Zilog Z80 Architecture

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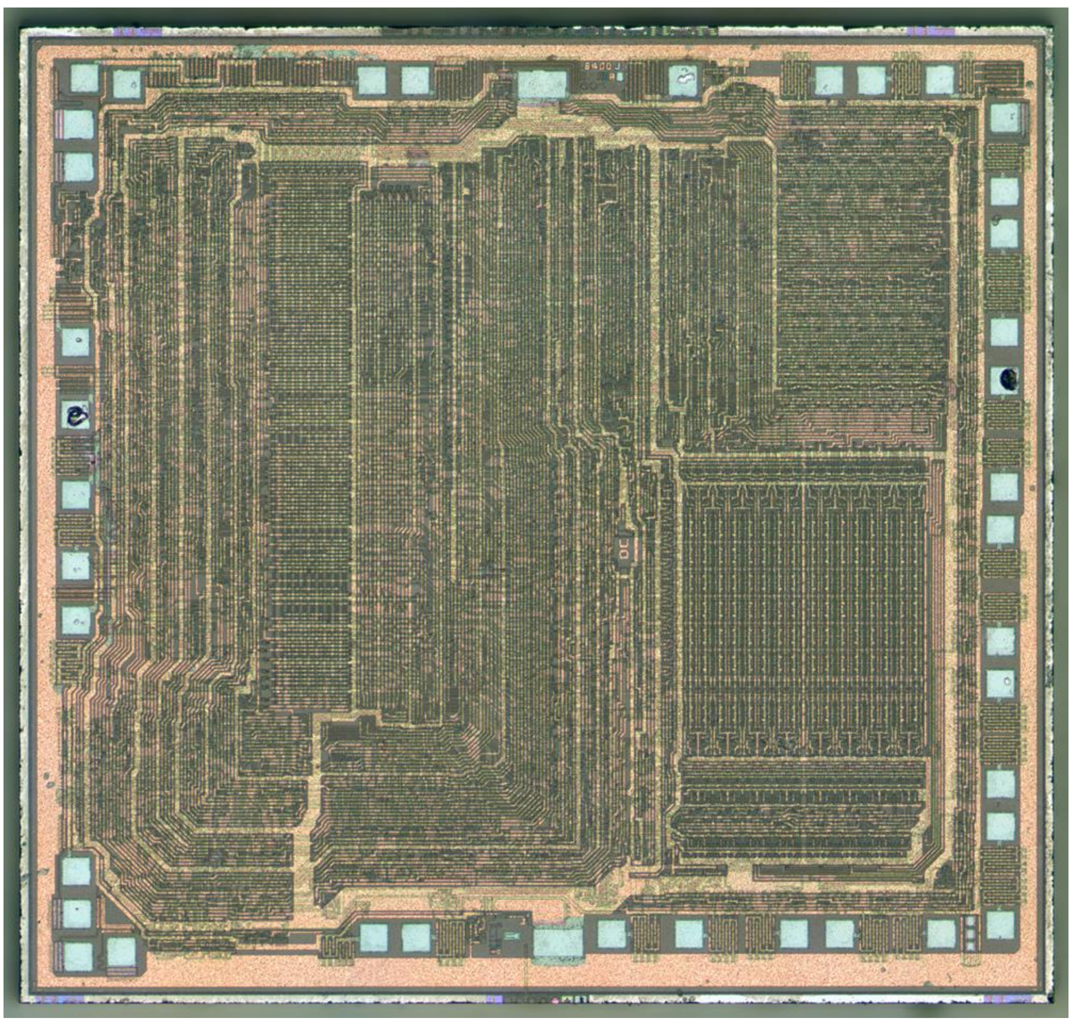

Figure 1. Z80 Die [1]

Introduction

The Zilog Z80 microprocessor is an 8-bit CPU that was released in 1976. It was designed to be an improved and compatible competitor to the Intel 8080 [2]. The processor was used in embedded systems and consumer electronics such as the TRS-80 home computer, TI-83 calculator, and the Nintendo Game Boy Advance. It was a very popular CPU choice for mainstream home products and is still used today in microcontrollers for embedded systems [3].

Architecture Overview

The information that follows is provided by [4]. The Z80 has an 8-bit architecture and is available in clock rates from 6 to 20 MHz. There are six 8-bit general purpose registers that can also be paired into three 16-bit registers, an accumulator, and a flags register. These registers are duplicated in a separate set that can be exchanged at any time by the programmer. In addition to these two sets, the Z80 contains two 16-bit index registers, an interrupt register, a memory refresh register, a stack pointer, and a program counter. Figure 2 depicts the layout of registers.

