AVR505: Migration between ATmega16/32 and ATmega164P/324P/644P

8-bit AVR® Microcontrollers

Application Note

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1 Introduction

The ATmega164P and the ATmega324P are new and enhanced versions of the ATmega16 and the ATmega32 respectively, and ATmega644P is a new 64kB device with the same features. An important improvement is the possibility for low voltage operation (1.8V) with ATmega164P/324P/644P and decreased power consumption. ATmega164P/324P/644P also features an extra USART and can run at frequencies up to 20 MHz.

This application note summarizes the differences between ATmega16/32 and ATmega164P/324P/644P and is a guide to assist current ATmega16/32 users in converting existing designs to the ATmega164P/324P/644P. Note that electrical differences such as power consumption and I/O driving capabilities are not covered in this document. Refer to the datasheets for detailed information on the devices. Migration from ATmega644 is covered by AVR508: Migration from ATmega644 to ATmega644P.

ATmega164P/324P/644P are pin compatible with ATmega163/323, and migration between these devices is possible but not within the scope of this application note. Refer to AVR083: Replacing ATmega163 by ATmega16 and AVR084: Replacing ATmega323 by ATmega32 for further details.

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2 General porting considerations

To make the porting process as easy as possible, we recommend to always refer to registers and bit positions using their defined names, as absolute addresses and values may change from device to device. When porting a design it is then often just necessary to include the correct definition file. Some examples are shown below.

```
PORTE |=  (1<<PORTE5);         // Set pin 5 on port E high
DDR   &= ~(1<<PORTE5);         // Set pin 5 on port E as input
// Configure USI
USICR  =  (1<<USISIE)|(0<<USIOIE)|(1<<USIWM1)|(0<<USIWM0)|
          (1<<USICS1)|(0<<USICS0)|(0<<USICLK)|(0<<USITC);
```

To avoid conflicts with added features and register functionality, never access registers that are marked as reserved. Reserved bits should always be written to zero if accessed. This ensures forward compatibility, and that added features will stay in their default states if not used.

3 Memories

The memory sizes are the same for the ATmega16 and the ATmega164P as well as for the ATmega32 and ATmega324P, hence this does not imply a considerable difference in migrating between them. Please note the different page size for 644P memories as shown in Table 3-2.

Table 3-1. Memory Sizes.

	ATmega16/164P	ATmega32/324P	Atmega644P
FLASH	16 kb	32 kb	64 kb
SRAM	1 kb	2 kb	4 kb
EEPROM	512 b	1 kb	2 kb

Table 3-2. Page Sizes.

	ATmega16/164P	ATmega32/324P	Atmega644P
FLASH	64 words	64 words	128 words
EEPROM	4 bytes	4 bytes	8 bytes

4 I/O Mapping and SRAM

The I/O memory space contains 64 addresses for CPU peripheral control registers. The ATmega164P/324P/644P I/O space and I/O range are changed and extended compared to ATmega16/32. The extended I/O space goes from 0x60 to 0xFF in data memory space where ST/STS/STD and LD/LDS/LDD instructions must be used.

The memory map is slightly different between the ATmega16/32 and the ATmega164P/324P/644P due to extended I/O space. The ATmega164P/324P/644P internal data SRAM addressing starts at 0x100 as opposed to 0x60 in ATmega16/32.

5 EEPROM Programming

In ATmega16/32 EEPROM data programming is done in one atomic operation, in ATmega164P/324P/644P it is also possible to split the erase and write operations in two different operations. The typical EEPROM programming times are also reduced in ATmega164P/324P/644P.

Table 5-1. EEPROM Programming Time.

	ATmega16/32		**ATmega164P/324P/644P**	
	Number of Calibrated RC Oscillator Cycles	Typical Programming Time	Number of Calibrated RC Oscillator Cycles	Typical Programming Time
EEPROM write from CPU	8448	8.5 ms	26368	3.3 ms

6 External 32 kHz Watch Crystal

When operating the timer/counter from an external 32.768 kHz watch crystal or an external clock source, external capacitors might be needed to the TOSC1/2 pins when using ATmega164P/324P/644P, as opposed to ATmega16/32 where the crystal can be connected directly between the pins. The internal capacitance of ATmega164P/324P/644P low-frequency oscillator is typically 6pF, but the tracks to the crystal will add some additional capacitance. Refer to the datasheet for details on crystal connections.

