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PROJECT STRETCH
FILE MEMO #3

COMPANY CONFIDENTIAL

SUBJECT: A Ring Accumulator
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DATE: November 29, 1955

This memorandum describes an arithmetic system using a ring accumulator. The system is based upon the conditions set forth in Stretch File Memo #2. It is being presented at this time as a guide for work on packaging and automation of design, and to assist in developing a method of error diagnosis and autocorrection for the Stretch Computer.

Purpose of the Ring

Most accumulators approximate to some degree the form of a ring. This memorandum considers the arithmetic system from this viewpoint. The advantage of a ring is its symmetry, which results in an elegance and simplicity of design which is a relatively ideal starting point for automation of design. Since every accumulator position is connected to its neighbors in identical fashion, it is highly adaptable to modular construction. A standard accumulator unit fits equally well into every position of the ring, and into secondary as well as primary accumulator rings in the machine.

Only the master arithmetic unit will be discussed in this memorandum, but it is to be understood that the secondary exponent and address accumulators can be executed in a similar manner. The latter would, of course, omit the multiply-divide and shift controls.

Make-up of the Ring

The master accumulator ring would be made up of 96 accumulator positions each connected identically to its neighbors. It is represented pictorally by the attached Diagram 1.

The 48 positions in the right semicircle are capable of binary addition and subtraction, complementing, carry, shifting, read in, and read out. Those in the left semicircle, with the exception of positions 49 and 96, are degenerate accumulator positions which have part but not all of the above capabilities. Positions 49 and 96 are required to have full accumulator capabilities for use in multiplication and division.

The pluggable units for the adder can be designed in such a way that a single type of unit can be plugged into any of the 96 positions of the accumulator or into secondary accumulators in case of breakdown.

Shifting

The ring must be provided with means for shifting the number in each accumulator position to its neighbors at the left and at the right. This results in a precession of the data around the ring.

For the present, the following shifts are proposed:

1. Counterclockwise 1 position.
2. No shift.
3. Clockwise 1 position.
4. Clockwise 2 positions.
5. Clockwise 4 positions.
6. Clockwise 8 positions.

Carry

Until further data is available, it will be assumed that carry will be executed in blocks of 18 positions, rather than across all 96 accumulator positions each cycle. One or more additional cycles would be taken for long carries.

Accumulator Matrix

Each position of the accumulator might be executed as a pair of matrices, one providing addition and subtraction, and the other carry and shifting. Through the use of blocking oscillators or similar devices, the data would be transferred continuously back and forth between one class of matrices and the other. Thus, the developing result would be held dynamically in the matrix system and would not come to rest in registers until the arithmetic operation is completed.

Associated with the accumulator would be four 48 position registers, two associated with the factors, and two with the result. It is obvious that fewer registers might be used. Four are assured to be used so that the factors can be held undisturbed throughout the arithmetic operation. In this way they remain available for recomputation if an arithmetic error is made.

Addition-Subtraction

Diagram 2 shows the operation of the ring for addition and subtraction. The addend and augend are held in the two factor registers. These registers are connected to the accumulator matrix on succeeding cycles, resulting in their addition or subtraction. The result is later read out to a result register.

If the operation were in floating point, the arithmetic operation would have been preceded by a computation upon the exponents of the two numbers. This computation determines which number is larger, and therefore must be treated as the addend. It also determines the offset of the two numbers, and the shifting cycles required between entry of the two numbers to obtain the offset.

After completion of the floating point arithmetic operation, the result would be shifted clockwise or counterclockwise as required until its highest significant position is in position 48 of the ring.

Multiplication

Diagram 3 illustrates multiplication. This diagram shows the manner in which the factors are entered and the result removed from the ring. Multiplication consists of the controlled addition of the multiplicand to the developing product and the simultaneous precessing of the multiplier and product around the ring.

The multiplier is shifted progressively into positions 91-96 of the ring where it is examined to establish the multiply control. Each time the multiplicand is added to the product, a 1 is subtracted from the multiplier. When the multiplicand is subtracted, a 1 is added to the multiplier. As a result, the multiplier is diminished as the product builds up. An examination of each multiplier digit to establish that it has been reduced to zero provides direct proof that the multiplication has been executed properly.

Division

Diagram 4 illustrates division. The process is very much like that of multiplication. Repeated subtraction of the divisor from the dividend reduces it toward zero. As it is reduced, it is precessed to the left so that its highest significant bit lies in position 48.

