

Features

- High-performance, Low-power Atmel AVR® 8-bit Microcontroller
- Advanced RISC Architecture
 - 130 Powerful Instructions – Most Single Clock Cycle Execution
 - 32 x 8 General Purpose Working Registers + Peripheral Control Registers
 - Fully Static Operation
 - Up to 16 MIPS Throughput at 16 MHz
 - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory segments
 - 64 Kbytes of In-System Reprogrammable Flash program memory
 - 2 Kbytes EEPROM
 - 4 Kbytes Internal SRAM
 - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
 - Data retention: 20 years at 85°C/100 years at 25°C⁽¹⁾
 - Optional Boot Code Section with Independent Lock Bits
 - In-System Programming by On-chip Boot Program
 - True Read-While-Write Operation
 - Up to 64 Kbytes Optional External Memory Space
 - Programming Lock for Software Security
 - SPI Interface for In-System Programming
- JTAG (IEEE std. 1149.1 Compliant) Interface
 - Boundary-scan Capabilities According to the JTAG Standard
 - Extensive On-chip Debug Support
 - Programming of Flash, EEPROM, Fuses, and Lock Bits through the JTAG Interface
- Peripheral Features
 - Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes
 - Two Expanded 16-bit Timer/Counters with Separate Prescaler, Compare Mode, and Capture Mode
 - Real Time Counter with Separate Oscillator
 - Two 8-bit PWM Channels
 - 6 PWM Channels with Programmable Resolution from 1 to 16 Bits
 - 8-channel, 10-bit ADC
 - 8 Single-ended Channels
 - 7 Differential Channels
 - 2 Differential Channels with Programmable Gain (1x, 10x, 200x)
 - Byte-oriented Two-wire Serial Interface
 - Dual Programmable Serial USARTs
 - Master/Slave SPI Serial Interface
 - Programmable Watchdog Timer with On-chip Oscillator
 - On-chip Analog Comparator
- Special Microcontroller Features
 - Power-on Reset and Programmable Brown-out Detection
 - Internal Calibrated RC Oscillator
 - External and Internal Interrupt Sources
 - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby and Extended Standby
 - Software Selectable Clock Frequency
 - ATmega103 Compatibility Mode Selected by a Fuse
 - Global Pull-up Disable
- I/O and Packages
 - 53 Programmable I/O Lines
 - 64-lead TQFP and 64-pad QFN/MLF
- Operating Voltages
 - 2.7V - 5.5V for Atmel ATmega64L
 - 4.5V - 5.5V for Atmel ATmega64
- Speed Grades
 - 0 - 8 MHz for ATmega64L
 - 0 - 16 MHz for ATmega64



8-bit Atmel Microcontroller with 64K Bytes In-System Programmable Flash

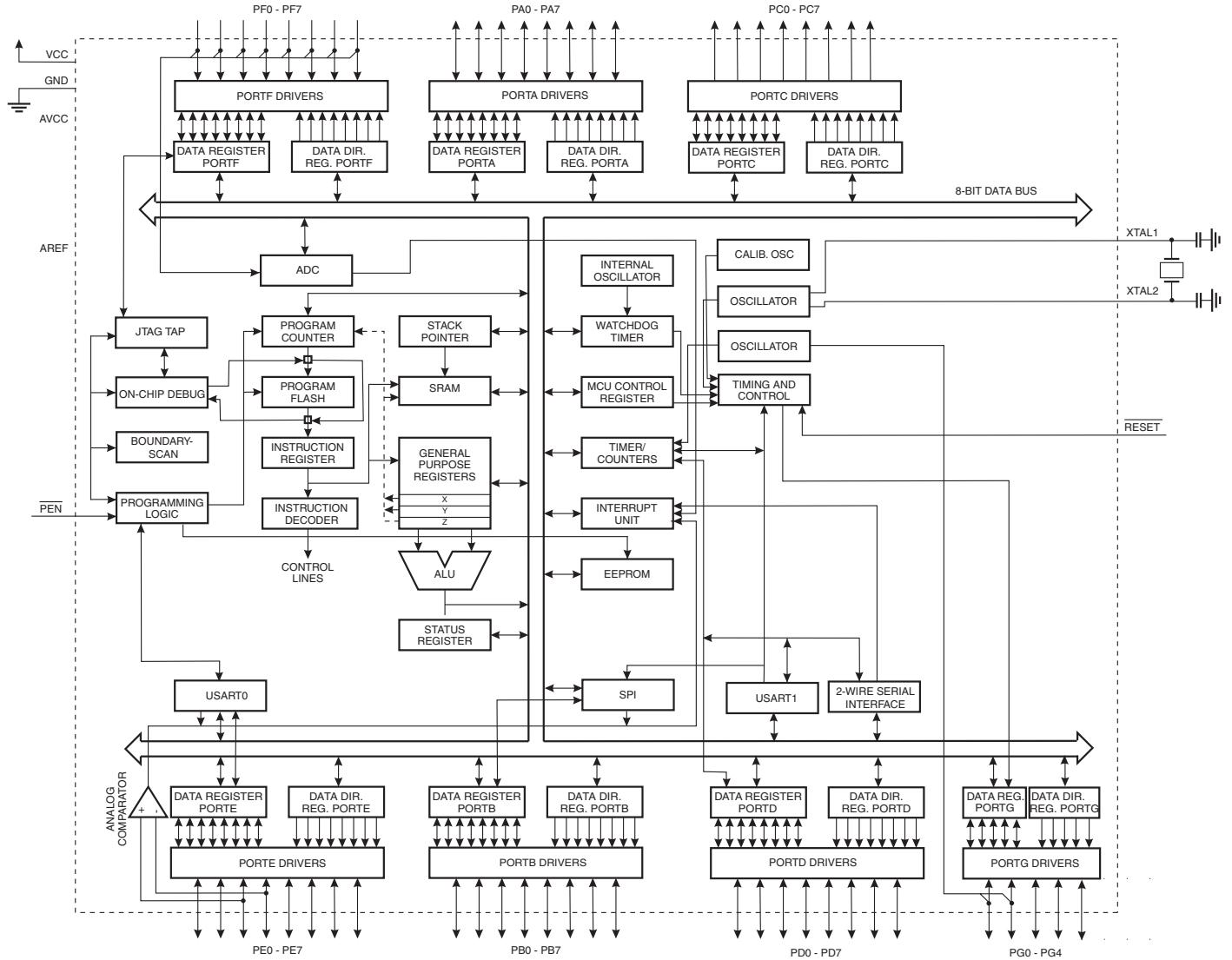
ATmega64
ATmega64L

Overview

The ATmega64 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 ATmega64 achieves throughputs approaching 1 MIPS per MHz, allowing the system designer to optimize power consumption versus processing speed.

