Features

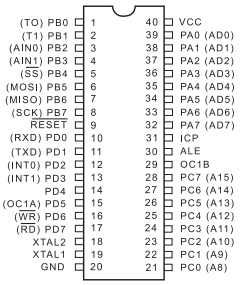
- **Utilizes the *AVR*® Enhanced RISC Architecture**
- **AV*R* - High Performance and Low Power RISC Architecture**
- **120 Powerful Instructions - Most Single Clock Cycle Execution**
- **4K bytes of In-System Reprogrammable Downloadable Flash**
  - **SPI Serial Interface for Program Downloading**
  - **Endurance: 1,000 Write/Erase Cycles**
- **256 bytes EEPROM**
  - **Endurance: 100,000 Write/Erase Cycles**
- **256 bytes Internal SRAM**
- **32 x 8 General Purpose Working Registers**
- **32 Programmable I/O Lines**
- **Programmable Serial UART**
- **SPI Serial Interface**
- **V_{CC}: 2.7 - 6.0V**
- **Fully Static Operation, 0 - 8 MHz (4.0 - 6.0V), 0 - 4 MHz (2.7 - 4.0V)**
- **Up to 8 MIPS Throughput at 8 MHz**
- **One 8-Bit Timer/Counter with Separate Prescaler**
- **One 16-Bit Timer/Counter with Separate Prescaler and Compare and Capture Modes**
- **Dual PWM**
- **External and Internal Interrupt Sources**
- **Programmable Watchdog Timer with On-Chip Oscillator**
- **On-Chip Analog Comparator**
- **Low Power Idle and Power Down Modes**
- **Programming Lock for Software Security**

Description

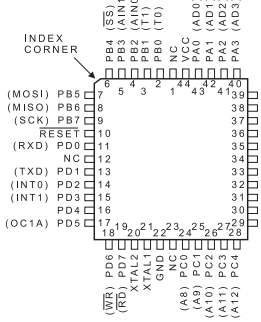
The AT90S4414 is a low-power CMOS 8-bit microcontroller based on the *AVR*® enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the AT90S4414 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

