

Birth of the Computer

Birth of the Computer:

From Relays to Vacuum Tubes

By

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PART I

PRECURSOR MACHINES

Chapters 1 to 8

The idea of automated computation has been a concept in the human mind for several thousand years. Discoveries of ancient machines, such as the Antikythera mechanism, reveal that our ancestors had some understanding of the basic concepts of computation, although contemporary technology was not up to the task of performing such computations.

The true history of computing begins in the early 1900s. These early days were largely characterized by electromechanical computing engines rather than true computing systems. However, these systems were replaced in the late 40s and early 50s by vacuum tube machines. The machines discussed here are considered by some not to be true computers because they did not have a provision for storing programs internally. Others, however, do not make such a distinction as they consider such machines to have their primary storage only in external media, e.g., paper tape and magnetic tape. There is no benefit in continuing that debate here and we will not do so.

By the 1930s, after Hollerith's success with tabulating machines, several companies, such as Burroughs (manufacturing calculators) and National Cash Register (manufacturing cash registers), understood the elements of computing. The time seemed ripe for someone to put the pieces together and realize that the process could be automated. Konrad Zuse, John Atanasoff, and George Stibitz were among those people. In England, Alan Turing, aided by Max Newman, Tommy Flowers, and a host of other dedicated civil servants, developed and implemented the Colossus. In the United States, Howard Aiken also realized the utility of automating computation and developed several machines that contributed to a better understanding of how to build computing systems. Finally, IBM was transforming lessons learned from the ASCC into one of its first true computing systems, IBM 650.

The film, *Computer Pioneers and Pioneer Computers: Dawn of Electronic Computing: 1935-1945*, narrated by Gordon Bell and produced by the Computer History Museum, provides some photos and videos of the machines described in this section.

Chapters:

1. Konrad Zuse's Computers
2. The Atanasoff-Berry Computer
3. Stibitz's Relay Computers
4. Colossus
5. Aiken's ASCC/Mark I
6. Harvard Mark Machines
7. IBM's Selective Sequence Electronic Calculator
8. Who invented the Computer?

CHAPTER ONE

KONRAD ZUSE'S COMPUTERS

Konrad Zuse was one of the “fathers of computing” (Rojas, Speiser, and Zuse 2001). Zuse built several different computing machines – each of increasing complexity and capability. He also created one of the first companies whose sole purpose was to build computing machines.

Zuse started his career working for the German aviation industry. As an engineer, he was familiar with the large number of calculations required to analyze and design the static structures of an aircraft. This led him to think about how he could mechanize some of these monotonous and repetitive calculations. He reasoned that a machine should be able to follow a set of carefully laid out steps in a repetitive fashion. He envisioned that numbers would be entered from an input unit and that results would be placed in an output unit to be read.

The computing machine would be comprised of a memory (*Speicherwerk*), an arithmetic unit (*Rechenwerk*), and a control unit (*Programwerk*). Arithmetic would be performed using a floating point representation, with separate units for handling the exponent and fraction. Numbers and instructions would be represented in the binary number system. The control unit would move the numbers into and out of the memory and specified what arithmetic operations were to be performed. The instructions and numbers would be stored on a strip of punched tape (*Lochstreifen*).

The machine's components would be synchronized by a central clock. Zuse recognized that all operations could be performed logically from combinations of the Boolean operators AND, OR, and NOT. To follow his dream, Zuse quit his job in 1936 in order to develop his ideas further.

Konrad Zuse (1910-1996)
Konrad Zuse was born in Berlin in 1910. He earned his technical education at the Technische Hochschule in Berlin-Charlottenburg, where he majored in architecture and civil engineering. By 1933, he had begun to think about how to build a universal computing machine. As noted below, he developed several models of computing machines through the war

years. At the end of World War II, he founded Zuse Ingenieurbo, Hopferau bei Fussen. Throughout the 1950s, he developed new computers under a contract with Remington Rand. In 1967, he sold Zuse KG to Siemens Corporation and became a professor at the University of Gottingen. He designed one of the first programming languages, Plankalkul. Zuse received many accolades and awards, including the AFIPS Harry Goode Memorial Award in 1965 and the IEEE Computer Pioneer Medal in 1982. The picture below depicts Konrad Zuse circa 1992.