Block Diagram

Figure 2. Block Diagram



The AVR core 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.

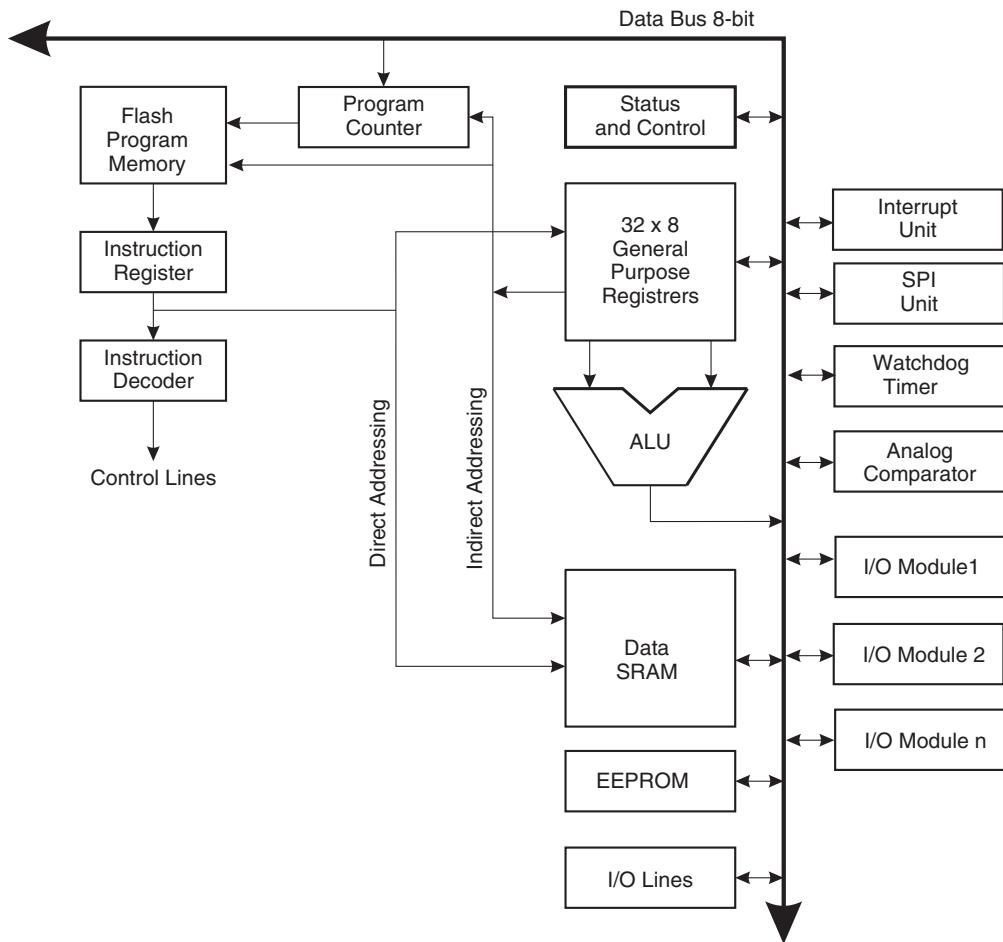
AVR CPU Core

Introduction

This section discusses the AVR core architecture in general. The main function of the CPU core is to ensure correct program execution. The CPU must therefore be able to access memories, perform calculations, control peripherals, and handle interrupts.

Architectural Overview

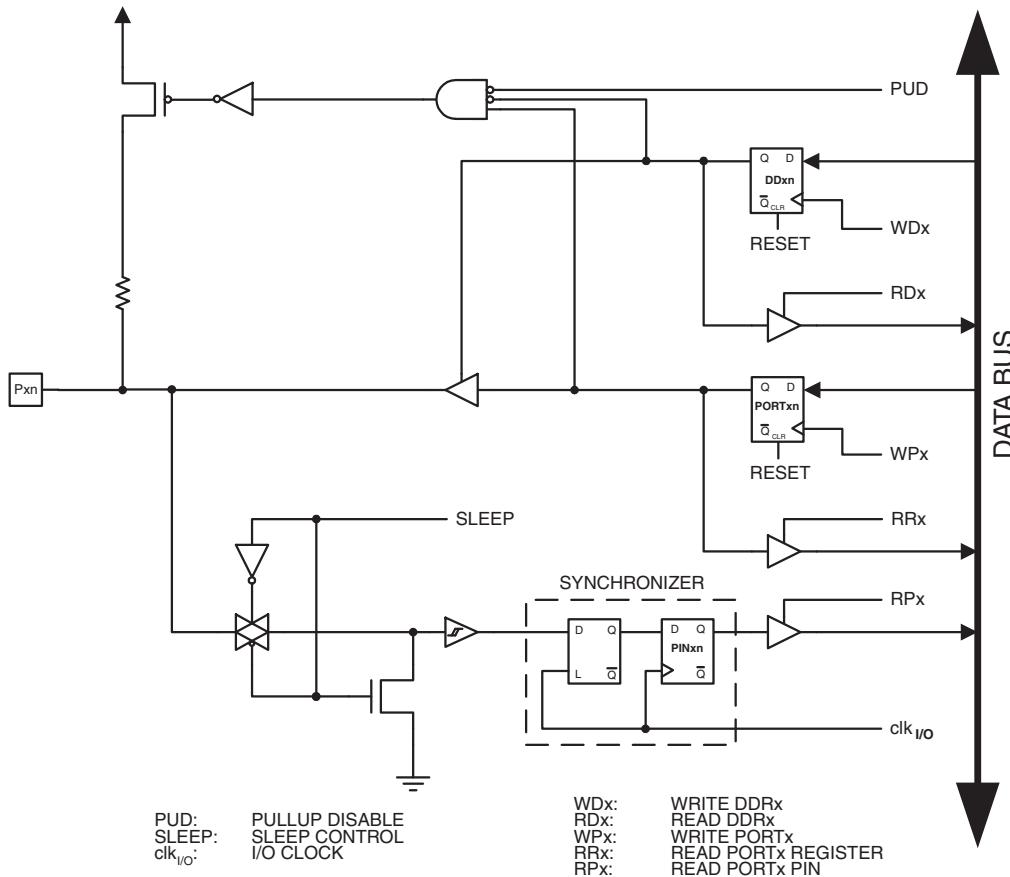
Figure 3. Block Diagram of the AVR MCU Architecture



