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ATMega328P Microprocessor

Contents

Introduction

The ATmega328P is a microprocessor that is well known for its use onboard the popular Arduino Uno microcontroller. These devices are commonly used to introduce concepts in computer science, programming, and electronics because the essential components used by nearly all modern computers are included in a simple affordable package. As the owner of several Arduino devices used for various family science projects, this central processing unit (CPU) is a sensible choice to examine in detail.

Like other modern CPUs, the components of the ATmega328P's CPU include the arithmetic and logic unit (ALU), registers, control units, and information transmission components or busses to communicate with internal and external sources. Additionally, specialized circuits including timers, logical circuits, interfaces, and an analog to digital converter are part of the design (Atmel 1, 4). Common applications that take advantage of this CPU's capabilities most often include instrumentation and control (I&C) of small networks of input and output (I/O) devices like detectors, measurement devices, valves, motors, and displays. Though its design targets specific applications and its complexity exceeds that of the Machine Architecture that is Really Intuitive and Easy (MARIE), the fetch, decode, execute life cycle is still integral to the operation and architecture of the ATmega328P.

Details

The CPU (See Figure *1*) is a single core with access to the following registers: 32 8 bit general purpose registers (GPR), a program counter, status register, and an instruction register (Atmel 9). General purpose registers are common in CPUs as they serve as the closest source of data and are thus quicker to access than main memory. Additional flexibility is afforded by allowing 3 pairs of GPRs to be optionally used as 16-bit registers for indirect addressing and are

renamed as X, Y, and Z when used in this manner (Atmel 13). This is necessary as 32K of program memory requires more than 8 bits to address, therefore two registers are needed to hold the address.

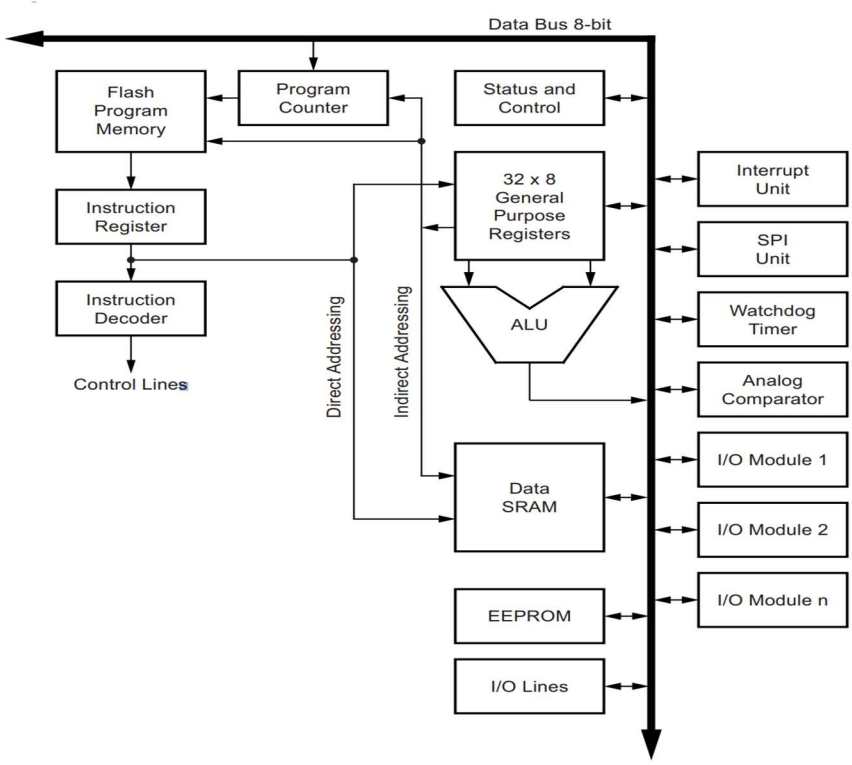

Figure 1: CPU Block Diagram, ATmega328P 8-bit AVR Microcontroller with 32K Bytes In-System, Atmel Corporation, 2015, p. 9.

Registers that serve specific purposes include the program counter, instruction register, and the status register. The program counter stores the address of the next instruction to be executed and the instruction register holds the current instruction to be decoded and used by the control unit to coordinate the details of execution. Lastly, a status register is used to indicate very specific pieces of information regarding each executed instruction. Information such as the sign, whether an overflow occurred, or a special result such as zero is commonly reflected in the status bits.

