THE RC 4000 REAL-TIME CONTROL SYSTEM
AT PULAWY*

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Abstract.

This paper describes a real-time control system implemented on the RC 4000 computer with an internal store of 4096 words. The system permits a number of independent programs to be executed periodically on a time-sharing basis. The first version of the system performs supervisory control of the ammonium nitrate plant Pulawy II in Poland.

After a description of the Pulawy system, the choice of a time-sharing scheme and the handling of shared facilities are discussed. This is followed by an evaluation of the size and performance of the system.

Introduction.

The multiprogramming system described in this paper was developed by Regnecentralen on contract with the Danish engineering company Haldor Topsøe. In connection with this project, Regnecentralen also developed a medium-sized computer, the RC 4000, which is specially suited for real-time control applications (Ref. 1).

The system is implemented on the RC 4000 computer with an internal store of 4096 words (backing storage is not used). It permits a number of independent programs to be executed periodically under the real-time control of a monitor. For each program, the operator can select the start time of its first execution and the time interval between its subsequent executions. The programs are executed in a simple time-sharing scheme, in which each program in turn is allotted a small quantum of computing time. A critical feature of any multiprogramming system is the handling of shared facilities. We have adopted the technique of binary semaphores suggested by E. W. Dijkstra (Ref. 2).

The first version of the system will be installed in 1967 in the ammonium nitrate plant Pulawy II, constructed by Haldor Topsøe in Poland. Here, the RC 4000 will perform regular alarm scanning, data logging, and evaluation of production and consumption figures.

In the following, we describe the supervision of the Pulawy plant in order to illustrate the requirements of a real-time control system and

the difficulties of implementation. This is followed by a discussion of the time-sharing approach.

The RC 4000 computer.

The RC 4000 is a single-address, binary computer with typical instruction execution times of from 2.5 to 5.5 microseconds. The following characteristics apply to the basic model used in the Pulawy plant.

_Storage:_ The internal store has a capacity of 4096 words. Each word contains 24 information bits, 1 parity bit, and 1 protection bit.

_Registers:_ There are four working registers of 24 bits each. Three of these also function as index registers. The registers are addressable as the first four words of the internal store.

_Addressing:_ Words of 24 bits and half-words of 12 bits are directly addressable. Address modification includes indexing, indirect addressing, and relative addressing.

_Arithmetic:_ Integer arithmetic with operands of 12 and 24 bits is standard.

/Input/Output:_ The standard data channel performs transfers of single words between low-speed devices and working registers under program control. Program execution continues while input/output operations are in progress.

_Program Protection:_ In the RC 4000, the monitor program consists of all storage words in which the protection bits are set. A program stored in an unprotected area can neither alter nor jump to a protected area. All input/output operations as well as control of the interruption system and storage protection are handled by privileged instructions, which can only be executed within the monitor. Attempts to violate the protection system cause program interruption.

_Program Interruption:_ The interruption system can register up to 24 signals simultaneously. These can be enabled and disabled individually. The interrupts are examined after each instruction; an enabled interrupt will transfer control from the current program to the monitor. All interrupts are disabled when the monitor is entered; they can be enabled again by a privileged instruction.

The Pulawy Installation.

The Pulawy II plant consists of three units for the production of ammonia, nitric acid, and ammonium nitrate, respectively. The plant is operated manually under the supervision of the computer. This section describes the configuration of peripheral equipment at Pulawy.