In order to maximize performance and parallelism, the AVR uses a Harvard architecture – with separate memories and buses for program and data. Instructions in the program memory are executed with a single level pipelining. While one instruction is being executed, the next instruction is pre-fetched from the program memory. This concept enables instructions to be executed in every clock cycle. The program memory is In-System Reprogrammable Flash memory.

The fast-access Register File contains 32 x 8-bit general purpose working registers with a single clock cycle access time. This allows single-cycle Arithmetic Logic Unit (ALU) operation. In a typical ALU operation, 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-bit indirect address register pointers for Data Space addressing – enabling efficient address calculations. One of the these address pointers

Figure 30. General Digital I/O⁽¹⁾

Note: 1. WPx, WDx, RRx, RPx, and RDx are common to all pins within the same port. clk_{I/O}, SLEEP, and PUD are common to all ports.

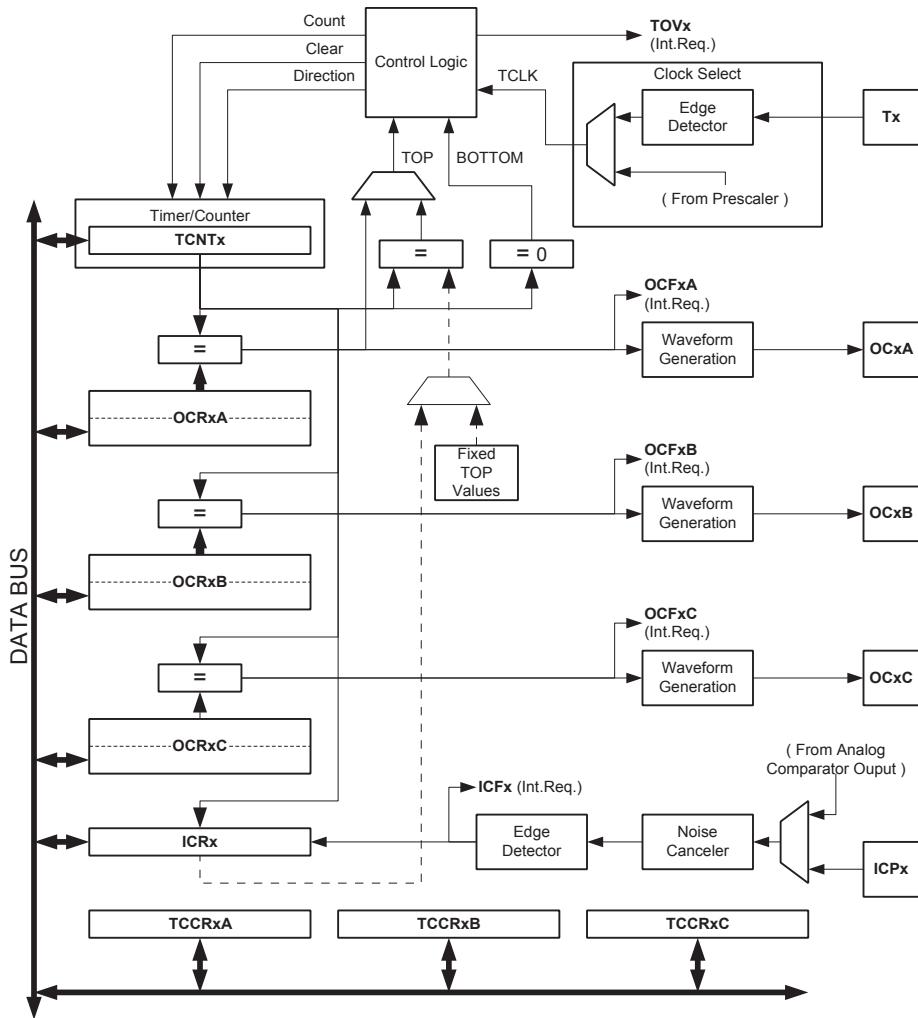
Configuring the Pin

Each port pin consists of three register bits: DDxn, PORTTxn, and PINxn. As shown in “[Register Description for I/O Ports](#)” on page 87, the DDxn bits are accessed at the DDRx I/O address, the PORTTxn bits at the PORTx I/O address, and the PINxn bits at the PINx I/O address.

The DDxn bit in the DDRx Register selects the direction of this pin. If DDxn is written logic one, Pxn is configured as an output pin. If DDxn is written logic zero, Pxn is configured as an input pin.

If PORTTxn is written logic one when the pin is configured as an input pin, the pull-up resistor is activated. To switch the pull-up resistor off, PORTTxn has to be written logic zero or the pin has to be configured as an output pin. The port pins are tri-stated when a reset condition becomes active, even if no clocks are running.