Busses are used to interconnect the individual modules of the CPU. The data bus indicated in Fig 1 is 8 bits wide and the components it serves are primarily I/O modules and the GPRs which share the same bit width. Previously, it was mentioned that 6 of the GPRs can be used to store 16-bit addresses indicating the size of the 16-bit width of the indirect address bus. Meanwhile, communication with external components is accomplished with I/O modules between the data bus and the external pins. These ports are labelled B, C, and D with B and D being 8 bits and C having 7 bits (Atmel 4).

Synchronizing the activities of the CPU falls to its clock and its power consumption is closely related to clock speed. Rather than operating at a single frequency, the clock operates on a range of frequencies based on operating voltage (Figure 2 CPU Clock Frequency Range, ATmega328P 8-bit AVR Microcontroller with 32K Bytes In-System, Atmel Corporation, 2015, p. 260.. The range from 4.5 to 5.5 V supports a maximum clock speed of 16MHz corresponding with the execution of approximately 16 million instructions per second (MIPS).

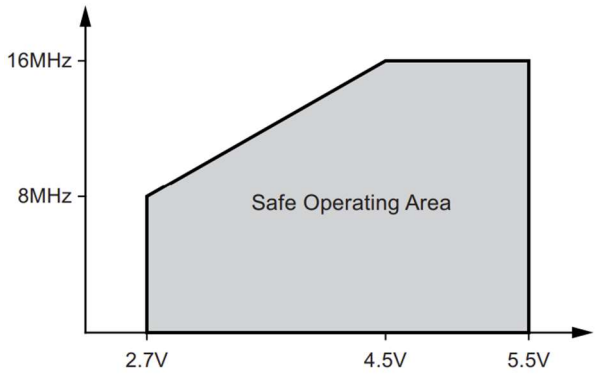

Figure 2 CPU Clock Frequency Range, ATmega328P 8-bit AVR Microcontroller with 32K Bytes In-System, Atmel Corporation, 2015, p. 260.

The overall heat load of the processor depends on its operating state. From Table 1 and using the equation for electrical power, $P = IV$, it can be calculated that the power usage at max load is 70mW and 1.8mW at the lowest possible idle state.

T_A = –40°C to +125°C, V_{CC} = 2.7V to 5.5V (unless otherwise noted)

Parameter	Condition	Symbol	Min.	Typ.(2)	Max.	Units
Power supply current(1)	Active 4MHz, V_{CC} = 3V	I_{CC}		1.5	2.4	mA
	Active 8MHz, V_{CC} = 5V			5.2	10	mA
	Active 16MHz, V_{CC} = 5V			9.2	14	mA
	Idle 4MHz, V_{CC} = 3V			0.25	0.6	mA
	Idle 8MHz, V_{CC} = 5V			1.0	1.6	mA
	Idle 16MHz, V_{CC} = 5V			1.9	2.8	mA
Power-down mode(3)	WDT enabled, V_{CC} = 3V				44	µA
	WDT enabled, V_{CC} = 5V				66	µA
	WDT disabled, V_{CC} = 3V				40	µA
	WDT disabled, V_{CC} = 5V				60	µA

Notes: 1. Values with Section 9.10 "Minimizing Power Consumption" on page 36 enabled (0xFF).
2. Typical values at 25°C.
3. The current consumption values include input leakage current.

Table 1 DC Characteristics, ATmega328P 8-bit AVR Microcontroller with 32K Bytes In-System, Atmel Corporation, 2015, p. 260.

Conclusion

This small low powered CPU contains all the major functional components found in any other CPU even though its intended application is very different from the conventional laptop, phone, or desktop. Activities such as information logistics, accessing and executing instructions, interfacing with external devices, and regulating control activities all still need to be performed to meet the functional requirements. Registers, timers, memory, and logical circuits for control and manipulation can all be found in the ATmega328P. With these common uses and components, it is easy to see that the fetch, decode, and execute cycle is still the guiding principle of operation.

References

Atmel. "ATmega328P 8-bit AVR Microcontroller with 32K Bytes In-System." San Jose: Atmel Corporation, 2015. Document.