Position 49 receives a 1 wherever the divisor is subtracted, with the result that the quotient progressively develops across positions 49-96.

The dividend and divisor are compared at positions 43-48 to determine whether a subtraction can or cannot be made.

Checking and Autocorrection

There is a large measure of inherent checking in the system. The individual positions of the accumulator, being symmetrical matrices, are self-checking. Proof that the proper add-subtract cycles were taken during multiplication and division is obtained directly by reducing the multiplier and developing the quotient in the same accumulator that holds the product and the dividend. Control and proof of shifting will be provided by the exponent accumulator.

In case a failure should be sensed, the arithmetic unit would stop immediately, print out the factors and the result, which may be only partially developed. It would then reread the factors and endeavor to repeat the operation correctly.

Possible Variations

Of the many possible variations of the arrangement discussed in this memo, two deserve comment.

1. It may be that a simpler control of multiplication and division can be obtained if a 97 or 98 position accumulator is used in place of the 96 position unit discussed here. Further detailing of the controls will disclose whether or not this is true.

2. It is possible to reverse the functions of the two halves of the circle in division. This would relocate the divide controls so that they would fall in the same position as those for multiplication, and should reduce switching requirements for them. However, it would require that the divisor enter the left side of the ring, with the result that all 96 positions of the accumulator must be capable of performing all accumulator functions.

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SWD/mms
Attachment: 4 Diagrams