If PORTTxn is written logic one when the pin is configured as an output pin, the port pin is driven high (one). If PORTTxn is written logic zero when the pin is configured as an output pin, the port pin is driven low (zero).

Figure 46. 16-bit Timer/Counter Block Diagram⁽¹⁾

Note: 1. Refer to [Figure 1 on page 2](#), [Table 30 on page 74](#), and [Table 39 on page 81](#) for Timer/Counter1 and 3 pin placement and description.

Registers

The *Timer/Counter* (TCNTn), *Output Compare Registers* (OCRnA/B/C), and *Input Capture Register* (ICRn) are all 16-bit registers. Special procedures must be followed when accessing the 16-bit registers. These procedures are described in the section “[Accessing 16-bit Registers](#)” on [page 115](#). The *Timer/Counter Control Registers* (TCCRnA/B/C) are 8-bit registers and have no CPU access restrictions. Interrupt requests (shorten as Int.Req.) signals are all visible in the *Timer Interrupt Flag Register* (TIFR) and *Extended Timer Interrupt Flag Register* (ETIFR). All interrupts are individually masked with the *Timer Interrupt Mask Register* (TIMSK) and *Extended Timer Interrupt Mask Register* (ETIMSK). (E)TIFR and (E)TIMSK are not shown in the figure since these registers are shared by other timer units.

The Timer/Counter can be clocked internally, via the prescaler, or by an external clock source on the Tn pin. The Clock Select logic block controls which clock source and edge the Timer/Counter uses to increment (or decrement) its value. The Timer/Counter is inactive when no clock source is selected. The output from the Clock Select logic is referred to as the timer clock (clk_{Tn}).

The double buffered Output Compare Registers (OCRnA/B/C) are compared with the Timer/Counter value at all time. The result of the compare can be used by the Waveform Generator to generate a PWM or variable frequency output on the Output Compare Pin (OCnA/B/C).

USART

The Universal Synchronous and Asynchronous serial Receiver and Transmitter (USART) is a highly flexible serial communication device. The main features are:

- Full Duplex Operation (Independent Serial Receive and Transmit Registers)
- Asynchronous or Synchronous Operation
- Master or Slave Clocked Synchronous Operation
- High Resolution Baud Rate Generator
- Supports Serial Frames with 5, 6, 7, 8, or 9 Data Bits and 1 or 2 Stop Bits
- Odd or Even Parity Generation and Parity Check Supported by Hardware
- Data OverRun Detection
- Framing Error Detection
- Noise Filtering Includes False Start Bit Detection and Digital Low Pass Filter
- Three Separate Interrupts on TX Complete, TX Data Register Empty and RX Complete
- Multi-processor Communication Mode
- Double Speed Asynchronous Communication Mode

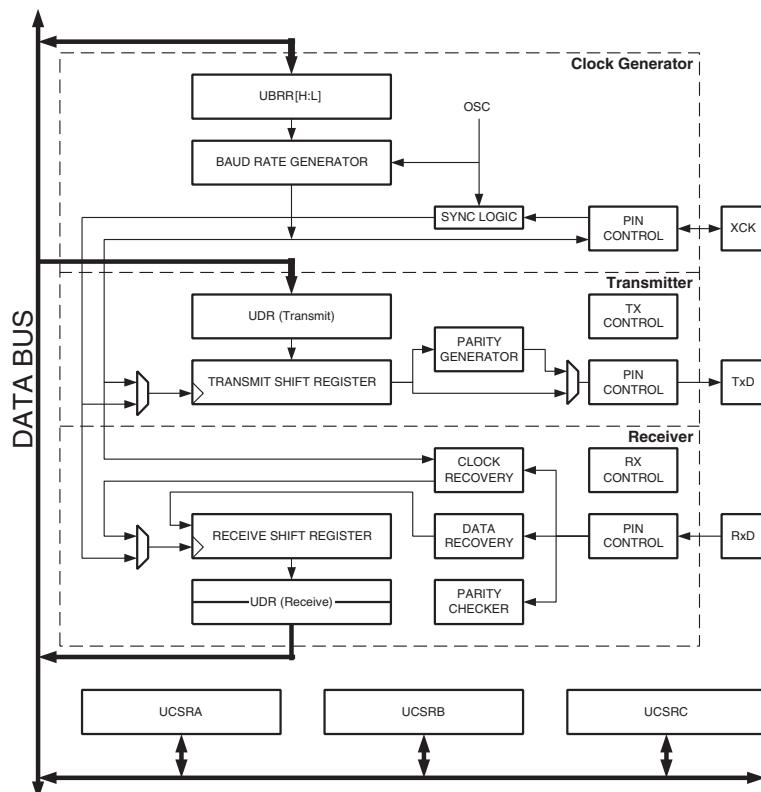
Dual USART

The ATmega64 has two USART's, USART0 and USART1. The functionality for both USART's is described below. USART0 and USART1 have different I/O Registers as shown in “[Register Summary](#) on page 392”. Note that in ATmega103 compatibility mode, USART1 is not available, neither is the UBRR0H or UCRC0C registers. This means that in ATmega103 compatibility mode, the ATmega64 supports asynchronous operation of USART0 only.

Overview

A simplified block diagram of the USART Transmitter is shown in [Figure 79](#). CPU accessible I/O Registers and I/O pins are shown in bold.

Figure 79. USART Block Diagram⁽¹⁾



Note: 1. Refer to [Figure 1 on page 2](#), [Table 36 on page 78](#), and [Table 39 on page 81](#) for USART pin placement.

