

# A/D Converter

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Atmel AVR Core

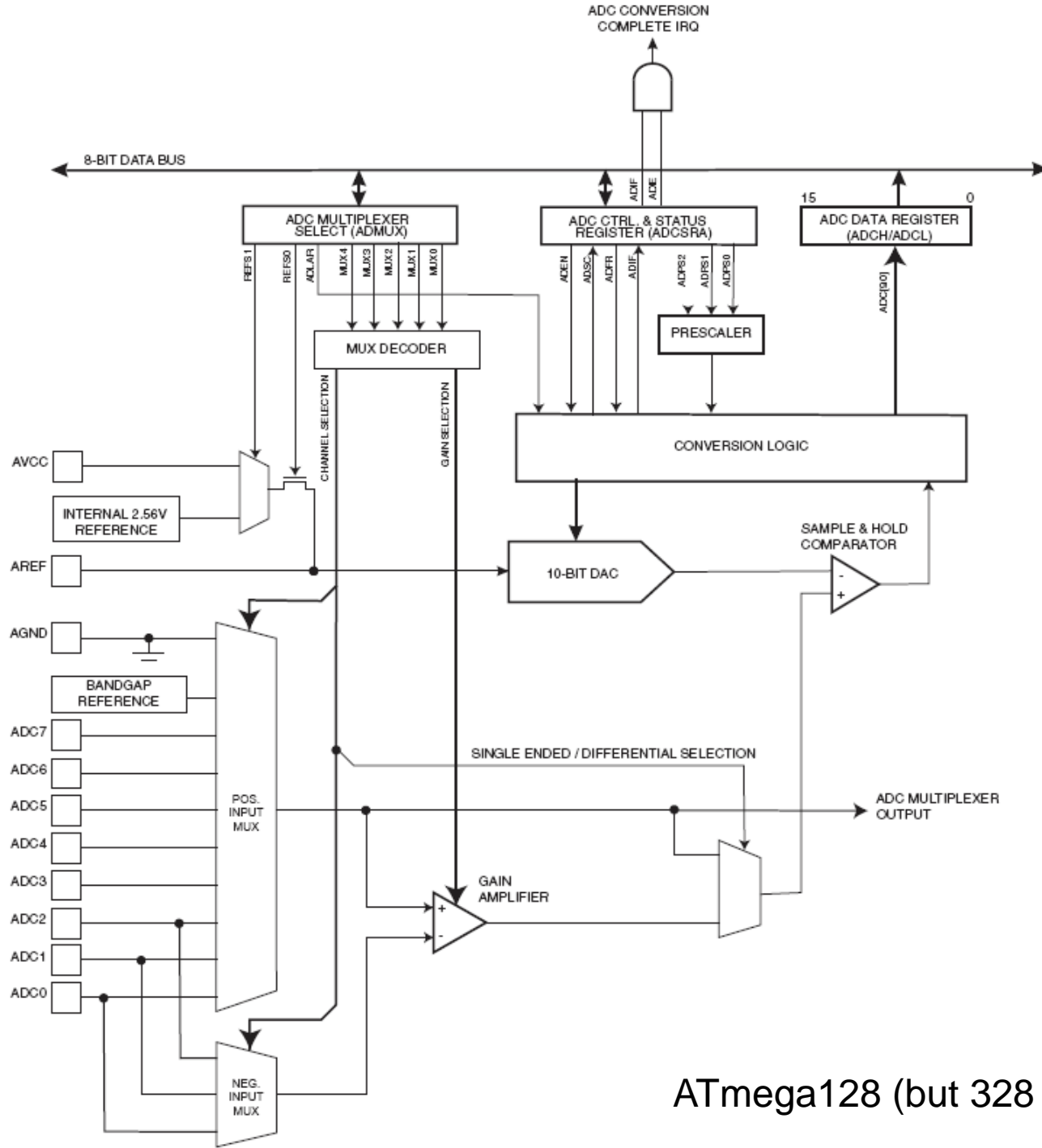
ATmega128 + ATmega328PB





# Feature overview

- 10-bit
- 13-260 us
- 15 kSPS@max resolution, 76.9 kSPS total max.
- 8 channels, multiplex
- input 0-Vcc
- internal reference / external reference
  - 2.56V for ATmega128, 1.1V for ATmega328PB
- Free-run / Single sample
- Interrupt on ADC complete
- “Sleep mode noise canceller”