Pin Configurations

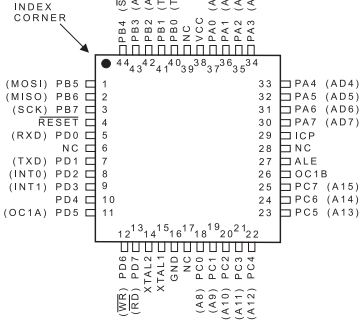
PDIP



PLCC



TQFP



8-Bit *AVR*® Microcontroller with 4K bytes Downloadable Flash

AT90S4414 Preliminary

Rev. 0840BS-B–12/97

Block Diagram

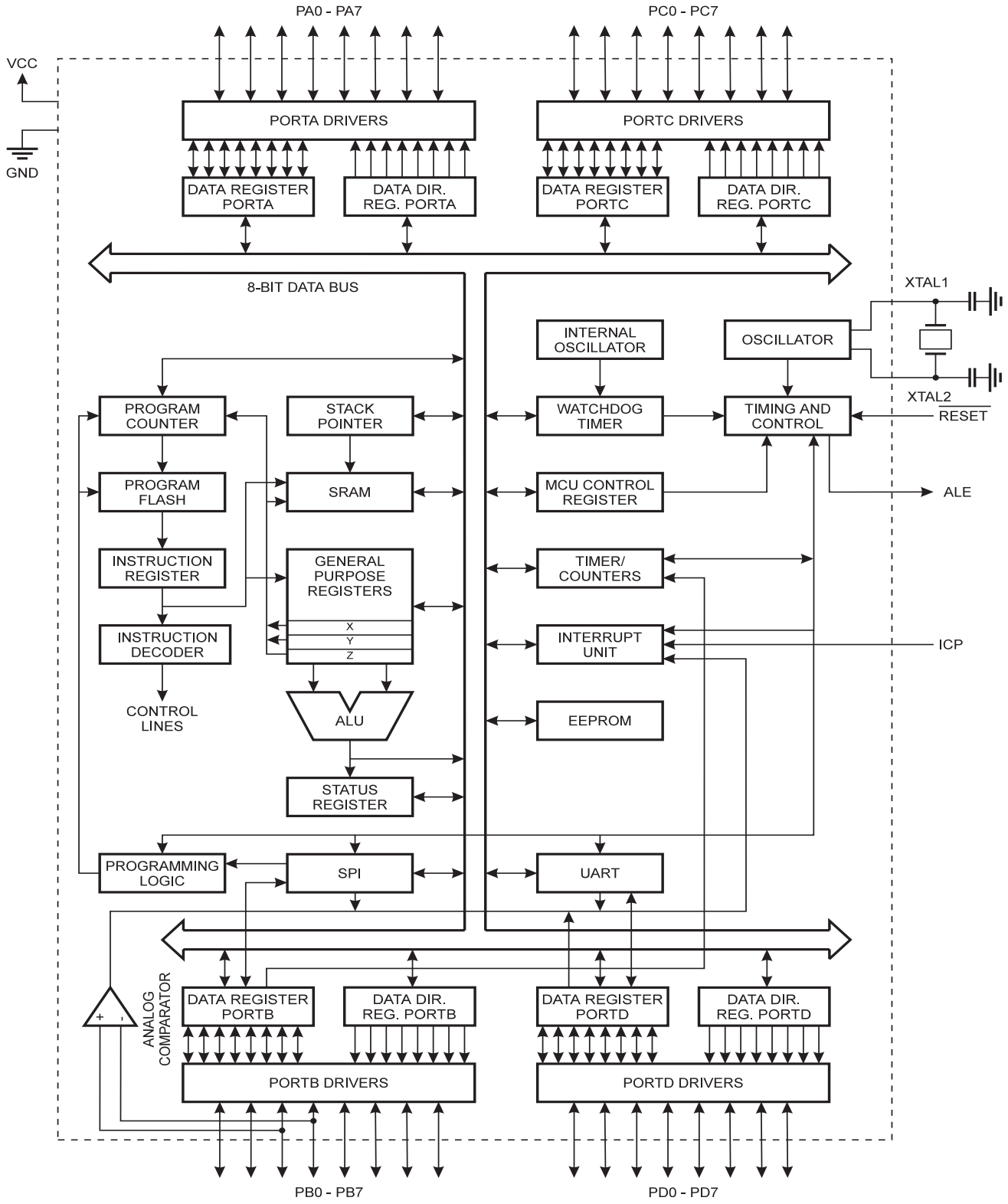


Figure 1. The AT90S4414 Block Diagram

Description (Continued)

The *AVR* core is based on an enhanced RISC architecture that combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

The AT90S4414 provides the following features: 4K bytes of Downloadable Flash, 256 bytes EEPROM, 256 bytes SRAM, 32 general purpose I/O lines, 32 general purpose working registers, flexible timer/counters with compare modes, internal and external interrupts, a programmable serial UART, programmable Watchdog Timer with internal oscillator, an SPI serial port and two software selectable power saving modes. The Idle Mode stops the CPU while allowing the SRAM, timer/counters, SPI port and interrupt system to continue functioning. The power down mode saves the register contents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

The device is manufactured using Atmel's high density non-volatile memory technology. The on-chip Downloadable Flash allows the program memory to be reprogrammed in-system through an SPI serial interface or by a conventional nonvolatile memory programmer. By combining an enhanced RISC 8-bit CPU with Downloadable Flash on a monolithic chip, the Atmel AT90S4414 is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The AT90S4414 *AVR* is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, in-circuit emulators, and evaluation kits.

Pin Descriptions

VCC

Supply voltage

GND

Ground

Port A (PA7..PA0)

Port A is an 8-bit bidirectional I/O port. Port pins can provide internal pullups (selected for each bit). The Port A output buffers can sink 20mA and can drive LED displays directly. When pins PA0 to PA7 are used as inputs and are externally pulled low, they will source current (I_{IL}) if the internal pullups are activated.