Electrical Characteristics – TA = -40°C to 85°C

Absolute Maximum Ratings*

Operating Temperature.....	-55°C to +125°C
Storage Temperature	-65°C to +150°C
Voltage on any Pin except <u>RESET</u> with respect to Ground	-0.5V to V _{CC} +0.5V
Voltage on <u>RESET</u> with respect to Ground.....	-0.5V to +13.0V
Maximum Operating Voltage	6.0V
DC Current per I/O Pin	40.0 mA
DC Current V _{CC} and GND Pins.....	200.0 - 400.0 mA

*NOTICE: Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

T_A = -40°C to 85°C, V_{CC} = 2.7V to 5.5V (unless otherwise noted)

Symbol	Parameter	Condition	Min	Typ	Max	Units
V _{IL}	Input Low Voltage except XTAL1 and <u>RESET</u> pins	V _{CC} = 2.7V - 5.5V	-0.5		0.2 V _{CC} ⁽¹⁾	V
V _{IH}	Input High Voltage except XTAL1 and <u>RESET</u> pins	V _{CC} = 2.7V - 5.5V	0.6 V _{CC} ⁽²⁾		V _{CC} + 0.5	
V _{IL1}	Input Low Voltage XTAL1 pin	V _{CC} = 2.7V - 5.5V	-0.5		0.1 V _{CC} ⁽¹⁾	
V _{IH1}	Input High Voltage XTAL1 pin	V _{CC} = 2.7V - 5.5V	0.7 V _{CC} ⁽²⁾		V _{CC} + 0.5	
V _{IL2}	Input Low Voltage <u>RESET</u> pin	V _{CC} = 2.7V - 5.5V	-0.5		0.2 V _{CC} ⁽¹⁾	
V _{IH2}	Input High Voltage <u>RESET</u> pin	V _{CC} = 2.7V - 5.5V	0.85 V _{CC} ⁽²⁾		V _{CC} + 0.5	
V _{OL}	Output Low Voltage ⁽³⁾ (Ports A,B,C,D, E, F, G)	I _{OL} = 20 mA, V _{CC} = 5V I _{OL} = 10 mA, V _{CC} = 3V			0.7 0.5	V V
V _{OH}	Output High Voltage ⁽⁴⁾ (Ports A,B,C,D, E, F, G))	I _{OH} = -20 mA, V _{CC} = 5V I _{OH} = -10 mA, V _{CC} = 3V	4.2 2.2			V V
I _{IL}	Input Leakage Current I/O Pin	V _{CC} = 5.5V, pin low (absolute value)			1.0	µA
I _{IH}	Input Leakage Current I/O Pin	V _{CC} = 5.5V, pin high (absolute value)			1.0	µA
R _{RST}	Reset Pull-up Resistor		30		60	kΩ
R _{PEN}	PEN Pull-up Resistor		30		60	
R _{PU}	I/O Pin Pull-up Resistor		20		50	

DC Characteristics

$T_A = -40^\circ\text{C}$ to 85°C , $V_{CC} = 2.7\text{V}$ to 5.5V (unless otherwise noted) (Continued)

Symbol	Parameter	Condition	Min	Typ	Max	Units
I_{CC}	Power Supply Current	Active 4 MHz, $V_{CC} = 3\text{V}$ (ATmega64L)		4.1	5	mA
		Active 8 MHz, $V_{CC} = 5\text{V}$ (ATmega64)		15.5	20	
		Idle 4 MHz, $V_{CC} = 3\text{V}$ (ATmega64L)		2	2	
		Idle 8 MHz, $V_{CC} = 5\text{V}$ (ATmega64)		8	12	
	Power-down mode ⁽⁵⁾	WDT enabled, $V_{CC} = 3\text{V}$		< 10	20	μA
		WDT disabled, $V_{CC} = 3\text{V}$		< 4	10	
V_{ACIO}	Analog Comparator Input Offset Voltage	$V_{CC} = 5\text{V}$ $V_{in} = V_{CC}/2$	-40		40	mV
I_{ACLK}	Analog Comparator Input Leakage Current	$V_{CC} = 5\text{V}$ $V_{in} = V_{CC}/2$	-50		50	nA
t_{ACPD}	Analog Comparator Propagation Delay	$V_{CC} = 2.7\text{V}$ $V_{CC} = 4.0\text{V}$		750 500		ns

- Notes:
1. "Max" means the highest value where the pin is guaranteed to be read as low
 2. "Min" means the lowest value where the pin is guaranteed to be read as high
 3. Although each I/O port can sink more than the test conditions (20 mA at $V_{CC} = 5\text{V}$, 10 mA at $V_{CC} = 3\text{V}$) under steady state conditions (non-transient), the following must be observed:
TQFP and QFN/MLF Package:
 1] The sum of all IOL, for all ports, should not exceed 400 mA.
 2] The sum of all IOL, for ports A0 - A7, G2, C3 - C7 should not exceed 100 mA.
 3] The sum of all IOL, for ports C0 - C2, G0 - G1, D0 - D7, XTAL2 should not exceed 100 mA.
 4] The sum of all IOL, for ports B0 - B7, G3 - G4, E0 - E7 should not exceed 100 mA.
 5] The sum of all IOL, for ports F0 - F7, should not exceed 100 mA.
 If IOL exceeds the test condition, VOL may exceed the related specification. Pins are not guaranteed to sink current greater than the listed test condition.
 4. Although each I/O port can source more than the test conditions (20 mA at $V_{CC} = 5\text{V}$, 10 mA at $V_{CC} = 3\text{V}$) under steady state conditions (non-transient), the following must be observed:
TQFP and QFN/MLF Package:
 1] The sum of all IOH, for all ports, should not exceed 400 mA.
 2] The sum of all IOH, for ports A0 - A7, G2, C3 - C7 should not exceed 100 mA.
 3] The sum of all IOH, for ports C0 - C2, G0 - G1, D0 - D7, XTAL2 should not exceed 100 mA.
 4] The sum of all IOH, for ports B0 - B7, G3 - G4, E0 - E7 should not exceed 100 mA.
 5] The sum of all IOH, for ports F0 - F7, should not exceed 100 mA.
 If IOH exceeds the test condition, VOH may exceed the related specification. Pins are not guaranteed to source current greater than the listed test condition.
 5. Minimum V_{CC} for Power-down is 2.5V.

