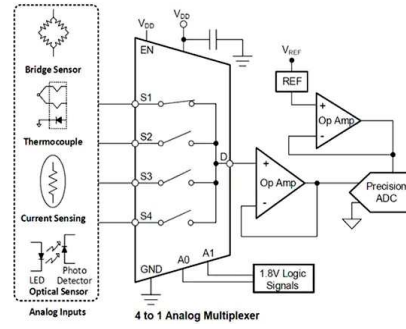
Frequency Response Curve



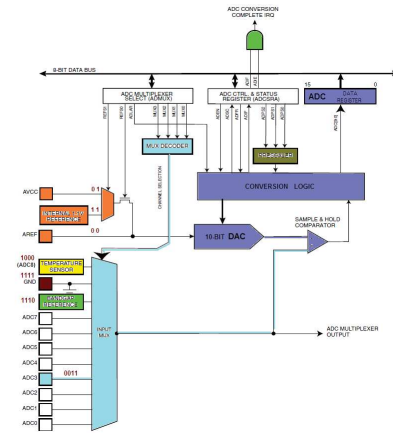
Multiplexer



Multiplexer



Teraz už poznáme všetky základné bloky, ktoré sa nachádzajú v tom ADC ktorý je implementovaný v ATmega328P



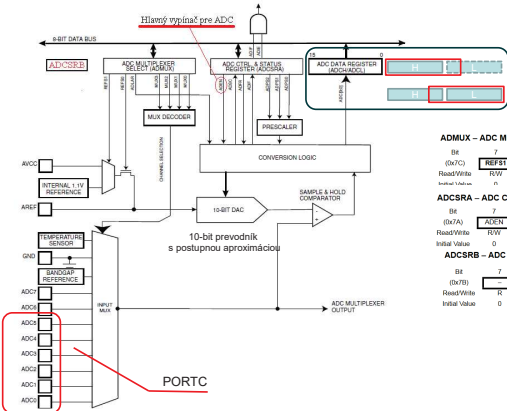
Bit	7	6	5	4	3	2	1	0
ADSC	ADSC7	ADSC6	ADSC5	ADSC4	ADSC3	ADSC2	ADSC1	ADSC0
Read/Write	R	R	R	R	R	R	R	R
Initial Value	0	0	0	0	0	0	0	0

Bit	7	6	5	4	3	2	1	0
ADIF	ADIF7	ADIF6	ADIF5	ADIF4	ADIF3	ADIF2	ADIF1	ADIF0
ADIFC	R	R	R	R	R	R	R	R
Initial Value	0	0	0	0	0	0	0	0

Bit	7	6	5	4	3	2	1	0
ADIFC	ADIFC7	ADIFC6	ADIFC5	ADIFC4	ADIFC3	ADIFC2	ADIFC1	ADIFC0
Read/Write	R	R	R	R	R	R	R	R
Initial Value	0	0	0	0	0	0	0	0

Bit	7	6	5	4	3	2	1	0
ADIFC	ADIFC7	ADIFC6	ADIFC5	ADIFC4	ADIFC3	ADIFC2	ADIFC1	ADIFC0
Read/Write	R	R	R	R	R	R	R	R
Initial Value	0	0	0	0	0	0	0	0

Bit	7	6	5	4	3	2	1	0
ADIFC	ADIFC7	ADIFC6	ADIFC5	ADIFC4	ADIFC3	ADIFC2	ADIFC1	ADIFC0
Read/Write	R	R	R	R	R	R	R	R
Initial Value	0	0	0	0	0	0	0	0



ADMUX - ADC Multiplexer Selection Register

Bit	7	6	5	4	3	2	1	0
REFS1	REFS0	ADLAR	MUX3	MUX2	MUX1	MUX0		
Read/Write	RW	RW	RW	R	RW	RW	RW	RW
Initial Value	0	0	0	0	0	0	0	0