Port A serves as Multiplexed Address/Data input/output when using external SRAM.

Port B (PB7..PB0)

Port B is an 8-bit bidirectional I/O pins with internal pullups. The Port B output buffers can sink 20 mA. As inputs, Port B pins that are externally pulled low will source current (I_{IL}) if the pullups are activated.

Port B also serves the functions of various special features of the AT90S4414 as listed on Page 58.

Port C (PC7..PC0)

Port C is an 8-bit bidirectional I/O port with internal pullups. The Port C output buffers can sink 20 mA. As inputs, Port C pins that are externally pulled low will source current (I_{IL}) if the pullups are activated.

Port C also serves as Address output when using external SRAM.

Port D (PD7..PD0)

Port D is an 8-bit bidirectional I/O port with internal pullups. The Port D output buffers can sink 20 mA. As inputs, Port D pins that are externally pulled low will source current (I_{IL}) if the pullups are activated.

Port D also serves the functions of various special features of the AT90S4414 as listed on Page 64

AT90S4414 Architectural Overview

The fast-access register file concept contains 32 x 8-bit general purpose working registers with a single clock cycle access time. This means that during one single clock cycle, one ALU (Arithmetic Logic Unit) operation is executed. Two operands are output from the register file, the operation is executed, and the result is stored back in the register file - in one clock cycle. Six of the 32 registers can be used as three 16-bits indirect address register pointers for Data Space addressing - enabling efficient address calculations. One of the three address pointers is also used as the address pointer for the constant table look up function. These added function registers are the 16-bits X-register, Y-register and Z-register.