Instruction Set Summary

Mnemonics	Operands	Description	Operation	Flags	#Clocks
ARITHMETIC AND LOGIC INSTRUCTIONS					
ADD	Rd, Rr	Add two Registers	$Rd \leftarrow Rd + Rr$	Z,C,N,V,H	1
ADC	Rd, Rr	Add with Carry two Registers	$Rd \leftarrow Rd + Rr + C$	Z,C,N,V,H	1
ADIW	RdI,K	Add Immediate to Word	$Rdh:Rdl \leftarrow Rdh:Rdl + K$	Z,C,N,V,S	2
SUB	Rd, Rr	Subtract two Registers	$Rd \leftarrow Rd - Rr$	Z,C,N,V,H	1
SUBI	Rd, K	Subtract Constant from Register	$Rd \leftarrow Rd - K$	Z,C,N,V,H	1
SBC	Rd, Rr	Subtract with Carry two Registers	$Rd \leftarrow Rd - Rr - C$	Z,C,N,V,H	1
SBCI	Rd, K	Subtract with Carry Constant from Reg.	$Rd \leftarrow Rd - K - C$	Z,C,N,V,H	1
SBIW	RdI,K	Subtract Immediate from Word	$Rdh:Rdl \leftarrow Rdh:Rdl - K$	Z,C,N,V,S	2
AND	Rd, Rr	Logical AND Registers	$Rd \leftarrow Rd \bullet Rr$	Z,N,V	1
ANDI	Rd, K	Logical AND Register and Constant	$Rd \leftarrow Rd \bullet K$	Z,N,V	1
OR	Rd, Rr	Logical OR Registers	$Rd \leftarrow Rd \vee Rr$	Z,N,V	1
ORI	Rd, K	Logical OR Register and Constant	$Rd \leftarrow Rd \vee K$	Z,N,V	1
EOR	Rd, Rr	Exclusive OR Registers	$Rd \leftarrow Rd \oplus Rr$	Z,N,V	1
COM	Rd	One's Complement	$Rd \leftarrow 0xFF - Rd$	Z,C,N,V	1
NEG	Rd	Two's Complement	$Rd \leftarrow 0x00 - Rd$	Z,C,N,V,H	1
SBR	Rd,K	Set Bit(s) in Register	$Rd \leftarrow Rd \vee K$	Z,N,V	1
CBR	Rd,K	Clear Bit(s) in Register	$Rd \leftarrow Rd \bullet (0xFF - K)$	Z,N,V	1
INC	Rd	Increment	$Rd \leftarrow Rd + 1$	Z,N,V	1
DEC	Rd	Decrement	$Rd \leftarrow Rd - 1$	Z,N,V	1
TST	Rd	Test for Zero or Minus	$Rd \leftarrow Rd \bullet Rd$	Z,N,V	1
CLR	Rd	Clear Register	$Rd \leftarrow Rd \oplus Rd$	Z,N,V	1
SER	Rd	Set Register	$Rd \leftarrow 0xFF$	None	1
MUL	Rd, Rr	Multiply Unsigned	$R1:R0 \leftarrow Rd \times Rr$	Z,C	2
MULS	Rd, Rr	Multiply Signed	$R1:R0 \leftarrow Rd \times Rr$	Z,C	2
MULSU	Rd, Rr	Multiply Signed with Unsigned	$R1:R0 \leftarrow Rd \times Rr$	Z,C	2
FMUL	Rd, Rr	Fractional Multiply Unsigned	$R1:R0 \leftarrow (Rd \times Rr) \ll 1$	Z,C	2
FMULS	Rd, Rr	Fractional Multiply Signed	$R1:R0 \leftarrow (Rd \times Rr) \ll 1$	Z,C	2
FMULSU	Rd, Rr	Fractional Multiply Signed with Unsigned	$R1:R0 \leftarrow (Rd \times Rr) \ll 1$	Z,C	2
BRANCH INSTRUCTIONS					
RJMP	k	Relative Jump	$PC \leftarrow PC + k + 1$	None	2
IJMP		Indirect Jump to (Z)	$PC \leftarrow Z$	None	2
JMP	k	Direct Jump	$PC \leftarrow k$	None	3
RCALL	k	Relative Subroutine Call	$PC \leftarrow PC + k + 1$	None	3
ICALL		Indirect Call to (Z)	$PC \leftarrow Z$	None	3
CALL	k	Direct Subroutine Call	$PC \leftarrow k$	None	4
RET		Subroutine Return	$PC \leftarrow STACK$	None	4
RETI		Interrupt Return	$PC \leftarrow STACK$	I	4
CPSE	Rd,Rr	Compare, Skip if Equal	if ($Rd = Rr$) $PC \leftarrow PC + 2$ or 3	None	1/2/3
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 ($Rr(b)=0$) $PC \leftarrow PC + 2$ or 3	None	1/2/3
SBRSS	Rr, b	Skip if Bit in Register is Set	if ($Rr(b)=1$) $PC \leftarrow PC + 2$ or 3	None	1/2/3
SBIC	P, b	Skip if Bit in I/O Register Cleared	if ($P(b)=0$) $PC \leftarrow PC + 2$ or 3	None	1/2/3
SBIS	P, b	Skip if Bit in I/O Register is Set	if ($P(b)=1$) $PC \leftarrow PC + 2$ or 3	None	1/2/3
BRBS	s, k	Branch if Status Flag Set	if ($SREG(s) = 1$) then $PC \leftarrow PC + k + 1$	None	1/2
BRBC	s, k	Branch if Status Flag Cleared	if ($SREG(s) = 0$) then $PC \leftarrow PC + k + 1$	None	1/2
BREQ	k	Branch if Equal	if ($Z = 1$) then $PC \leftarrow PC + k + 1$	None	1/2
BRNE	k	Branch if Not Equal	if ($Z = 0$) then $PC \leftarrow PC + k + 1$	None	1/2
BRCS	k	Branch if Carry Set	if ($C = 1$) then $PC \leftarrow PC + k + 1$	None	1/2
BRCC	k	Branch if Carry Cleared	if ($C = 0$) then $PC \leftarrow PC + k + 1$	None	1/2
BRSH	k	Branch if Same or Higher	if ($C = 0$) then $PC \leftarrow PC + k + 1$	None	1/2
BRLO	k	Branch if Lower	if ($C = 1$) then $PC \leftarrow PC + k + 1$	None	1/2
BRMI	k	Branch if Minus	if ($N = 1$) then $PC \leftarrow PC + k + 1$	None	1/2
BRPL	k	Branch if Plus	if ($N = 0$) then $PC \leftarrow PC + k + 1$	None	1/2
BRGE	k	Branch if Greater or Equal, Signed	if ($(N \oplus V) = 0$) then $PC \leftarrow PC + k + 1$	None	1/2
BRLT	k	Branch if Less Than Zero, Signed	if ($(N \oplus V) = 1$) then $PC \leftarrow PC + k + 1$	None	1/2
BRHS	k	Branch if Half Carry Flag Set	if ($H = 1$) then $PC \leftarrow PC + k + 1$	None	1/2
BRHC	k	Branch if Half Carry Flag Cleared	if ($H = 0$) then $PC \leftarrow PC + k + 1$	None	1/2
BRTS	k	Branch if T Flag Set	if ($T = 1$) then $PC \leftarrow PC + k + 1$	None	1/2
BRTC	k	Branch if T Flag Cleared	if ($T = 0$) then $PC \leftarrow PC + k + 1$	None	1/2
BRVS	k	Branch if Overflow Flag is Set	if ($V = 1$) then $PC \leftarrow PC + k + 1$	None	1/2
BRVC	k	Branch if Overflow Flag is Cleared	if ($V = 0$) then $PC \leftarrow PC + k + 1$	None	1/2

