COMPUTER-PROGRAMMED PREVENTIVE MAINTENANCE FOR INTERNAL MEMORY SECTIONS OF THE ERA 1103 COMPUTER SYSTEM

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Introduction

The ERA 1103 is a recent addition to Remington Rand's line of general purpose digital computer systems. It was designed and is being produced in quantity by the Engineering Research Associates Division. The system incorporates large internal storage capacity with very high computation rates and is intended for real time control problems as well as general scientific computation. A perspective view of this equipment is shown in Figure 1. The system operates in the parallel mode, and arithmetic is performed in the one's complement binary system. Basic internal word size is 36 binary digits. A word may represent an instruction, a pure number, or an arbitrarily-coded quantity.

Two-address instructions are employed with a program address counter normally providing the storage address of the next instruction. The form of the instruction is shown in Figure 2.

Of the 64 possible combinations in the six-bit operation code portion of the instruction, 45 are actually employed in the system repertoire. The two 15-bit address portions of the instruction generally refer to the location of operands in storage, but in some cases they specify the number of shifts or other information related to the performance of the instruction.

OPERATION	u ADDRESS	v ADDRESS
6 BITS	15 BITS	15 BITS

Figure 2. Two-Address Instruction

All arithmetic operations are performed in a double-length accumulator. This 72-bit register permits the summing of full-length products and performance of double-precision operations with a minimum of program instructions. In addition to the normal arithmetic operations, a large variety of logical operations and jump instructions are included in the system repertoire.

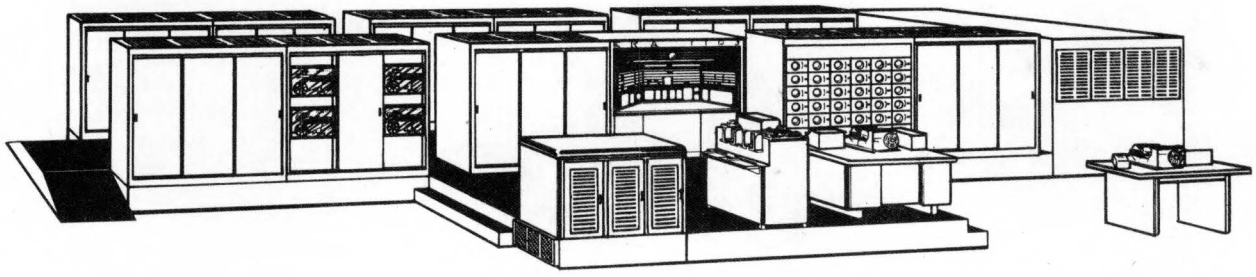


Figure 1. ERA 1103 Computer

Storage Systems

The internal memory of the ERA 1103 employs three storage media. The rapid-access portion of the memory consists of 1024 words of electrostatic (CRT) storage with an access time of 10 microseconds. The medium-speed portion consists of 16,384 words of magnetic drum storage with an average random access time of 17 milliseconds. The slow-speed memory consists of 200,000 words of magnetic tape storage on four magnetic tape mechanisms. In addition to these internal storage units, a number of external magnetic tape units and punched card equipment or other input-output devices may be used under direct system control through the input-output registers of the ERA 1103. An EXTERNAL FUNCTION instruction permits the equipment to "reach out" in effect and control external units with a wide variety of characteristics.

The electrostatic and magnetic drum storage systems are individually addressed, providing a total of 17,408 registers of directly-addressed storage. Each of these storage units communicates directly with the arithmetic system, and the magnetic drum does not depend on the electrostatic storage as a buffer. These features permit the magnetic drum system to test the electrostatic system as an isolated unit, and they permit the electrostatic system to test the magnetic drum as an isolated unit.

Preventive Maintenance

Rather elaborate provisions have been made in the ERA 1103 to detect aging elements in the computer system before the elements have become sufficiently marginal to cause failure during normal system operation. Preventive maintenance periods are scheduled at the beginning of every eight-hour period of operation. During these periods a rigorous procedure is followed which reveals any component in the system that has deteriorated to a point where it may cause failure during the following operation. A predetermined margin is thus insured about the normal operating conditions of the system. For this an extensive set of maintenance programs have been prepared which systematically examine every portion of the system as a unit while abnormally severe conditions are imposed on that unit. In the event of failure, sub-routines are provided which analyze the failure and present to maintenance personnel, via a monitoring typewriter, that portion of the system which failed. Spare plug-in chassis are provided for every position in the system so that the faulty unit may be re-