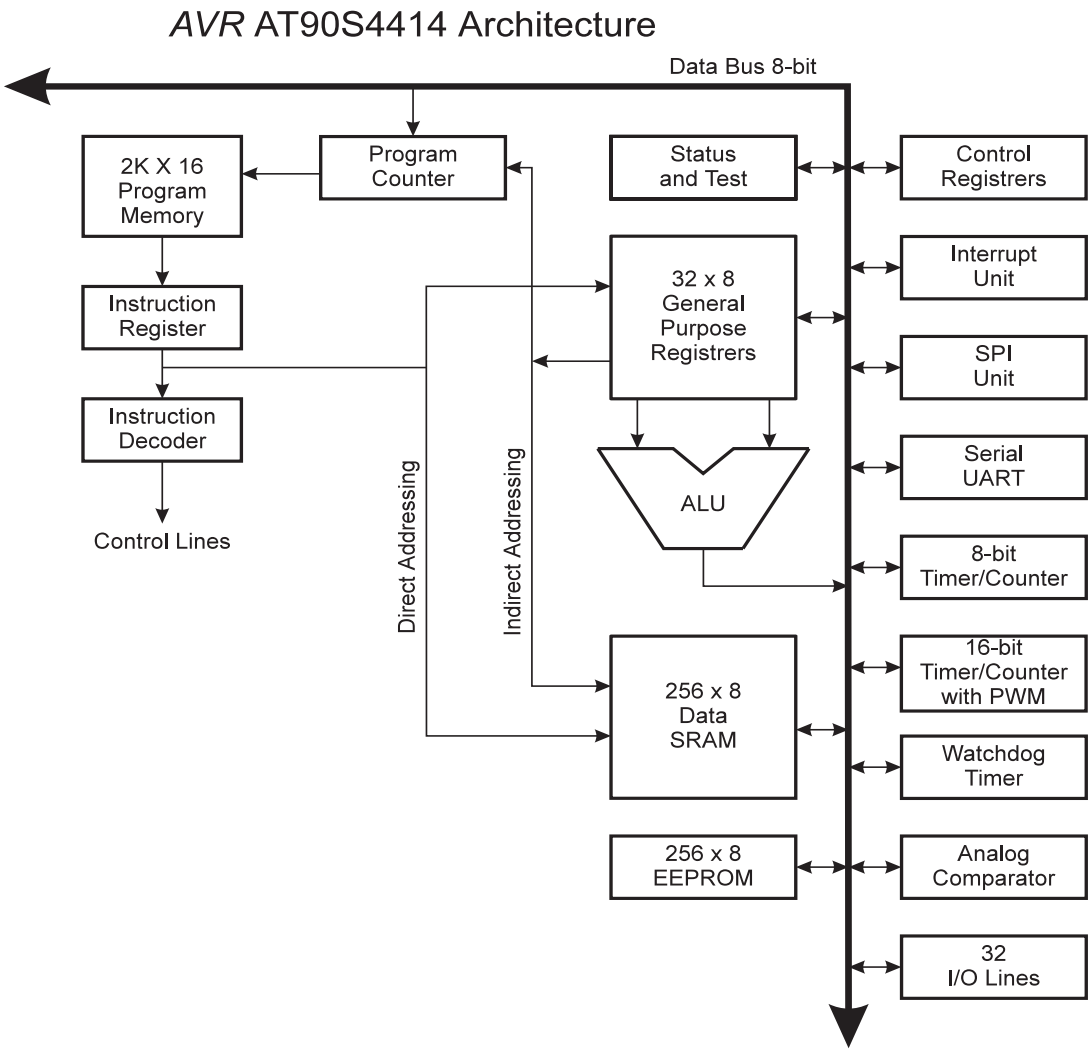


Figure 2. The AT90S4414 *AVR* Enhanced RISC Architecture

The ALU supports arithmetic and logic functions between registers or between a constant and a register. Single register operations are also executed in the ALU. Figure 2 shows the AT90S4414 *AVR* Enhanced RISC microcontroller architecture.

In addition to the register operation, the conventional memory addressing modes can be used on the register file as well. This is enabled by the fact that the register file is assigned the 32 lowermost Data Space addresses ($00 - $1F), allowing them to be accessed as though they were ordinary memory locations.

The I/O memory space contains 64 addresses for CPU peripheral functions as Control Registers, Timer/Counters, A/D-converters, and other I/O functions. The I/O Memory can be accessed directly, or as the Data Space locations following those of the register file, $20 - $5F.