Instruction Set Summary (Continued)

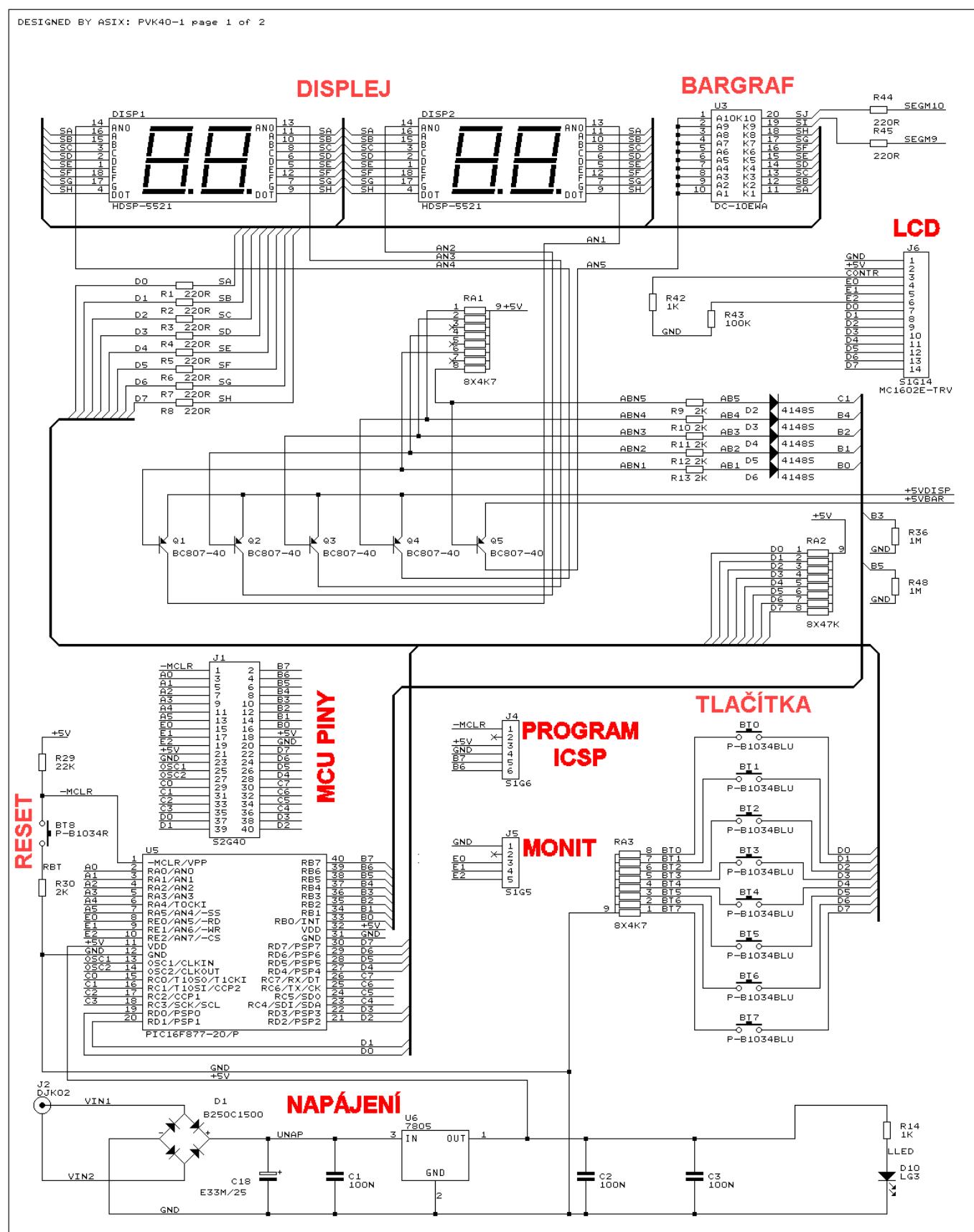
BRIE	k	Branch if Interrupt Enabled	if (I = 1) then PC ← PC + k + 1	None	1/2
BRID	k	Branch if Interrupt Disabled	if (I = 0) then PC ← PC + k + 1	None	1/2
DATA TRANSFER INSTRUCTIONS					
MOV	Rd, Rr	Move Between Registers	Rd ← Rr	None	1
MOVW	Rd, Rr	Copy Register Word	Rd+1:Rd ← Rr+1:Rr	None	1
LDI	Rd, K	Load 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	2
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	2
LPM		Load Program Memory	R0 ← (Z)	None	3
LPM	Rd, Z	Load Program Memory	Rd ← (Z)	None	3
LPM	Rd, Z+	Load Program Memory and Post-Inc	Rd ← (Z), Z ← Z+1	None	3
SPM		Store Program Memory	(Z) ← R1:R0	None	-
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