Diagram 1

Ring Accumulator

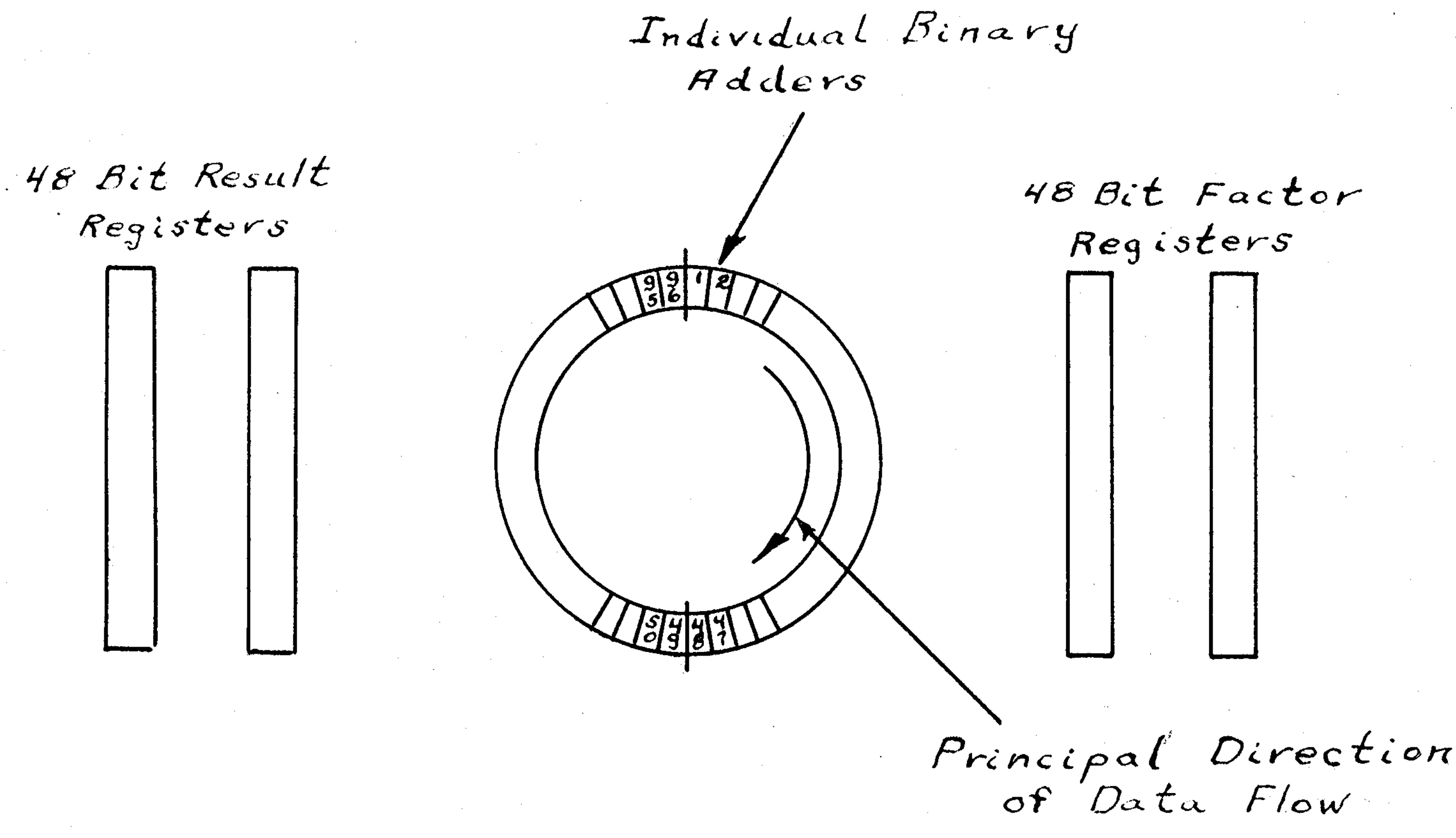

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Diagram 2

Addition - Subtraction

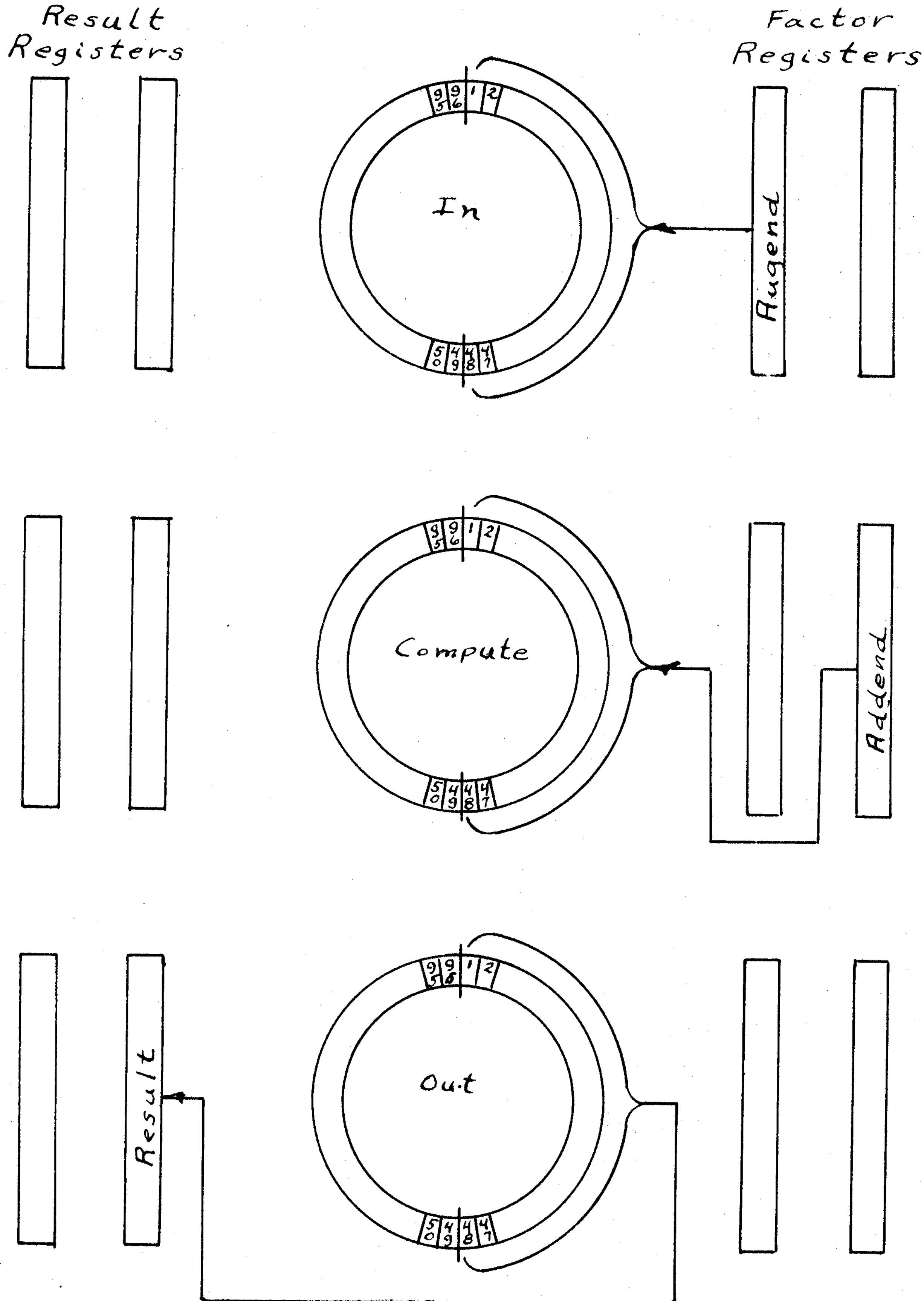