AT90S4414 Register Summary

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
$3F ($5F)	SREG	I	T	H	S	V	N	Z	C	19
$3E ($5E)	SPH	SP15	SP14	SP13	SP12	SP11	SP10	SP9	SP8	20
$3D ($5D)	SPL	SP7	SP6	SP5	SP4	SP3	SP2	SP1	SP0	20
$3C ($5C)	Reserved									
$3B ($5B)	GIMSK	INT1	INT0	-	-	-	-	-	-	25
$3A ($5A)	GIFR	INTF1	INTF0							25
$39 ($59)	TIMSK	TOIE1	OCIE1A	OCIE1B	-	TICIE1	-	TOIE0	-	25
$38 ($58)	TIFR	TOV1	OCF1A	OCF1B	-	ICF1	-	TOV0	-	26
$37 ($57)	Reserved									
$36 ($56)	Reserved									
$35 ($55)	MCUCR	SRE	SRW	SE	SM	ISC11	ISC10	ISC01	ISC00	27
$34 ($54)	Reserved									
$33 ($53)	TCCR0	-	-	-	-	-	CS02	CS01	CS00	30
$32 ($52)	TCNT0	Timer/Counter0 (8 Bit)								31
$31 ($51)	Reserved									
$30 ($50)	Reserved									
$2F ($4F)	TCCR1A	COM1A1	COM1A0	COM1B1	COM1B0	-	-	PWM11	PWM10	33
$2E ($4E)	TCCR1B	ICNC1	ICES1	-	-	CTC1	CS12	CS11	CS10	34
$2D ($4D)	TCNT1H	Timer/Counter1 - Counter Register High Byte								35
$2C ($4C)	TCNT1L	Timer/Counter1 - Counter Register Low Byte								35
$2B ($4B)	OCR1AH	Timer/Counter1 - Output Compare Register A High Byte								36
$2A ($4A)	OCR1AL	Timer/Counter1 - Output Compare Register A Low Byte								36
$29 ($49)	OCR1BH	Timer/Counter1 - Output Compare Register B High Byte								36
$28 ($48)	OCR1BL	Timer/Counter1 - Output Compare Register B Low Byte								36
$27 ($47)	Reserved									
$26 ($46)	Reserved									
$25 ($45)	ICR1H	Timer/Counter1 - Input Capture Register High Byte								36
$24 ($44)	ICR1L	Timer/Counter1 - Input Capture Register Low Byte								36
$23 ($43)	Reserved									
$22 ($42)	Reserved									
$21 ($41)	WDTCR	-	-	-	WDTOE	WDE	WDP2	WDP1	WDP0	39
$20 ($40)	Reserved									
$1F ($3F)	EEARH	-	-	-	-	-	-	-	EEAR9	40
$1E ($3E)	EEARL	EEPROM Address Register Low								40
$1D ($3D)	EEDR	EEPROM Data Register								40
$1C ($3C)	EECR	-	-	-	-	-	EEMWE	EEWE	EERE	41
$1B ($3B)	PORTA	PORTA7	PORTA6	PORTA5	PORTA4	PORTA3	PORTA2	PORTA1	PORTA0	55
$1A ($3A)	DDRA	DDA7	DDA6	DDA5	DDA4	DDA3	DDA2	DDA1	DDA0	55
$19 ($39)	PINA	PINA7	PINA6	PINA5	PINA4	PINA3	PINA2	PINA1	PINA0	55
$18 ($38)	PORTB	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0	57
$17 ($37)	DDRB	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0	57
$16 ($36)	PINB	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0	57
$15 ($35)	PORTC	PORTC7	PORTC6	PORTC5	PORTC4	PORTC3	PORTC2	PORTC1	PORTC0	62
$14 ($34)	DDRC	DDC7	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0	62
$13 ($33)	PINC	PINC7	PINC6	PINC5	PINC4	PINC3	PINC2	PINC1	PINC0	62
$12 ($32)	PORTD	PORTD7	PORTD6	PORTD5	PORTD4	PORTD3	PORTD2	PORTD1	PORTD0	64
$11 ($31)	DDRD	DDD7	DDD6	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0	64
$10 ($30)	PIND	PIND7	PIND6	PIND5	PIND4	PIND3	PIND2	PIND1	PIND0	64
$0F ($2F)	SPDR	SPI Data Register								46
$0E ($2E)	SPSR	SPIF	WCOL	-	-	-	-	-	-	45
$0D ($2D)	SPCR	SPIE	SPE	DORD	MSTR	CPOL	CPHA	SPR1	SPR0	45
$0C ($2C)	UDR	UART I/O Data Register								49
$0B ($2B)	USR	RXC	TXC	UDRE	FE	OR	-	-	-	49
$0A ($2A)	UCR	RXCIE	TXCIE	UDRIE	RXEN	TXEN	CHR9	RXB8	TXB8	50
$09 ($29)	UBRR	UART Baud Rate Register								52
$08 ($28)	ACSR	ACD	-	ACO	ACI	ACIE	ACIC	ACIS1	ACIS0	53
…	Reserved									
$00 ($20)	Reserved									