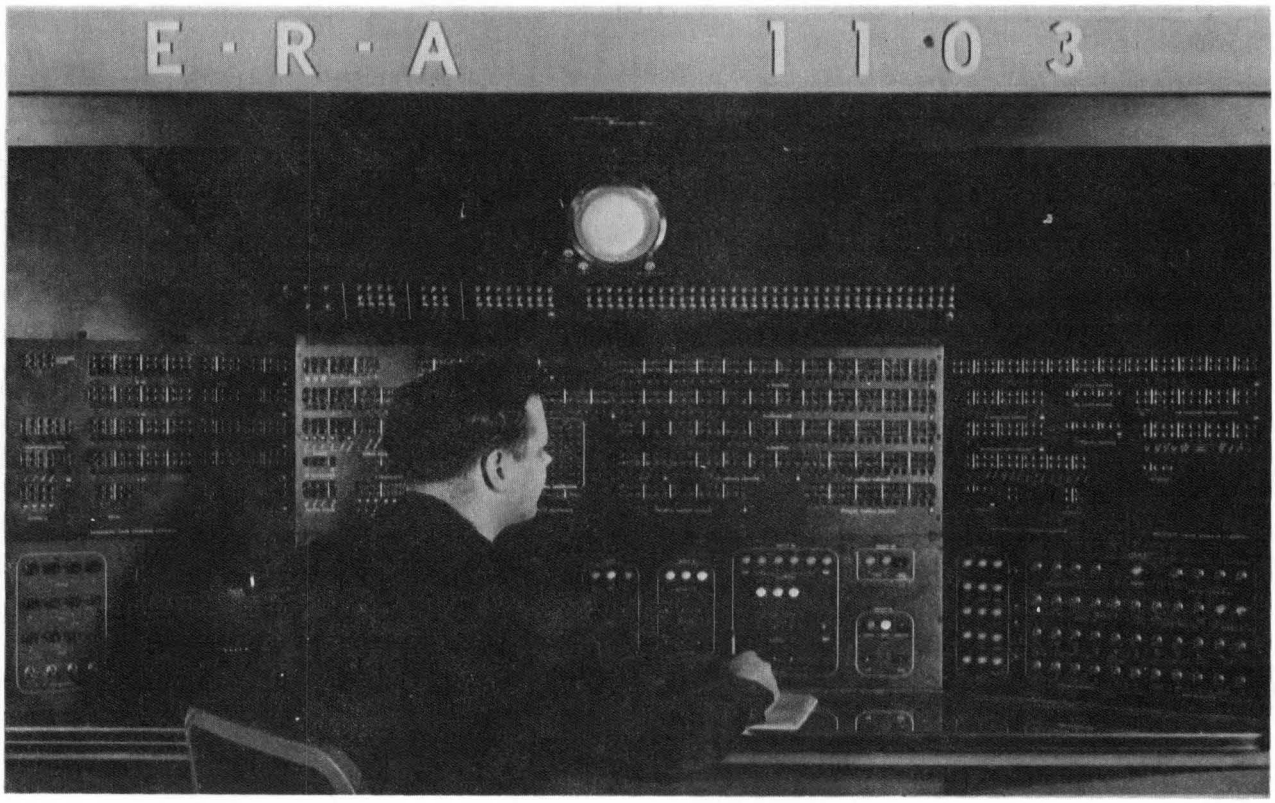


Figure 3. ERA 1103 Control Panel

placed for later repair.

Certain vital portions of the arithmetic section of the computer cannot be effectively analyzed by the maintenance program alone. For failures in this portion of the system, a control panel is provided on which both the "one" and "zero" side of every flip-flop in the system is indicated with a neon lamp. This panel is shown in Figure 3. A faulty flip-flop is identified by both lamps on, or both lamps off. Faulty transmission paths are checked by running a specially-prepared program at reduced speed. This program provides easily-identified visual indication of that transmission path which failed.

The various preventive maintenance programs are stored on a section of magnetic tape. During the scheduled maintenance periods, this magnetic tape is placed on one of the four internal magnetic tape units which are under computer control. The maintenance procedure is then a matter of selecting the desired test by manual insertion of a code number on the control panel and starting the computer in a mode designated as "Magnetic Tape Start". The desired test is then transferred from the magnetic tape to the computer directly addressed memory by an automatic "boot strap" routine on the magnetic tape.

Marginal Checks

The predetermined operating margin previously mentioned is established during maintenance periods by three types of marginal checking devices. Experience has shown that no one of these devices is really sufficient for the system as a whole, but taken together they provide a really effective overall operating margin. These abnormal conditions which are temporarily imposed on a unit during the test period fall into three categories.

(1) Reduced Filament Voltage.

During a portion of the maintenance test period, the vacumm tube heater voltage in the section of the computer under test is reduced from 6.3 volts to 5.5 volts. This provides a very effective check on the pulse amplifier and gate circuits in the system, a partial check on the flip-flop circuits, and a relatively ineffective check on the reading amplifiers in storage sections of the computer.

(2) Power Supply Variations.