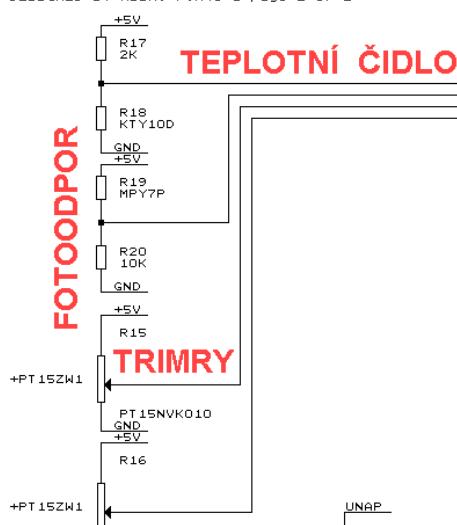
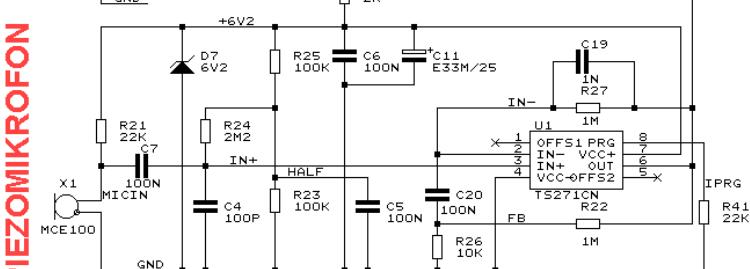
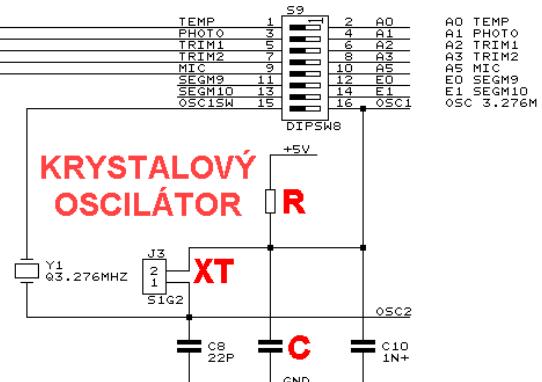
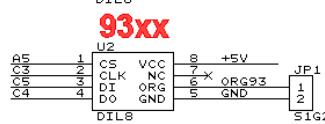
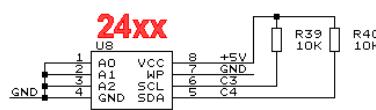
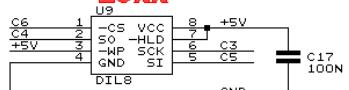
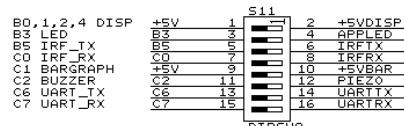
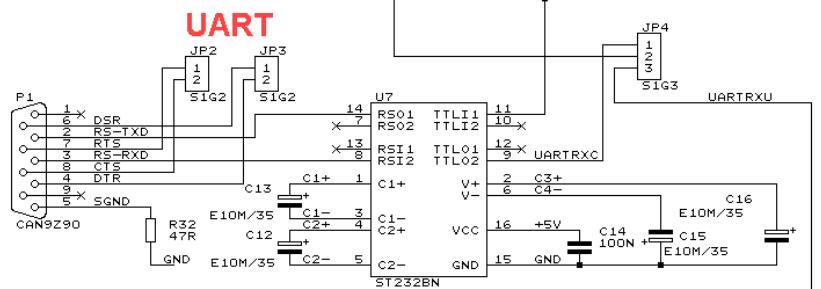
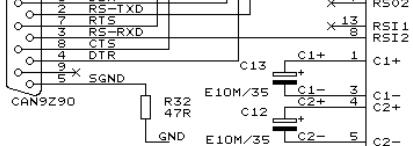
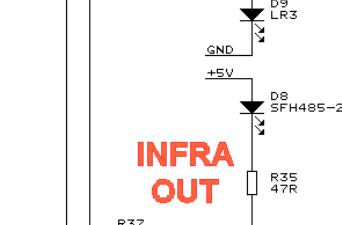
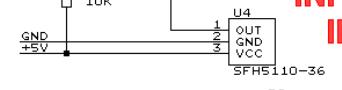
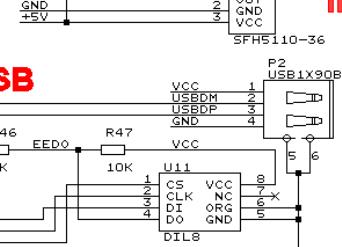
Instruction Set Summary (Continued)

CLH		Clear Half Carry Flag in SREG	H ← 0	H	1
MCU CONTROL INSTRUCTIONS					
NOP		No Operation		None	1
SLEEP		Sleep	(see specific descr. for Sleep function)	None	1
WDR		Watchdog Reset	(see specific descr. for WDR/timer)	None	1
BREAK		Break	For On-chip Debug Only	None	N/A

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