AT90S4414 Instruction Set Summary

Mnemonics	Operands	Description	Operation	Flags	#Clocks
ARITHMETIC AND LOGIC INSTRUCTIONS					
ADD	Rd, Rr	Add two Registers	Rd ← Rd + Rr	Z,C,N,V,H	1
ADC	Rd, Rr	Add with Carry two Registers	Rd ← Rd + Rr + C	Z,C,N,V,H	1
ADIW	Rdl,K	Add Immediate to Word	Rdh:Rdl ← Rdh:Rdl + K	Z,C,N,V,S	2
SUB	Rd, Rr	Subtract two Registers	Rd ← Rd - Rr	Z,C,N,V,H	1
SUBI	Rd, K	Subtract Constant from Register	Rd ← Rd - K	Z,C,N,V,H	1
SBC	Rd, Rr	Subtract with Carry two Registers	Rd ← Rd - Rr - C	Z,C,N,V,H	1
SBCI	Rd, K	Subtract with Carry Constant from Reg.	Rd ← Rd - K - C	Z,C,N,V,H	1
SBIW	Rdl,K	Subtract Immediate from Word	Rdh:Rdl ← Rdh:Rdl - K	Z,C,N,V,S	2
AND	Rd, Rr	Logical AND Registers	Rd ← Rd • Rr	Z,N,V	1
ANDI	Rd, K	Logical AND Register and Constant	Rd ← Rd • K	Z,N,V	1
OR	Rd, Rr	Logical OR Registers	Rd ← Rd v Rr	Z,N,V	1
ORI	Rd, K	Logical OR Register and Constant	Rd ← Rd v K	Z,N,V	1
EOR	Rd, Rr	Exclusive OR Registers	Rd ← Rd ⊕ Rr	Z,N,V	1
COM	Rd	One's Complement	Rd ← $FF – Rd	Z,C,N,V	1
NEG	Rd	Two's Complement	Rd ← $00 – Rd	Z,C,N,V,H	1
SBR	Rd,K	Set Bit(s) in Register	Rd ← Rd v K	Z,N,V	1
CBR	Rd,K	Clear Bit(s) in Register	Rd ← Rd • ($FF - K)	Z,N,V	1
INC	Rd	Increment	Rd ← Rd + 1	Z,N,V	1
DEC	Rd	Decrement	Rd ← Rd – 1	Z,N,V	1
TST	Rd	Test for Zero or Minus	Rd ← Rd • Rd	Z,N,V	1
CLR	Rd	Clear Register	Rd ← Rd ⊕ Rd	Z,N,V	1
SER	Rd	Set Register	Rd ← $FF	None	1
BRANCH INSTRUCTIONS					
RJMP	k	Relative Jump	PC ← PC + k + 1	None	2
IJMP		Indirect Jump to (Z)	PC ← Z	None	2
RCALL	k	Relative Subroutine Call	PC ← PC + k + 1	None	3
ICALL		Indirect Call to (Z)	PC ← Z	None	3
RET		Subroutine Return	PC ← STACK	None	4
RETI		Interrupt Return	PC ← STACK	I	4
CPSE	Rd,Rr	Compare, Skip if Equal	if (Rd = Rr) PC ← PC + 2 or 3	None	1 / 2
CP	Rd,Rr	Compare	Rd – Rr	Z, N,V,C,H	1
CPC	Rd,Rr	Compare with Carry	Rd – Rr – C	Z, N,V,C,H	1
CPI	Rd,K	Compare Register with Immediate	Rd – K	Z, N,V,C,H	1