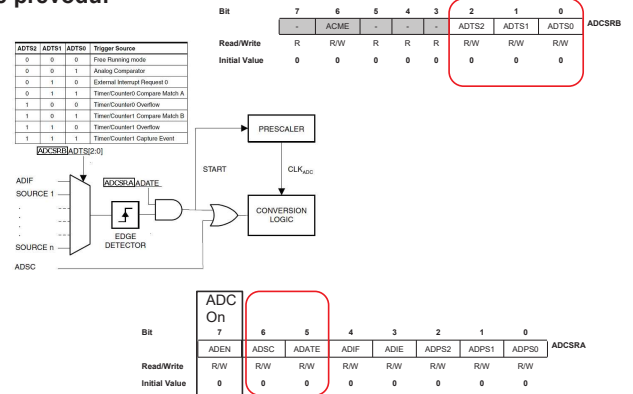
ADCSRA - ADC Control and Status Register A

Bit	7	6	5	4	3	2	1	0
ADEN	ADSC	ADIFC	ADIF	ADIF0	ADIF1	ADIF2	ADIF3	ADIF0
Read/Write	RW	RW	RW	RW	RW	RW	RW	RW
Initial Value	0	0	0	0	0	0	0	0

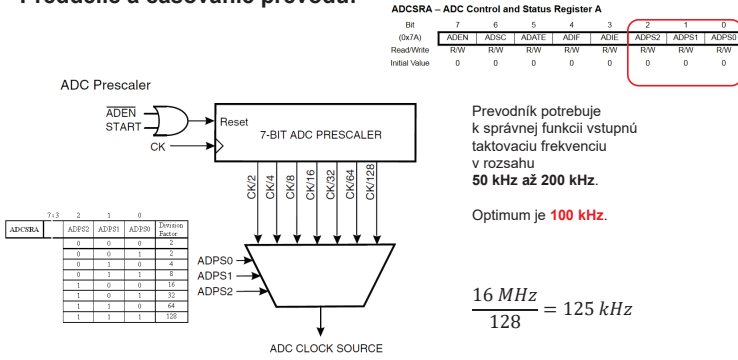
ADCSRB - ADC Control and Status Register B

Bit	7	6	5	4	3	2	1	0
ADIFC	ADIFC							
Read/Write	R	RW	R	R	R	RW	RW	RW
Initial Value	0	0	0	0	0	0	0	0

Spustenie prevodu:



Preddelič a časovanie prevodu:



Časovanie prevodu:

Figure 23-5. ADC Timing Diagram, Single Conversion

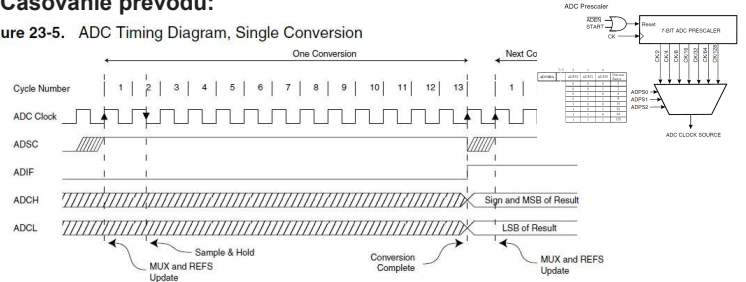


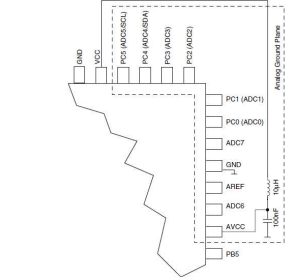
Table 23-1. ADC Conversion Times

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

Prevonník potrebuje k správnej funkcii vstupnú taktovaciu frekvenciu v rozsahu **50 kHz až 200 kHz**.
Optimum je **100 kHz**.