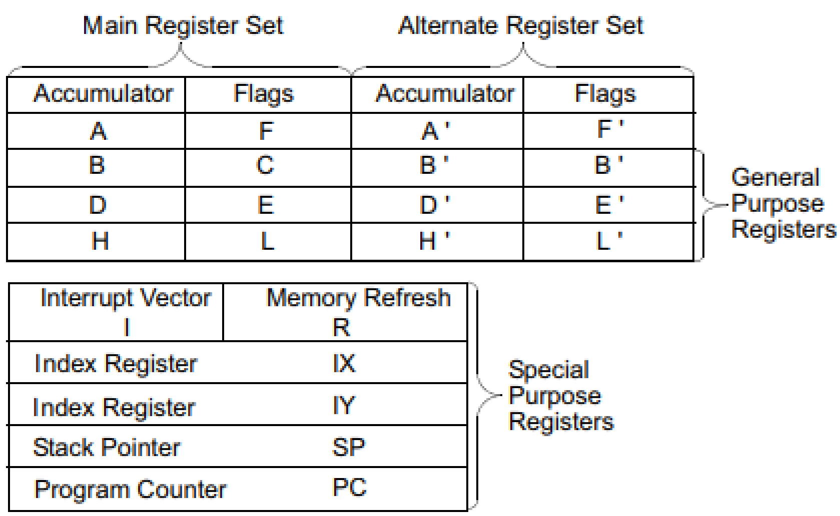

Figure 2. CPU Register Configuration [4]

Memory is addressed using 16 bits, allowing 64k of RAM, and I/O is port mapped using 8-bit addresses, allowing 256 I/O devices. The chip pinout is shown in Figure 3. The CPU uses Von Neumann architecture, and so has a single data path for memory and instructions. All 78 instructions of the Intel 8080A processor are available, with 80 additional instruction types totaling 158; since this Zilog CPU has a large ISA with many specialized instructions, it is considered a CISC processor. The Z80 is not pipelined.

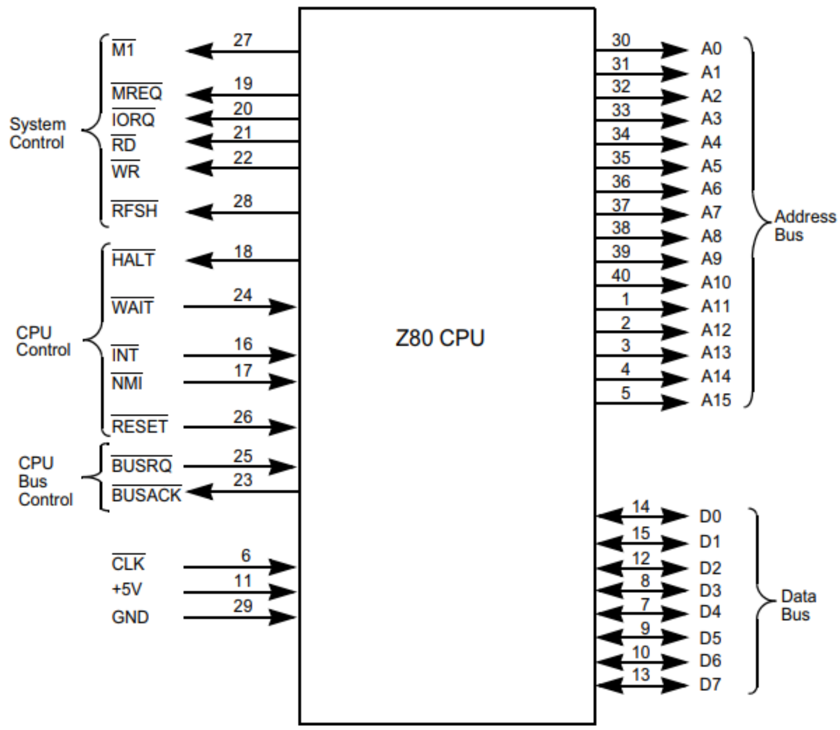

Figure 3. I/O Pin Configuration [4]

The ALU of the Z80 uses an accumulator architecture. Operations on register values, memory contents, and immediate values are always computed with and stored back into the accumulator A register. Contrary to the bus size of 8 bits, the ALU is a 4-bit unit [5]. This means that arithmetic and logical operations are internally performed in multiple cycles. Despite this, there are instructions that perform 16-bit arithmetic using register pairs as described previously.