SBRC	Rr, b	Skip if Bit in Register Cleared	if (Rr(b)=0) PC ← PC + 2 or 3	None	1 / 2
SBRS	Rr, b	Skip if Bit in Register is Set	if (Rr(b)=1) PC ← PC + 2 or 3	None	1 / 2
SBIC	P, b	Skip if Bit in I/O Register Cleared	if (P(b)=0) PC ← PC + 2 or 3	None	1 / 2
SBIS	P, b	Skip if Bit in I/O Register is Set	if (P(b)=1) PC ← PC + 2 or 3	None	1 / 2
BRBS	s, k	Branch if Status Flag Set	if (SREG(s) = 1) then PC←PC+k + 1	None	1 / 2
BRBC	s, k	Branch if Status Flag Cleared	if (SREG(s) = 0) then PC←PC+k + 1	None	1 / 2
BREQ	k	Branch if Equal	if (Z = 1) then PC ← PC + k + 1	None	1 / 2
BRNE	k	Branch if Not Equal	if (Z = 0) then PC ← PC + k + 1	None	1 / 2
BRCS	k	Branch if Carry Set	if (C = 1) then PC ← PC + k + 1	None	1 / 2
BRCC	k	Branch if Carry Cleared	if (C = 0) then PC ← PC + k + 1	None	1 / 2
BRSH	k	Branch if Same or Higher	if (C = 0) then PC ← PC + k + 1	None	1 / 2
BRLO	k	Branch if Lower	if (C = 1) then PC ← PC + k + 1	None	1 / 2
BRMI	k	Branch if Minus	if (N = 1) then PC ← PC + k + 1	None	1 / 2
BRPL	k	Branch if Plus	if (N = 0) then PC ← PC + k + 1	None	1 / 2
BRGE	k	Branch if Greater or Equal, Signed	if (N ⊕ V= 0) then PC ← PC + k + 1	None	1 / 2
BRLT	k	Branch if Less Than Zero, Signed	if (N ⊕ V= 1) then PC ← PC + k + 1	None	1 / 2
BRHS	k	Branch if Half Carry Flag Set	if (H = 1) then PC ← PC + k + 1	None	1 / 2
BRHC	k	Branch if Half Carry Flag Cleared	if (H = 0) then PC ← PC + k + 1	None	1 / 2
BRTS	k	Branch if T Flag Set	if (T = 1) then PC ← PC + k + 1	None	1 / 2
BRTC	k	Branch if T Flag Cleared	if (T = 0) then PC ← PC + k + 1	None	1 / 2
BRVS	k	Branch if Overflow Flag is Set	if (V = 1) then PC ← PC + k + 1	None	1 / 2
BRVC	k	Branch if Overflow Flag is Cleared	if (V = 0) then PC ← PC + k + 1	None	1 / 2
BRIE	k	Branch if Interrupt Enabled	if (I = 1) then PC ← PC + k + 1	None	1 / 2
BRID	k	Branch if Interrupt Disabled	if (I = 0) then PC ← PC + k + 1	None	1 / 2