The low frequency crystal oscillator of the ATmega164P/324P/644P is optimized for very low power consumption and thus the crystal driver strength is reduced compared to the ATmega16/32. This means that when selecting a crystal, its load capacitance and Equivalent Series Resistance (ESR) must be taken into consideration. Both values are specified by the crystal vendor. Table 6-1 shows the ESR recommendations for ATmega164P/324P/644P.

Table 6-1. ESR recommendation 32.768 kHz crystals with ATmega164P/324P/644P.

Crystal CL [pF]	**Max ESR [kΩ][1]**
6.5	75
9	65
12.5	30

Note: 1. The values stated are for an oscillator allowance safety margin of 5. Since the oscillator's transconductance is temperature compensated one can use a safety margin of 4, thus giving a max ESR of 90, 80 and 40 kΩ respectively.

For examples of crystals that comply with the requirements see Appendix A.

The startup times are also increased as shown in Table 6-2.

Table 6-2. Startup times with 32.768 kHz crystals.

Crystal CL [pF]	Startup time[2] [ms] ATmega16/32	Startup time[2] [ms] ATmega164P/324P/644P
6.5	-	600
9	300	700
12.5	400	1700

Note: 2. Crystals usually need ~3000ms before they are completely stable with any oscillator design. The time stated is before the crystal is running with a sufficient amplitude and frequency stability.

7 Changes To Register and Bit Names

Several modifications have been done in register and bit naming conventions between ATmega16/32 and ATmega164P/324P/644P. The locations of the registers are changed considerably.

7.1 Registers

Table 7-1. Changes to Register Names and Locations.

Address in ATmega16/32	Register Name in ATmega16/32	Address in ATmega164P/324P/ 644P	Register Name in ATmega164P/324P/ 644P
$3C ($5C)	OCR0	$27 ($47)	OCR0A
$3B ($5B)	GICR	$1D ($3D)	EIMSK
$3A ($5A)	GIFR	$1C ($3C)	EIFR
$39 ($59)	TIMSK	($6E) ($6F) ($70)	TIMSK0 TIMSK1 TIMSK2
$38 ($58)	TIFR	$15 ($35) $16 ($36) $17 ($37)	TIFR0 TIFR1 TIFR2
$37 ($57)	SPMCR	$37 ($57)	SPMCSR
$36 ($56)	TWCR	($BC)	TWCR
$35 ($55)	MCUCR	$33 ($53) ($69)	SMCR EICRA
$34 ($54)	MCUCSR	$34 ($54)	MCUSR(3)
$33 ($53)	TCCR0	$24 ($44)	TCCR0A(3)
$32 ($52)	TCNT0	$26 ($46)	TCNT0
$31 ($51)	OSCCAL OCDR	($66) 31 ($51)	OSCCAL OCDR
$30 ($50)	SFIOR	($7B)	ADCSRB(3)
$2F ($4F)	TCCR1A	($80)	TCCR1A(3)
$2E ($4E)	TCCR1B	($81)	TCCR1B
$2D ($4D)	TCNT1H	($85)	TCNT1H
$2C ($4C)	TCNT1L	($84)	TCNT1L