Power supply voltage variations of plus and minus ten percent of normal are used to establish margins, particularly on the static elements in the system. Eight supply voltages are used in the 1103 system, and these are sequentially varied over a 20 percent range about normal while the test routine is running. This check is quite effective in establishing flip - flop margins and crystal diode network tolerances.

(3) Threshold Levels.

In the storage sections of the computer, the most effective marginal check is a variation in the reading amplifier signal threshold levels. Special equipment is provided to raise or lower the threshold clipping level during the maintenance routine in each reading amplifier in the selected storage section. Satisfactory operation with the lower threshold level establishes that no noise is within the predetermined margin of the normal discrimination level. Satisfactory operation with the upper threshold level establishes that every signal pulse is greater than the normal discrimination level by at least the predetermined margin.

Electrostatic Storage

The electrostatic portion of the 1103 memory provides 1024 words of storage with an access time between 8 and 12 microseconds depending on the phase of regeneration at the time of reference request from the control section of the system. Storage is provided by 36 special five inch cathode ray tubes using a dot-diagonal-dash type of beam deflection. Each storage tube supplies one binary digit for each of the 1024 words in a 32 by 32 array of dots and dashes. The storage tube, with associated reading amplifier and control circuitry for a digit of memory, is packaged in a plug-in unit for ease of maintenance.

ES Cycle Test

The ES Cycle Test is designed to check the access control circuitry, the addressing and deflection circuits, and the normal storage properties of the electrostatic system, but it does not check the read-around ratio of the storage tubes. The test takes 59 seconds of system time and makes over two million operand references to the ES storage with no program references. The program is operated entirely out of the magnetic drum storage section so that abnormal conditions imposed on the ES storage section will not jeopardize the proper operation of the program.

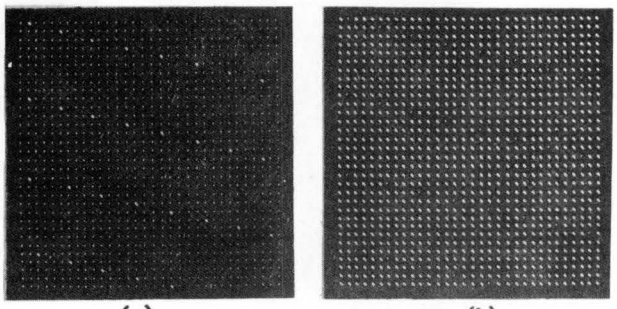
The storage pattern used in the cycle test is defined by the expression:

$$(k) = 2^k \pmod{2^{36}-1}$$

That is, the word stored at address k is the binary number 2^k corrected to machine modulus. Each word contains a single "one", in a digit position determined by k. A typical pattern which appears on the storage tubes during this test is shown in figure 4a. This pattern, when cycled through all of the ES address positions, presents many of the data singularities which can occur in a random distribution.

Considerable use is made in this and other maintenance programs of an 1103 instruction

called the "Repeat Instruction." This instruction provides for the automatic repetition of the next instruction in the program up to 1024 times with selective advancing of the execution addresses and without further references to storage. The use of this instruction permits a great reduction in program time wherever repetitive processes are involved.



(a) (b)

Figure 4. E.S. Cycle Test Patterns

Operation of the ES Cycle Test may be outlined as follows.

(1) The 1024 word pattern defined by the above expression is generated in the magnetic drum storage section and then copied into the ES storage section. The pattern is formed on the magnetic drum in one drum revolution using a repeated "Add and Transmit" instruction. Then, using a repeated "Transmit Positive" instruction, the pattern is transferred in a block to the ES system.

(2) The pattern is cycled through the ES address positions by repeated "Transmit Positive" instructions from address k to address k-1, with the execution addresses advanced after each operation. (The repeat instruction treats the ES storage system as a closed address set, with the last address followed by the first.) The effect of these repeated transmissions is a regression of the test pattern by one address location for each 1023 transmissions.

(3) After approximately 300,000 such transmissions, the pattern has regressed one third of a complete cycle. At this point in the program the "Transmit Positive" instruction is changed to a "Transmit Negative" with the result that for the next 300,000 transmissions the pattern alternates between predominately ones and predominately zeros.

(4) After an odd number of negations of the entire pattern, the repeated instruction is returned to a "Transmit Positive", and the remainder of the cycle is completed with a predominance of ones stored, as shown in Figure 4b.