Mnemonics	Operands	Description	Operation	Flags	#Clocks
DATA TRANSFER INSTRUCTIONS					
MOV	Rd, Rr	Move Between Registers	Rd ← Rr	None	1
LDI	Rd, K	Load Immediate	Rd ← K	None	1
LD	Rd, X	Load Indirect	Rd ← (X)	None	2
LD	Rd, X+	Load Indirect and Post-Inc.	Rd ← (X), X ← X + 1	None	2
LD	Rd, - X	Load Indirect and Pre-Dec.	X ← X - 1, Rd ← (X)	None	2
LD	Rd, Y	Load Indirect	Rd ← (Y)	None	2
LD	Rd, Y+	Load Indirect and Post-Inc.	Rd ← (Y), Y ← Y + 1	None	2
LD	Rd, - Y	Load Indirect and Pre-Dec.	Y ← Y - 1, Rd ← (Y)	None	2
LDD	Rd,Y+q	Load Indirect with Displacement	Rd ← (Y + q)	None	2
LD	Rd, Z	Load Indirect	Rd ← (Z)	None	2
LD	Rd, Z+	Load Indirect and Post-Inc.	Rd ← (Z), Z ← Z+1	None	2
LD	Rd, -Z	Load Indirect and Pre-Dec.	Z ← Z - 1, Rd ← (Z)	None	2
LDD	Rd, Z+q	Load Indirect with Displacement	Rd ← (Z + q)	None	2
LDS	Rd, k	Load Direct from SRAM	Rd ← (k)	None	3
ST	X, Rr	Store Indirect	(X) ← Rr	None	2
ST	X+, Rr	Store Indirect and Post-Inc.	(X) ← Rr, X ← X + 1	None	2
ST	- X, Rr	Store Indirect and Pre-Dec.	X ← X - 1, (X) ← Rr	None	2
ST	Y, Rr	Store Indirect	(Y) ← Rr	None	2
ST	Y+, Rr	Store Indirect and Post-Inc.	(Y) ← Rr, Y ← Y + 1	None	2
ST	- Y, Rr	Store Indirect and Pre-Dec.	Y ← Y - 1, (Y) ← Rr	None	2
STD	Y+q,Rr	Store Indirect with Displacement	(Y + q) ← Rr	None	2
ST	Z, Rr	Store Indirect	(Z) ← Rr	None	2
ST	Z+, Rr	Store Indirect and Post-Inc.	(Z) ← Rr, Z ← Z + 1	None	2
ST	-Z, Rr	Store Indirect and Pre-Dec.	Z ← Z - 1, (Z) ← Rr	None	2
STD	Z+q,Rr	Store Indirect with Displacement	(Z + q) ← Rr	None	2
STS	k, Rr	Store Direct to SRAM	(k) ← Rr	None	3
LPM		Load Program Memory	R0 ← (Z)	None	3
IN	Rd, P	In Port	Rd ← P	None	1
OUT	P, Rr	Out Port	P ← Rr	None	1
PUSH	Rr	Push Register on Stack	STACK ← Rr	None	2
POP	Rd	Pop Register from Stack	Rd ← STACK	None	2
BIT AND BIT-TEST INSTRUCTIONS					
SBI	P,b	Set Bit in I/O Register	I/O(P,b) ← 1	None	2
CBI	P,b	Clear Bit in I/O Register	I/O(P,b) ← 0	None	2
LSL	Rd	Logical Shift Left	Rd(n+1) ← Rd(n), Rd(0) ← 0	Z,C,N,V	1
LSR	Rd	Logical Shift Right	Rd(n) ← Rd(n+1), Rd(7) ← 0	Z,C,N,V	1
ROL	Rd	Rotate Left Through Carry	Rd(0)←C,Rd(n+1)← Rd(n),C←Rd(7)	Z,C,N,V	1
ROR	Rd	Rotate Right Through Carry	Rd(7)←C,Rd(n)← Rd(n+1),C←Rd(0)	Z,C,N,V	1
ASR	Rd	Arithmetic Shift Right	Rd(n) ← Rd(n+1), n=0..6	Z,C,N,V	1
SWAP	Rd	Swap Nibbles	Rd(3..0)←Rd(7..4),Rd(7..4)←Rd(3..0)	None	1
BSET	s	Flag Set	SREG(s) ← 1	SREG(s)	1
BCLR	s	Flag Clear	SREG(s) ← 0	SREG(s)	1
BST	Rr, b	Bit Store from Register to T	T ← Rr(b)	T	1
BLD	Rd, b	Bit load from T to Register	Rd(b) ← T	None	1
SEC		Set Carry	C ← 1	C	1
CLC		Clear Carry	C ← 0	C	1
SEN		Set Negative Flag	N ← 1	N	1
CLN		Clear Negative Flag	N ← 0	N	1
SEZ		Set Zero Flag	Z ← 1	Z	1
CLZ		Clear Zero Flag	Z ← 0	Z	1
SEI		Global Interrupt Enable	I ← 1	I	1
CLI		Global Interrupt Disable	I ← 0	I	1
SES		Set Signed Test Flag	S ← 1	S	1
CLS		Clear Signed Test Flag	S ← 0	S	1
SEV		Set Twos Complement Overflow.	V ← 1	V	1
CLV		Clear Twos Complement Overflow	V ← 0	V	1
SET		Set T in SREG	T ← 1	T	1
CLT		Clear T in SREG	T ← 0	T	1
SEH		Set Half Carry Flag in SREG	H ← 1	H	1
CLH		Clear Half Carry Flag in SREG	H ← 0	H	1
NOP		No Operation		None	1
SLEEP		Sleep	(see specific descr. for Sleep function)	None	3
WDR		Watchdog Reset	(see specific descr. for WDR/timer)	None	1