ATmega128 (but 328 is very similar)

# ADC Multiplexer Selection Register (ATmega128)



| ADMUX | 7     | 6     | 5     | 4    | 3    | 2    | 1    | 0    |
|-------|-------|-------|-------|------|------|------|------|------|
|       | REFS1 | REFS0 | ADLAR | MUX4 | MUX3 | MUX2 | MUX1 | MUX0 |
|       | R/W   | R/W   | R/W   | R/W  | R/W  | R/W  | R/W  | R/W  |
|       | 0     | 0     | 0     | 0    | 0    | 0    | 0    | 0    |

**MUX4-0** Analog Channel and Gain selector  
single-ended X differential 1x, 10x, 200x (X 1.23V, 0V)

**ADLAR** ADC Left Adjust Result

**REFS1-0** Reference Selector

00 ARef

01 AVcc

10 (reserved)

11 internal 2.56V

# ADC Control and Status Register A (ATmega128)



ADCSRA<sub>7</sub>

| 7    | 6    | 5    | 4    | 3    | 2     | 1     | 0     |
|------|------|------|------|------|-------|-------|-------|
| ADEN | ADSC | ADFR | ADIF | ADIE | ADPS2 | ADPS1 | ADPS0 |
| R/W  | R/W  | R/W  | R/W  | R/W  | R/W   | R/W   | R/W   |
| 0    | 0    | 0    | 0    | 0    | 0     | 0     | 0     |

ADPS2-0 ADC Prescaler Selector

2, 4, 8, 16, 32, 64, 128

ADIE      ADC Interrupt Enable

ADIF      ADC Interrupt Flag

ADFR      ADC Free Run Selector

ADSC      ADC Start Conversion

ADEN      ADC Enable

# ADC basic control (ATmega128)



- Enable A/D:  $ADEN = 1$
- Set clock 50-200kHz using ADPS0-2 prescaler
- If needed, set Free-run mode:  $ADFR = 1$
- If needed, provide interrupt handler + set ADIE
- Start conversion:  $ADSC = 1$   
(will be zeroed automatically after the conversion ends)
- If needed, check ADIF

# ADC Multiplexer Selection Register (ATmega328PB)



|       |       |       |       |    |      |      |      |      |
|-------|-------|-------|-------|----|------|------|------|------|
| ADMUX | 7     | 6     | 5     | 4  | 3    | 2    | 1    | 0    |
|       | REFS1 | REFS0 | ADLAR | -- | MUX3 | MUX2 | MUX1 | MUX0 |
|       | R/W   | R/W   | R/W   |    | R/W  | R/W  | R/W  | R/W  |
|       | 0     | 0     | 0     |    | 0    | 0    | 0    | 0    |

**MUX3-0** Analog Channel selector

ADC0-7, Temperature, 1.1V, 0V)

**ADLAR** ADC Left Adjust Result

**REFS1-0** Reference Selector

00 ARef

01 AVcc with external capacitor at AREF pin

10 (reserved)

11 internal 1.1V with external capacitor at AREF pin  
(AREF voltage still needed)

# ADC Control and Status Register A (ATmega328PB)



|                     |      |       |      |      |       |       |       |
|---------------------|------|-------|------|------|-------|-------|-------|
| ADCSRA <sub>7</sub> | 6    | 5     | 4    | 3    | 2     | 1     | 0     |
| ADEN                | ADSC | ADATE | ADIF | ADIE | ADPS2 | ADPS1 | ADPS0 |
| R/W                 | R/W  | R/W   | R/W  | R/W  | R/W   | R/W   | R/W   |
| 0                   | 0    | 0     | 0    | 0    | 0     | 0     | 0     |

