

## Konrad Zuse, a German Computer Pioneer

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In the year 2010 Germany issued a stamp (Scott #2576) honoring Konrad Zuse (1910-1995). Who was Konrad Zuse? He was a civil engineer who was weary of the tedious computations needed in civil engineering. So he decided to build a computer. His first machine, the Z1, was constructed already in 1935. It used binary numbers and floating-point numbers and was controlled by punch tape. The binary memory and the logic control were purely *mechanical*. Zuse was well aware that *logic* was a basic element for constructing computers. He developed himself a logical formalism, which turned out to be equivalent to Boole's propositional logic.

The Z1 never became fully operational. Therefore Zuse changed to relay technique. The arithmetic unit of his next machine, the Z2, was built with 600 relays. During the war, 1940, Zuse developed the first freely programmable binary machine Z3 with floating point number arithmetic. It used 22 bit words, 14 bits for the mantissa, one bit for the sign and 7 bits for the exponent. The arithmetic unit covered all four basic operations and in addition the square root. The computer cost was 25'000 Reichmark. It was damaged 1943 during an air raid and destroyed in 1944.

Already starting in 1941 Zuse worked on the Z4, which became operational 1944. It used still a *mechanical memory* of 64 words of 32 bits corresponding to 2048 bits. In relay technique this memory size would have required some 2500 relays what would have more than doubled the size, weight and cost of the machine. Its arithmetic unit contained 2200 relays. The Z4 was hired from 1950 to 1955 by the Swiss Federal Institute of Technology (ETHZ) in Zurich, where it was improved in several details. Zuse developed the algorithms to convert binary into decimal representation and all necessary algorithms for floating point operations. Particular were the use of special values like "infinity" ( $\infty$ ), "very large", "very small", each with and without sign, and also "indeterminate" (?). It was possible to compute with these values, for instance  $1/\infty = 0$ ,  $\infty - \infty = ?$ , etc.

It has to be noted that Zuse's developments were never really supported by the third Reich, although the "Deutsche Versuchsanstalt für Luftfahrt" (German Laboratory for Aviation) financed partially the Z3. For the Z4 the "Reichsluftfahrtministerium" (Ministry of

Aviation) backed Zuse. But these projects never had a great priority. Correspondingly the Z3 never was used in routine operation. Zuse was freed of military service because of his work in statics and his work on computers was carried out as a sideline job.

Zuse was, due to war times, not aware of parallel developments in the USA, for instance Aiken's Mark IV, nor of the ENIAC at the Moore School of Electrical Engineering of the University of Pennsylvania, which was 1946 presented to the public as the first fully electronic computer. But all of these machines were not yet fully *universal*. The *conditional jump* was missing, which allows, conditional on the value of some variable, to jump to a new instruction instead to follow the next instruction. This instruction was first introduced into the design of the EDVAC by Eckert, Mauchly and especially John von Neumann.

But Zuse had in this respect his own vision: He called his Z-computers *algebraic machines*. Beyond this concept he developed the idea of the "Plankalkül" (planning calculus), a formal description of computational processes, a kind of higher-level programming language. By computational processes he not only understood numerical calculation, but rather processes linking "circumstances" with "conditions" to obtain "results". Compare this to Aiken's statement "*If it should turn out that the basic logics of a machine designed for numerical solutions of differential equations should coincide with the logic of a machine intended to make bills for a department store, I would regard this as the most amazing coincidence I have ever encountered*". Zuse intended to build a *logic-machine*, which translates descriptions in the "Plankalkül" into programs for his algebraic machines. These visions were never realized. Computer technology took another turn after the war. Zuse also suggested 1967 the view of the universe as a *calculating space* and the concept of *digital physics*. These were really audacious ideas, which have gained much actuality and interest in today's foundations of physics.