Source: Courtesy of Dr.- Dr.-Ing. Habil. Horst Zuse

In 1949, Zuse formed Zuse KG to design and manufacture digital computers. Over the next 18 years, Zuse KG delivered over 250 computers. However, it had neither the size nor resources to compete with several English and US companies, which had begun to sell to European universities and companies. In 1967, Zuse sold his company to Siemens after it encountered financial problems.

1.1 The Z1

After graduation in 1931, Zuse became a structural engineer with Henschel Flugzeugwerke, but left soon after to pursue his ideas regarding the development of an electromechanical computer. He had not been trained in mechanical calculator construction. This allowed him to pursue his own ideas which represented an original approach unhindered by what the experts said could and could not be done. He designed and assembled this machine, the Z1 in his parent's apartment in Berlin with financing from his parents and various school friends (Weiss 1996).

Zuse's first computing machine was the electromechanical Z1, which demonstrated the limits of mechanical computing systems. It was about the size of a large dining room table. The Z1 used mechanical bistable switching elements for memory and arithmetic/logical circuits. The elements were represented by pins arranged in matrices to signify bit positions. A stack of metal sheets with slots moved over the pins to read data from the memory. The movement of a sheet depended on the positions of the pins in the slots. Zuse enlisted several friends to hand-cut the holes in the metal plates with an electric saw. By 1938, Zuse had a working model of the Z1 that represented sixteen 24-bit numbers and performed floating point binary arithmetic.

However, this machine did not work very well because of the difficulty of precisely hand-machining the parts and having them work together reliably. The memory worked well, but the arithmetic unit was unreliable. The Z1 architecture is depicted in Figure 1-1.

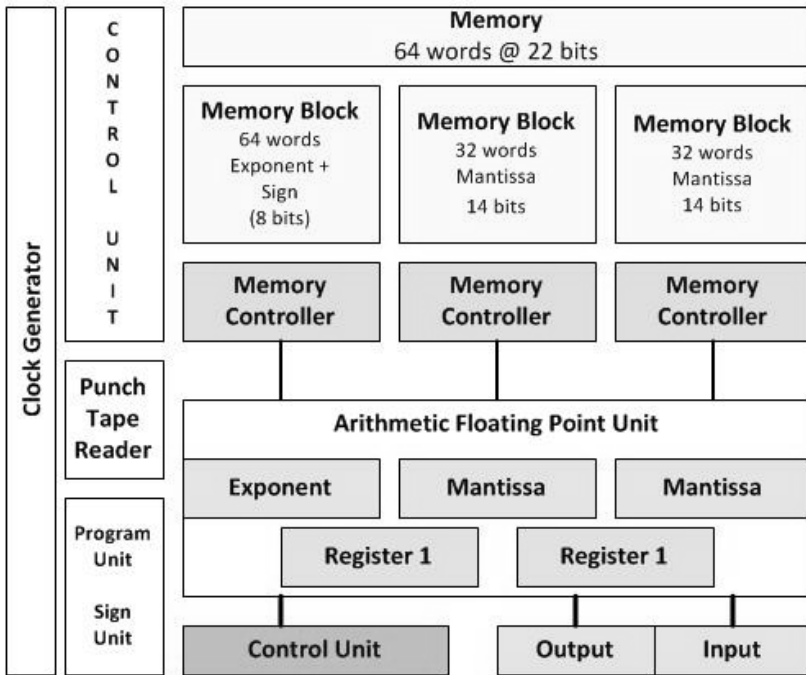


Figure 1-1. Z1 Architecture

Source: Adapted from

http://user.cs.tu-berlin.de/~zuse/Konrad_Zuse/en/rechner_z1.html

1.2 The Z2

Source: http://user.cs.tu-berlin.de/~zuse/Konrad_Zuse/en/rechner_z2.html

The Z2, an enhanced version of the Z1, was designed by Konrad Zuse and Helmut Schreyer and completed in 1939 (Deutsche Technik Museum 2005a). It was an experimental electromechanical machine that used electronic relays, which were more reliable. However, Zuse retained the mechanical memory of the Z1 in the Z2 implementation. The Z2 used 16-bit words and had a cycle time of about 3 seconds. It required about 8 seconds for an addition.

At the beginning of World War II, Zuse was called up for military duty as an infantryman just as he was completing the Z2. He tried to gain official support for his ideas, but these were often dismissed by the German government. After a year's service, he was discharged from the

German Army and he returned to Henschel Flugzeugwerke as a structural engineer. While continuing development of the Z2, he convinced the German Aeronautical Research Institute (Deutsche Versuchsanstalt für Luftfahrt) in 1940 to fund the development of another machine, the Z3.