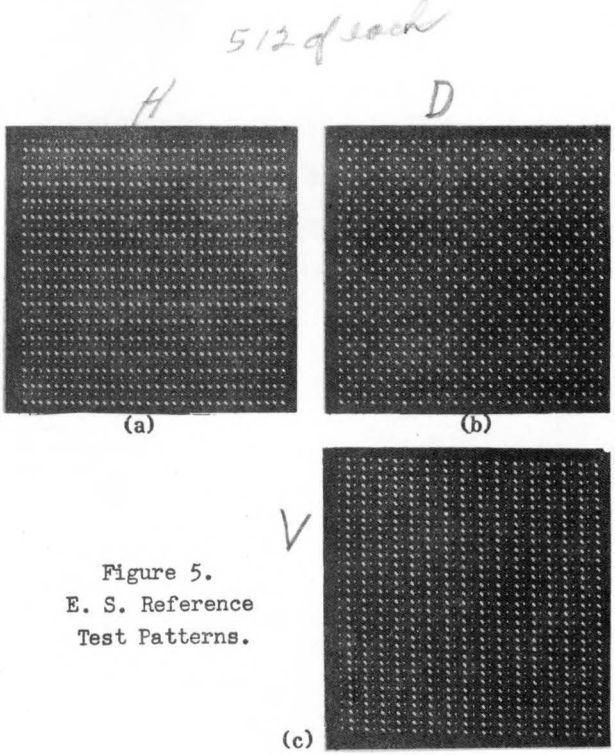
(5) After the completion of $(1023)^2$ such operations, the ES test pattern has regressed to its original position and is the complement of the original pattern as stored on the magnetic drum.

(6) A word-by-word comparison is then made with the original pattern on the magnetic drum. In the event of a discrepancy, a subroutine presents the digit position of failure to maintenance personnel through the monitoring typewriter. Since the circuitry for each digit position is contained in a unit chassis, the digit position of failure identifies which chassis must be removed for maintenance.

ES Reference Test

The "ES Reference Test" is designed to check interaction between storage positions as a result of repeated references to the same address. During this test each address in the ES storage system is sequentially referenced N times in rapid succession, where N is a parameter stored in the program with a normal value of 256. Following these repeated transmissions, a word-by-word comparison is made between the entire ES storage contents and a reference pattern on the magnetic drum. In the event of a discrepancy, indicating interaction in the ES system, the digit position of failure together with the reference number N and the type of pattern used, is presented to the maintenance personnel through the monitoring typewriter.

Any one of the three test patterns shown in Figure 5 may be selected for the ES Reference



(a) (b) (c)

Figure 5.
E. S. Reference
Test Patterns.

Test. Each test provides two scans of the entire pattern, once as shown in Figure 5 and once with the complement of that pattern. In this way each address location is tested both with a one and with a zero stored.

In the event of several simultaneous failures during a maintenance period, the repetition of the test with the three different patterns provides information as to adjustments that may be necessary on the dash deflection circuits which are common to all storage units. For example, if pattern 5a causes storage errors and patterns 5b and 5c do not, a change in the dash angle toward the horizontal is indicated. If only pattern 5c causes failures, the dash angle should be shifted toward the vertical.

Magnetic Drum Storage

The magnetic drum portion of the 1103 memory provides 16,384 words of directly-addressed storage. The information is divided into four groups of tracks with 4096 angular positions about the periphery of the drum. Surface speed is 1600 inches per second with a pulse density of 80 per inch. The period of the drum is 34 milliseconds. The reading and writing circuits are designed so that either a reading or a writing reference may be accepted every 32 microseconds. This feature is particularly valuable with the repeat instruction since many types of repeated operations can take advantage of the sequential character of the storage locations.

MD Storage Test

The preventive maintenance program for the magnetic drum storage system is operated entirely from the electrostatic system. This test takes 100 seconds of system time and includes 16 reading references and 16 writing references to each of the 16,348 addresses on the magnetic drum. Various combinations of adjacent data and transient conditions are tested for both a one and a zero stored in each bit position on the drum. These operations, performed with the repeat instruction and an eight-cell drum interlace, make 1024 references of alternate read and write per drum revolution. Each of the transient conditions of read after write with minimum spacing is checked for the four combinations of binary data. In the event of a check discrepancy in any one of the transfer verifications, the maintenance program provides for an automatic search of the entire drum contents and a presentation on the monitoring typewriter of the addresses involved in the failure and the conditions associated with the failure.

Results

Figure 6 presents a summary of operational experience on the ERA 1103 for the first six months of 1954. Scheduled maintenance periods are provided once per eight-hour shift. The unscheduled maintenance classification includes down time due to failures in auxiliary equipment and power failures as well as internal system failures.

	Jan.	Feb.	March	April	May	June
Total hours	338	325	400	366	409	549
Production time	61%	70%	68%	74%	75%	82%
Scheduled maintenance	30%	26%	25%	23%	21%	14%
Unscheduled maintenance	9%	4%	7%	3%	4%	4%
Average hours production time between unscheduled maintenance periods	18	21	24	25	28	41

Figure 6. Summary of ERA 1103 Operation.