Napájanie:

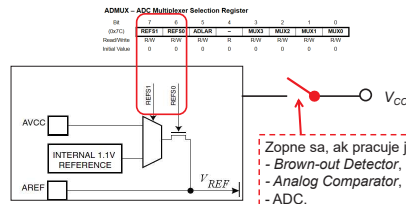
Figure 23-9. ADC Power Connections



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.

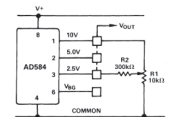
AREF - je pin analógového referenčného napätia pre A/D prevodník.

Zdroje napät'ovej referencie:

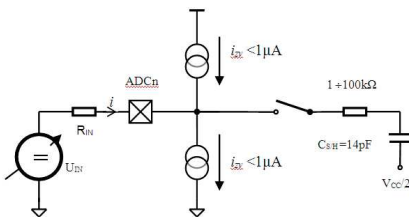


AD584 Cena cca 20Eur
4 referenčné napätia:
10.000 V, 7.500 V, 5.000 V, 2.500 V

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 _{SP}	Bandgap reference start-up time	V _{CC} =2.7 T _A =25°C		40	70	µs
I _{REF}	Bandgap reference current consumption	V _{CC} =2.7 T _A =25°C		10		µA



Vstup analógového kanála:



$$R_{IN} \leq \frac{0,5 \text{ LSB}}{I_{ZV}} = \frac{0,5 \cdot 5V}{1024 \cdot 1\mu A} \approx 2,4k\Omega$$

Vzorkovacia frekvencia A/D prevodníka

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

$$\frac{200\,000}{13} = 15\,000$$

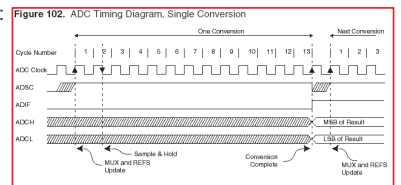
$$\frac{15\,000}{2} = 7500$$

$$(1/200\,000) \cdot 13 = 65 \text{ E-6}$$

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

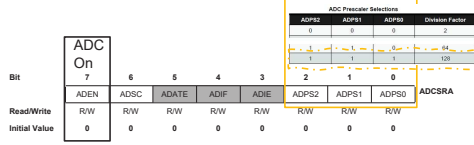
Čas jedného prevodu pozostáva z:

a trvá: cca 70 µs ; (200kHz)

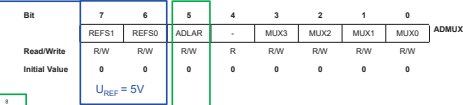


Pr. ADC: - inicializacia

```
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
}
```



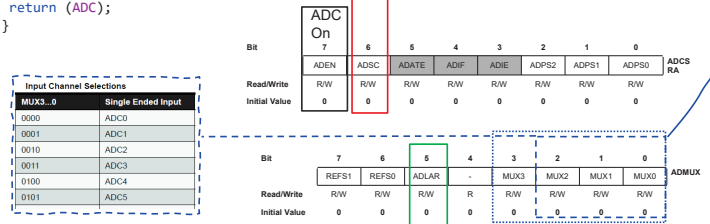
REFS1	REFS0	Voltage Reference Selection
0	0	AVCC with internal capacitor at REFS0 pin
0	1	AVCC with external capacitor at REFS0 pin
1	0	Internal 1.1V Voltage Reference with external capacitor at REFS0 pin
1	1	Internal 1.1V Voltage Reference with external capacitor at REFS1 pin



15	14	13	12	11	10	9	8
-	-	-	-	-	-	ADCF	ADCF
ADSC7	ADSC6	ADSC5	ADSC4	ADSC3	ADSC2	ADSC1	ADSC0

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);
}
```



MUX3..0	Single Ended Input
0000	ADC0
0001	ADC1
0010	ADC2
0011	ADC3
0100	ADC4
0101	ADC5

15	14	13	12	11	10	9	8
-	-	-	-	-	-	ADCF	ADCF
ADSC7	ADSC6	ADSC5	ADSC4	ADSC3	ADSC2	ADSC1	ADSC0