ADPS2-0 ADC Prescaler Selector

2, 4, 8, 16, 32, 64, 128

ADIE      ADC Interrupt Enable

ADIF      ADC Interrupt Flag

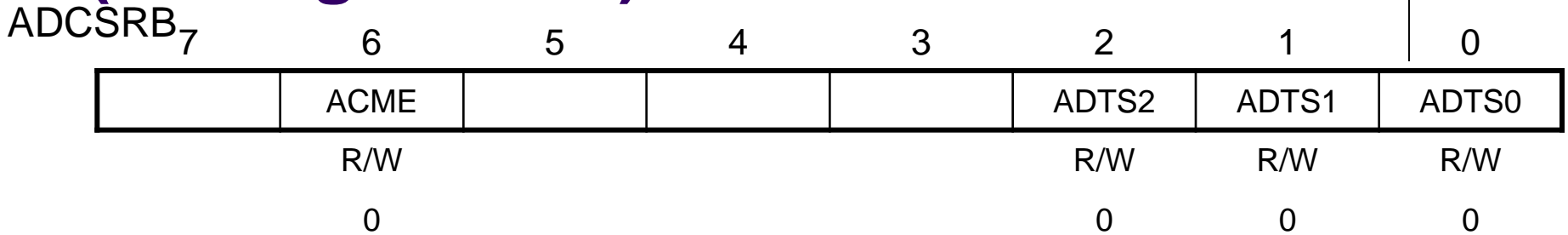
ADATE     ADC Auto Trigger Enable

ADSC      ADC Start Conversion

ADEN      ADC Enable



# ADC Control and Status Register B (ATmega328PB)



**ACME**      Analog Comparator Multiplexer Enable

**ADTS**      ADC Auto Trigger Source

000          Free Running Mode

001          Analog Comparator

010          External Interrupt 0

011+100      Timer/Counter0

101+110+111    Timer/Counter1

# Digital Input Disable Register 0 (ATmega328PB)



|       |       |       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| DIDR0 | 7     | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
|       | ADC7D | ADC6D | ADC5D | ADC4D | ADC3D | ADC2D | ADC1D | ADC0D |
|       | R/W   | R/W   | R/W   | R/W   | R/W   | R/W   | R/W   | R/W   |
|       | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |

Disables corresponding digital pin buffer

PINx always reads 0

Lower power consumption

# ADC basic control (ATmega328PB)



- Enable A/D:  $ADEN = 1$
- If needed, set Free-run mode:  $ADATE = 1$   
 $ADTS = 000$   
Auto Trigger:  $ADATE = 1$   
 $ADTS = xxx$
- Set clock 50-200kHz using ADPS0-2 prescaler
- If needed, provide interrupt handler + set ADIE
- Start conversion:  $ADSC = 1$   
(will be zeroed automatically after the conversion ends)
- If needed, check ADIF

# ADC temperature measurement (ATmega328PB)



- On-chip temperature sensor
- Sensitivity approx 1LSB/°C
- Accuracy  $\pm 10^{\circ}\text{C}$
- ADMUX = 1000
- Internal 1.1V reference needed
- $T = (\text{ADC} - T_{\text{OS}}) / k$ 
  - $T_{\text{OS}}$  ... temperature sensor offset
  - $k$  ... fixed coefficient (“typically,  $k$  is very close to 1.0”)
  - For calibration, see AN122



# Result – ADCH, ADCL

- first L then H !!
  - reading from L blocks changes of data registers, reading H unblocks
- when registers are blocked and a conversion occurs, its result is discarded
- interrupt is called even if the result is discarded



# ADC Noise Canceler

- ADC enabled and not busy, Single Conversion Mode set, ADC Conversion Complete interrupt enabled.
- Enter ADC Noise Reduction Mode or Idle Mode
  - ADC will start once the CPU has been halted
- When ADC is complete, the ADC interrupt will wake up the CPU and execute ADC Interrupt routine
  - If other interrupts occur before, they will be executed
- The CPU remains in active mode.