Title: The Zuse Z3. German predecessor of the Mark I
Author(s): William H. Desmonde and Klaus J. Berkling
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The Zuse Z3*

german predecessor of the mark I

by William H. Desmonde and Klaus J. Berkling

In 1941, three years before the Mark I was placed in operation at Harvard, a program-controlled computer was used by a leading German aeronautical research center. This machine, the Zuse Z3, was built by Konrad Zuse for the Deutsche Versuchsanstalt für Luftfahrt.

Little is popularly known in the United States about the pioneering activities of this German inventor and industrialist. Zuse, born in Berlin on June 22, 1910, started his career as an engineer in the aircraft industry. He soon became aware of the tremendous number of montonous calculations necessary for the analysis and design of static and other aircraft structures.

Pondering on methods for facilitating these time-consuming computations, he conceived of performing the calculations by machine. A computer machine, he reasoned as early as 1934, would have to be able to follow a sequence of simple computational steps, in which all variables and intermediate results would be named. Numbers would be entered from an input unit, and results would be placed in an output device. Internally there would have to be a memory, arithmetic unit, and a control section. Arithmetic would be performed in floating point, with separate units for the exponent and fraction. Numbers and instructions would be represented in the binary number system, and bistable switching units would be used. Machine operations would be synchronized by a central clock. Zuse claims he anticipated Shannon's symbolic analysis of relay circuits by recognizing that all arithmetic and control functions could be reduced to the logical operations AND, OR, and NOT. Zuse quit his job in the aircraft industry in 1936 to have more time to develop his ideas on program-controlled computers. For his first experimental machine, the Z1, he utilized mechanical bistable switching elements for memory and computing circuits. These elements were based on pins arranged in matrices to represent bit positions. Metal sheets with slots were stacked, and the movement of the sheets was transmitted by the pins. The movement of a sheet depended on the positions of the pins in the slots. In those

*ZIA 0046. ZuP 045/016. Version 1, Abbildungen fehlen. Durchgesehen von R. Rojas, G. Wagner, L. Scharf days, components of this type occupied less space and were more reliable than electro-magnetic circuits. By 1937, working in his parents' apartment, he had hand-built a test model for a mechanical memory for 16 – 24 bit numbers. The Zuse Z1, completed in 1938, was completely mechanical, with a binary floating point arithmetic unit.

Because of the difficulty of hand-producing exact mechanical parts, this experimental machine did not work satisfactorily. Zuse decided to make use of relays to attain greater precision. Combining the mechanical memory of the Z1 with an electromechanical arithmetic unit built from scrapped telephone relays, Zuse built a second computer, the Z2. The machine was just about complete when its inventor was called into military service at the outbreak of World War II.

At this juncture, Zuse sought support for his ideas about computers. Like many creative people before him in the history of technology, he met with a brushoff from officialdom, and in some quarters was denounced as a swindler. Succeeding after a year in obtaining a release from German armed forces, Zuse continued his development work. He finally received formal encouragement to build a more powerful computer from the Deutsche Versuchsanstalt für Luftfahrt, a German aeronautical research organization.

This computer, the Zuse Z3, was completed and placed in practical use in 1941. It was slightly faster than the Mark I, the first big American machine. The Z3 performed about three or four additions per second, and multiplied in from four to five seconds. The machine was a considerable advance over its predecessors. The program was entered by means of a movie film, eight-hole channels being punched in the reel to represent instructions. Commands available were Add, Subtract, Divide, Extract Square Root, Multiply by 2, Multiply by 10, Multiply by 01, Multiply by 1/2, and Multiply by -1. The relay memory had a capacity of sixty-four 22-bit floating point numbers; the exponent occupied seven bits, mantissa fourteen bits, and sign one bit. The Z3 had built-in translation from decimal to binary and from binary to decimal. Control circuits were composed of step-switches and chains of relays. Altogether there were 2600 relays in the computer, 600 of them used in the floating point arithmetic unit. Data were entered through a keyboard providing for four decimal numbers positioned with decimal point. Output likewise consisted of four decimal digits, displayed by light bulbs on the console.

Later on in World War II, Konrad Zuse founded his own small business, the Zuse Apparatebau. The firm built special computers for use in the production of guided missiles. Mass production of these weapons was causing intolerable deviations from the aerodynamic symmetry in the wings of the missiles. To correct for this about 100 measurements were made of each wing. This data was entered via an analog-to-digital converter into the Computer, which calculated the equivalent angle of incidence of each wing. So it was possible to equalize both wings and empennage by adjusting screws. This calculator, a forebear of our modern process control computers, was in operation day and night from 1942 to 1944.

During this period, Zuse built the Z4, an improved version of the Z3, but still with electromagnetic arithmetic unit and mechanical memory. This machine was the only survivor of World War II, by the end of which all of the other Zuse computers were lost. Following the war, Zuse reconditioned the Z4, equipped it with punched tape input for data and with conditional transfer instructions, and leased it in 1950 to the Eidgenossische Technische Hochschule in Zurich. Five years later, the Zuse Z4 was sold to the French Department of Defense, where it was used for another four years. The computer was so reliable that it was customary to let it work through the night unattended.

The success of the Z4 led Zuse to build another relay machine, the Z5, for the Leitz Optical Company in Wetzlar, Germany. This computer, delivered in 1953, was six times faster than the Z4. To handle iterations, instruction tapes were physically looped. Several program tape readers were provided for reading in loops containing different subroutines. Exit from the loops was controlled by conditional transfer instructions.

After producing the Z5, Zuse's firm, the Zuse Kommandit Gesellschaft (now owned by Brown Boveri Company), began manufacturing computers on an assembly line basis. By 1962 the company had delivered 200 computers. Among these were forty-two Z11's with relays, fifty Z22's with electron tubes, and thirty-four transistorized Z23's.

The Z22 was the firm's first electronic Computer. Development commenced in 1956, and deliveries began in 1958. But as early as 1937 Zuse had envisaged the electronic Computer. In that year, he teamed up with Dr. H. Schreyer to develop electron tubes and circuits for a Computer. Working together, they completed in 1942 a model circuit for 10-bit numbers, comprised of about 100 tubes. They jointly suggested to the German Government that the electronic Computer be built with 1500 tubes and a one millisecond clock-time. The idea was ignored as impossible and unimportant. Schreyer was eventually drafted, and the project was discontinued in 1942. Had they received more encouragement at the time, Zuse and Schreyer might well have developed the world's first electronic Computer.

In 1945, Dr. Zuse created a universal formula language that he called Plankalkül. This language was the forerunner of modern program languages.

Figure 1: William H. Desmonde, Ph. D., is the author of Computers and Their Uses und Real-Time Data Processing Systems: Introductory Concepts. He entered the Computer field in 1955 with Univac, later was a computer consultant for Price Waterhouse & Co. At present he is a research staff member, IBM Research Center.

Figure 2: Klaus J. Berkling has a Ph.D. in physics, joined IBM World Trade Corporation in Germany in 1961. He is now a research staff member at the IBM Research Center.

Figure 3: Dr. Konrad Zuse and the Zuse Z3. 1941 machine has floating point and built-in decimal/binary conversion.