Address in ATmega16/32	Register Name in ATmega16/32	Address in ATmega164P/324P/ 644P	Register Name in ATmega164P/324P/ 644P
$2B ($4B)	OCR1AH	($89)	OCR1AH
$2A ($4A)	OCR1AL	($88)	OCR1AL
$29 ($49)	OCR1BH	($8B)	OCR1BH
$28 ($48)	OCR1BL	($8A)	OCR1BL
$27 ($47)	ICR1H	($87)	ICR1H
$26 ($46)	ICR1L	($86)	ICR1L
$25 ($45)	TCCR2	($B0)	TCCR2A(3)
$24 ($44)	TCNT2	($B2)	TCNT2
$23 ($43)	OCR2	($B3)	OCR2A
$22 ($42)	ASSR	($B6)	ASSR(3)
$21 ($41)	WDTCR	($60)	WDTCSR(3)
$20 ($40)	UBRRH UCSRC	($C5) ($C2)	UBRR0H(3) UCSR0C(3)
$1F ($3F)	EEARH	$22 ($42)	EEARH
$1E ($3E)	EEARL	$21 ($41)	EEARL
$1D ($3D)	EEDR	$20 ($40)	EEDR
$1C ($3C)	EECR	$1F ($3F)	EECR
$1B ($3B)	PORTA	$02 ($22)	PORTA
$1A ($3A)	DDRA	$01 ($21)	DDRA
$19 ($39)	PINA	$00 ($20)	PINA
$18 ($38)	PORTB	$05 ($25)	PORTB
$17 ($37)	DDRB	$04 ($24)	DDRB
$16 ($36)	PINB	$03 ($23)	PINB
$15 ($35)	PORTC	$08 ($28)	PORTC
$14 ($34)	DDRC	$07 ($27)	DDRC
$13 ($33)	PINC	$06 ($26)	PINC
$12 ($32)	PORTD	$0B ($2B)	PORTD
$11 ($31)	DDRD	$0A ($2A)	DDRD
$10 ($30)	PIND	$09 ($29)	PIND
$0F ($2F)	SPDR	$2E ($4E)	SPDR
$0E ($2E)	SPSR	$2D ($4D)	SPSR
$0D ($2D)	SPCR	$2C ($4C)	SPCR
$0C ($2C)	UDR	($C6)	UDR0
$0B ($2B)	UCSRA	($C0)	UCSR0A(3)
$0A ($2A)	UCSRB	($C1)	UCSR0B(3)
$09 ($29)	UBRRL	($C4)	UBRR0L
$08 ($28)	ACSR	$30 ($50)	ACSR
$07 ($27)	ADMUX	($7C)	ADMUX
$06 ($26)	ADCSRA	($7A)	ADCSRA

Address in ATmega16/32	Register Name in ATmega16/32	Address in ATmega164P/324P/ 644P	Register Name in ATmega164P/324P/ 644P
$05 ($25)	ADCH	($79)	ADCH
$04 ($24)	ADCL	($78)	ADCL
$03 ($23)	TWDR	($BB)	TWDR
$02 ($22)	TWAR	($BA)	TWAR
$01 ($21)	TWSR	($B9)	TWSR
$00 ($20)	TWBR	($B8)	TWBR

Note: 3. Some of the register bits may be located in another register or the bit names are changed, see Table 7-2.

7.2 Bit Definitions

Some bits in ATmega164P/324P/644P have changed name and register location compared to ATmega16/32, other bits have changed location within the register.

Table 7-2. Changes to Bit Names and Locations.

Register in ATmega16/32	Bit Name in ATmega16/32	Register in ATmega164P/324P/ 644P	Bit Name in ATmega164P/324P/644 P
GICR	IVSEL, IVCE	MCUCR	IVSEL, IVCE
TIMSK	OCIE2 TICIE1 OCIE0	TIMSK2 TIMSK1 TIMSK0	OCIE2A ICIE1 OCIE0A
TIFR	TOV2 TOV1 TOV0	TIFR2 TIFR1 TIFR0	TOV2 TOV1 TOV0
TIFR	OCF2 OCF0	TIFR2 TIFR0	OCF2A OCF0A
MCUCSR	JTD ISC2	MCUCR EICRA	JTD ISC20
TCCR0	FOC0 COM01 COM00 CS02 CS01 CS00	TCCR0B TCCR0A TCCR0A TCCR0B TCCR0B TCCR0B	FOC0A COM0A1 COM0A0 CS02 CS01 CS00
SFIOR	PUD PSR2 PSR10	MCUCR GTCCR	PUD PSRASY PSRSYNC
TCCR1A	FOC1A FOC1B	TCCR1C	FOC1A FOC1B
TCCR2	FOC2 COM21 COM20 CS22 CS21 CS20	TCCR2B TCCR2A TCCR2A TCCR2B TCCR2B TCCR2B	FOC2A COM2A1 COM2A0 CS22 CS21 CS20