Components in the CPU are connected through the internal 8-bit data bus. 8-bit data stored into and loaded from memory is addressed through the 16-bit address bus. I/O is addressed with the bottom half (A0 through A7) of the address bus. The internal layout of the main processor components is show in Figure 4.

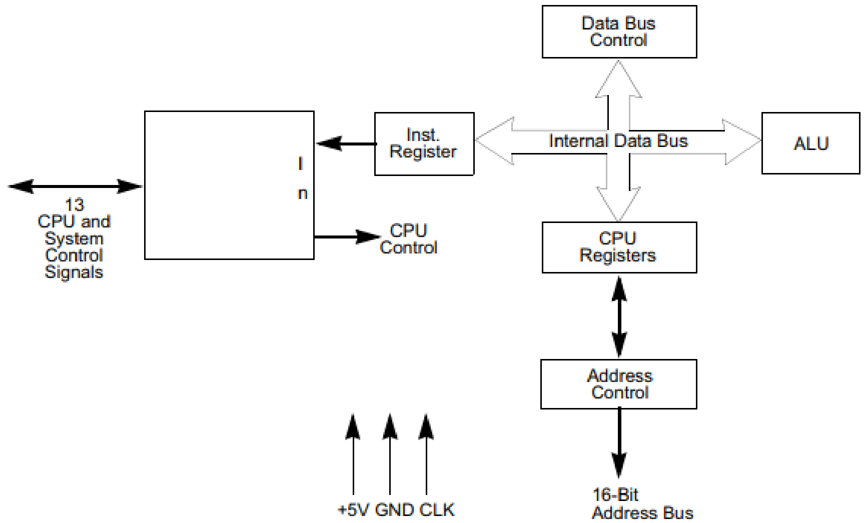

Figure 4. Z80 Block Diagram [4]

Strengths

The large ISA of the Z80 simplifies programming for this CPU. For example, the load instruction LD has 35 variants to move data between registers, memory, and immediate values. LD allows for virtually any combination of immediate, register, indirect, and indexed addressing modes structured in an intuitive form [4]. The instruction set also features instructions to move and search through arbitrarily sized blocks of memory with a single line of assembly. To have these available is greatly convenient for the programmer to increase programming productivity by reducing the need for boilerplate assembly code. The Z80 also supports bit-addressing a value stored in a register or in memory. The BIT instruction type checks the value of a specified bit, while SET and RES are used to set and reset a bit respectively.

Registers in the CPU are flexible in their use. Most can be used with any instruction that involves the register addressing mode, and many instruction types also support using register pairs as a single 16-bit register. The set of alternate registers that can be quickly exchanged are useful for fast interrupt response or simply as extra registers for the convenience of the programmer and reduced data transfer to and from memory.

Programs for the Z80 can be small compared to a RISC machine which means that less memory is needed to store a program and temporally expensive instruction fetches during execution are decreased.

Weaknesses

Due to its CISC architecture nature, the Z80 has notable weaknesses. The large ISA complicates the hardware design to support the decoding and control of many instruction formats with different lengths. Instructions vary in the number of cycles required for them to execute, from single cycle operations to seven clock cycles needed (for example: JR NC, e). RISC architectures with fewer, consistently-sized, and more simple instructions that require very few instructions have been shown to be quicker than CISC architectures like that of the Z80, putting it at a disadvantage in terms of execution speed.

The accumulator architecture used for the ALU can make arithmetic and logical operations cumbersome. If one of the operands in a computation is not already stored in the accumulator A register, then it must be moved there using a LD instruction first. Since the result of an ALU operation is always stored back into A, the programmer must use an additional LD instruction if the result is needed in a different register or main memory.

Overall Analysis

The 8-bit, non-pipelined, CISC architecture was designed to be simple to program and use. The large ISA provides many useful instructions that facilitate more productive programming and fewer mistakes. The six general purpose registers that can be used in pairs for larger data sizes simplify arithmetic and logical tasks, and the swappable register set allows for quick interrupt responses. Compact binary sizes mean that a program can be stored in less memory, and instruction fetches are fewer. The feature-rich ISA comes at the expense of more complicated circuitry and frequently unused instructions.

Conclusion

The Zilog Z80 was designed and produced before the concept of a RISC architecture had been introduced. Because RISC architectures had not yet been seen, the weaknesses of the processor were overlooked in shadow of its strengths. Its intuitive and convenient instruction set architecture added many new instructions to, yet remained fully compatible with, the Intel 8080 ISA. This improvement over the already popular 8080 had the Z80 widely adopted into consumer electronics and embedded systems where it can still be found today.

References

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