1.3 The Z3

Source: http://www.horst-zuse.homepage.t-online.de/Konrad_Zuse_index_english_html/rechner_z3.html

The Zuse Z3 was completed in 1941. It was based on electromagnetic relays, making it the first functional programmable computer. The Z3 performed about 4 additions per second and required about 5 seconds to perform a multiplication. A program was entered using movie film with eight-hole channels being punched in the reel to represent instructions. The Z3 was one of the first machines to have registers – two floating point registers R1 and R2 – for holding operands for arithmetic operations.

The German Aircraft Research Institute used it to perform statistical analyses of wing flutter. On 12 May 1941, the Z3 was presented to an audience of scientists, including professors Alfred Teichmann and Curt Schmieden of the Deutsche Versuchsanstalt für Luftfahrt in Berlin (KZIA 2015).

In 1960, Zuse KG recreated the Z3 for the Deutsche Museum. Figure 1-2 shows the reconstructed Z3 on display at the Deutsche Museum in Munich (Deutsche Technik Museum 2005c). The left frame contained the relays for the memory – 64 words of 22 bits each. At the bottom of the right frame one can see the micro-sequencers for instruction execution. They are the core of the Z3's control unit. The frame above them contained the relays for the arithmetic units.

The Z3 was built as a floating point machine. Burks, Goldstine, and von Neumann (1946) questioned whether floating point provided any advantage in performing arithmetic computations given the loss of memory capacity due to the increased number of bits required to represent floating point numbers and the complexity of the electronic circuits required to perform the arithmetic. The types of computations that Zuse was interested in performing with his machines necessitated floating point number representation. Software routines were exceedingly slow to execute and, perhaps, too large to fit in the available memory. What many do not realize is that Zuse had described the concepts of floating point arithmetic in 1934, more than a decade before Burks et al., and, in the Z3,

Zuse implemented his concept and demonstrated its feasibility. Table 1-1 describes the characteristics of the Z3.

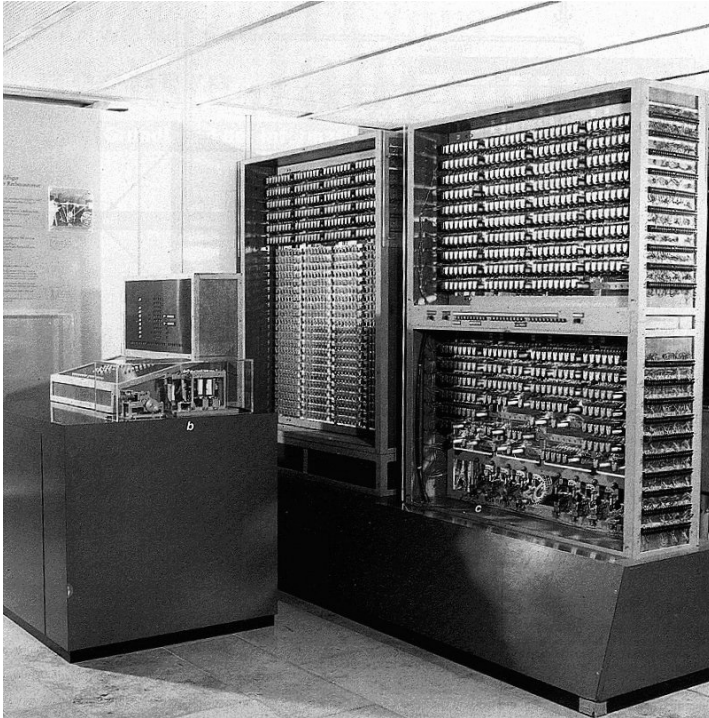


Figure 1-2. Zuse Z3 (Reconstructed)

Source: Courtesy of Dr.- Dr.-Ing. Habil. Horst Zuse

Table 1-1. Zuse Z3 – Basic Characteristics

Characteristic	Value/Explanation
Internal Representation	Floating Point Binary
# Bits/Word	22
# Instructions/Word	1
# Instructions	9
# Bits/Instruction	22
Instruction Type	One Address (?)
CPU Technology	Electromagnetic Relays: Clock Rate = 5.33 Hz
CPU Registers	Two Floating Point Registers: R1 and R2
Main Memory	Electromagnetic Relays: 64 words