Register in ATmega16/32	Bit Name in ATmega16/32	Register in ATmega164P/324P/644P	Bit Name in ATmega164P/324P/644P
ASSR	OCR2UB TCR2UB WDTOE	ASSR n/a(1)	OCR2AUB TCR2AUB n/a(1)
UBRRH	URSEL	n/a(1)	n/a(1)
UCRSC	URSEL UMSEL UPM1 UPM0 USBS UCSZ1 UCSZ2 UCPOL	n/a(1) UCSR0C UCSR1C UCSR0C UCSR0C UCSR0C UCSR1C UCSR0C	n/a(1) UMSEL00 UPM10 UPM00 USBS0 UCSZ00 UCSZ10 UCPOL0
UCSRA	RXC TXC UDRE FE DOR PE U2X MPCM	UCSR0A	RXC0 TXC0 UDRE0 FE0 DOR0 UPE0 U2X0 MPCM0
UCSRB	RXCIE TXCIE UDRIE RXEN TXEN UCSZ2 RXB8 TXB8	UCSR0B	RXCIE0 TXCIE0 UDRIE0 RXEN0 TXEN0 UCSZ02 RXB80 TXB80

Note: 1. The function of this bit has a different implementation in ATmega164P/324P/644P. Refer to datasheet for details.

8 Fuse Settings

ATmega164P/324P/644P has four fuse bytes instead of two in ATmega16/32. New features in ATmega164P/324P/644P imply other fuses and fuse settings.

Table 8-1. Comparing Fuses.

	ATmega16/32 Fuse	ATmega16/32 Default Setting	ATmega164P/324P/644P Fuse	ATmega164P/324P/644P Default Setting
Extended Fuse Byte	-	-	BODLEVEL2	1
	-	-	BODLEVEL1	1
	-	-	BODLEVEL0	1
Fuse High Byte	-	-	WDTON	1
	CKOPT	1	-	-
Fuse Low Byte	-	-	CKDIV8	0
	BODLEVEL	1	-	-
	BODEN	1	-	-

	ATmega16/32 Fuse	ATmega16/32 Default Setting	ATmega164P/324P/ 644P Fuse	ATmega164P/324P/ 644P Default Setting
	-	-	CKOUT	1
	CKSEL1	0	CKSEL1	1
	CKSEL0	1	CKSEL0	0

9 Interrupt Vectors

The ATmega164P/324P/644P has 31 interrupt vectors, located at different addresses than the ATmega16/32, which has 21 interrupt vectors. The ATmega16 and the ATmega32 also have different interrupt tables as shown in Table 9-1.

The additional interrupt vectors are due to extra peripherals not found on ATmega16/32

Table 9-1. Interrupt Table.

Vector #	ATmega16	ATmega32	ATmega164P/324P/644P
1	RESET	RESET	RESET
2	INT0	INT0	INT0
3	INT1	INT1	INT1
4	TIMER2_COMP	INT2	INT2
5	TIMER2_OVF	TIMER2_COMP	PCINT0
6	TIMER1_CAPT	TIMER2_OVF	PCINT1
7	TIMER1_COMPA	TIMER1_CAPT	PCINT2
8	TIMER1_COMPB	TIMER1_COMPA	PCINT3
9	TIMER1_OVF	TIMER1_COMPB	WDT
10	TIMER0_OVF	TIMER1_OVF	TIMER2_COMPA
11	SPI_STC	TIMER0_COMP	TIMER2_COMPB
12	USART_RXC	TIMER0_OVF	TIMER2_OVF
13	USART_UDRE	SPI_STC	TIMER1_CAPT
14	USART_TXC	USART_RXC	TIMER1_COMPA
15	ADC	USART_UDRE	TIMER1_COMPB
16	EE_RDY	USART_TXC	TIMER1_OVF
17	ANA_COMP	ADC	TIMER0_COMPA
18	TWI	EE_RDY	TIMER0_COMPB
19	INT2	ANA_COMP	TIMER0_OVF
20	TIMER0_COMP	TWI	SPI_STC
21	SPM_RDY	SPM_RDY	USART0_RX
22	-	-	USART0_UDRE
23	-	-	USART0_TX
24	-	-	ANALOG_COMP
25	-	-	ADC
26	-	-	EE_READY
27	-	-	TWI

Vector #	ATmega16	ATmega32	ATmega164P/324P/644P
28	-	-	SPM_READY
29	-	-	USART1_RX
30	-	-	USART1_UDRE
31	-	-	USART1_TX

10 IEEE 1149.1 (JTAG) Boundary Scan

The boundary scan has changed in ATmega164P/324P/644P where analog circuits no longer constitute a part of the scan chain. The order of the signal names in the boundary scan has also changed. Refer to datasheet for details.

11 Operational Range

Table 11-1. Operating voltage and Speed grades.

	Operating Voltage	Speed Grade
ATmega16/32	4.5-5.5V	0-16 MHz
ATmega16/32L	2.7-5.5V	0-8 MHz
ATmega164P/324P/644P	2.7-5.5V	0-20 MHz
ATmega164PV/324PV/644PV	1.8-5.5V	0-10 MHz

12 Appendix A

Table 12-1 is a selection of crystals that meet the ESR requirements of the ATmega164P/324P/644P. The crystals are listed based on datasheet information and are not tested with the actual device. Any other crystal that complies with the ESR requirements can also be used. Availability and RoHS compliance has not been investigated.

Table 12-1. Examples of crystals compliant with ATmega164P/324P/644P low-frequency Crystal Oscillator.

Vendor	Type	Mounting (SMD/HOLE)	Frequency Tolerance [±ppm]	Load Capacitance [pF]	Equivalent Series Resistance (ESR) [kΩ]
C-MAC	WATCH CRYSTALS	HOLE	20	6	50
C-MAC	85SMX	SMD	20	6	55
C-MAC	90SMX	SMD	20	6	60
ECLIPTEK	E4WC	HOLE	20	6	50
ENDRICH	90SMX	SMD	5	6	50
EPSON	C-001R	HOLE	20	6 -> 12.5 (specify)	35
EPSON	C-002RX	HOLE	20	6 -> 10 (specify)	50
EPSON	C-004R	HOLE	20	6 -> 10 (specify)	50
EPSON	C-005R	HOLE	20	6 -> 10 (specify)	50
EPSON	MC-30A	SMD	20	6 -> 10 (specify)	50
EPSON	MC-306	SMD	20	6 -> 10 (specify)	50
EPSON	MC-405	SMD	20	6 -> 10 (specify)	50

Vendor	Type	Mounting (SMD/HOLE)	Frequency Tolerance [±ppm]	Load Capacitance [pF]	Equivalent Series Resistance (ESR) [kΩ]
EPSON	MC-406	SMD	20	6 -> 10 (specify)	50
GOLLEDGE	GWX	HOLE	5	6, 8 or 12.5	35
GOLLEDGE	GSWX-26	SMD	10	6 , 8 or 12.5	35
GOLLEDGE	GDX1	HOLE	10	6	42
GOLLEDGE	GSX-200	SMD	5	6	50
IQD	WATCH CRYSTALS	HOLE	20	6	50
IQD	90SMX	HOLE	10	6	60
IQD	91SMX	HOLE	10	6	60
MICROCRYSTAL	MS3V-T1R	HOLE	20	7 or 9	65
MICROCRYSTAL	MS2V-T1R	HOLE	20	7 or 9	65
MICROCRYSTAL	CC4V-T1A	SMD	30	9	65
MICROCRYSTAL	CC1V-T1A	SMD	30	9	60
MICROCRYSTAL	CC7V-T1A	SMD	30	9	70
MMD	WC26	HOLE	8	8	35
MMD	WC38	HOLE	8	8	35
MMD	WC155	HOLE	8	8	40
MMD	WCSMC	SMD	20	6	50
OSCILENT	SERIES 111	HOLE	10	6 or 12.5	30
OSCILENT	SERIES 112	HOLE	10	6 or 12.5	40
OSCILENT	SERIES 113	HOLE	10	8	40
OSCILENT	SERIES 223	SMD	20	6	50
RALTRON	SERIES R38	HOLE	5	6 or 12.5	35
RALTRON	SERIES R26	HOLE	5	6 or 12.5	35
RALTRON	SERIES R145	HOLE	5	8	40
RALTRON	SERIES RSE A, B, C, D	SMD	20	6	50
SBTRON	SBX-13	SMD	20	6	50
SBTRON	SBX-20	SMD	20	6	50
SBTRON	SBX-21	SMD	20	6	50
SBTRON	SBX-24	SMD	20	6	50
SBTRON	SBX-23	SMD	20	6	50
SBTRON	SBX-22	SMD	20	6	50
SBTRON	SBX-14	HOLE	20	6	50
SUNTSU	SCT1	HOLE	20	6, 8, 10 or 12.5	40
SUNTSU	SCT2	HOLE	20	6, 8, 10	50
SUNTSU	SCT3	HOLE	20	6, 8, 10	50
SUNTSU	SCP1	SMD	20	6	50
SUNTSU	SCT2G	SMD	20	6 or 10	50

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