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Diagram 3
Multiplication

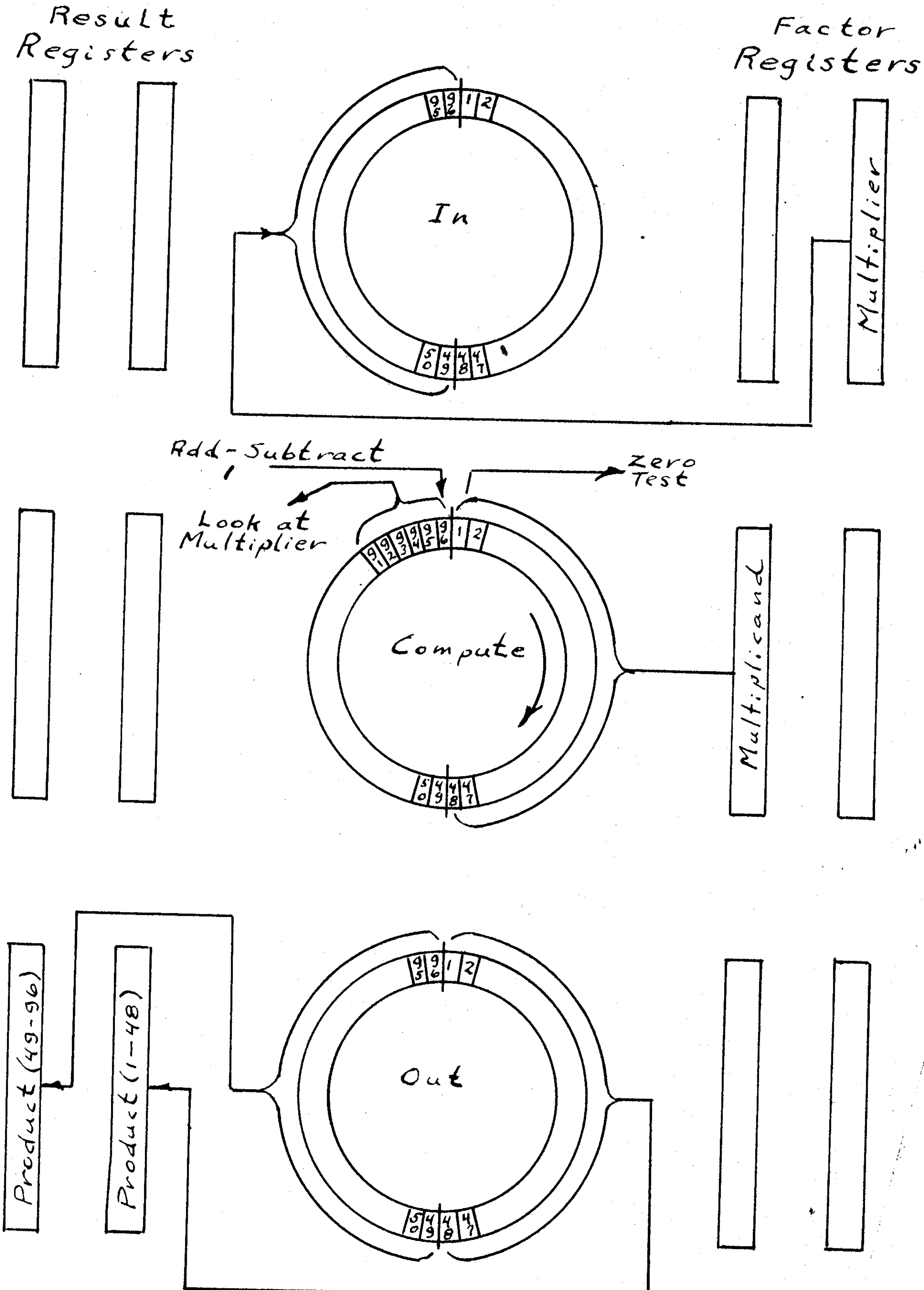

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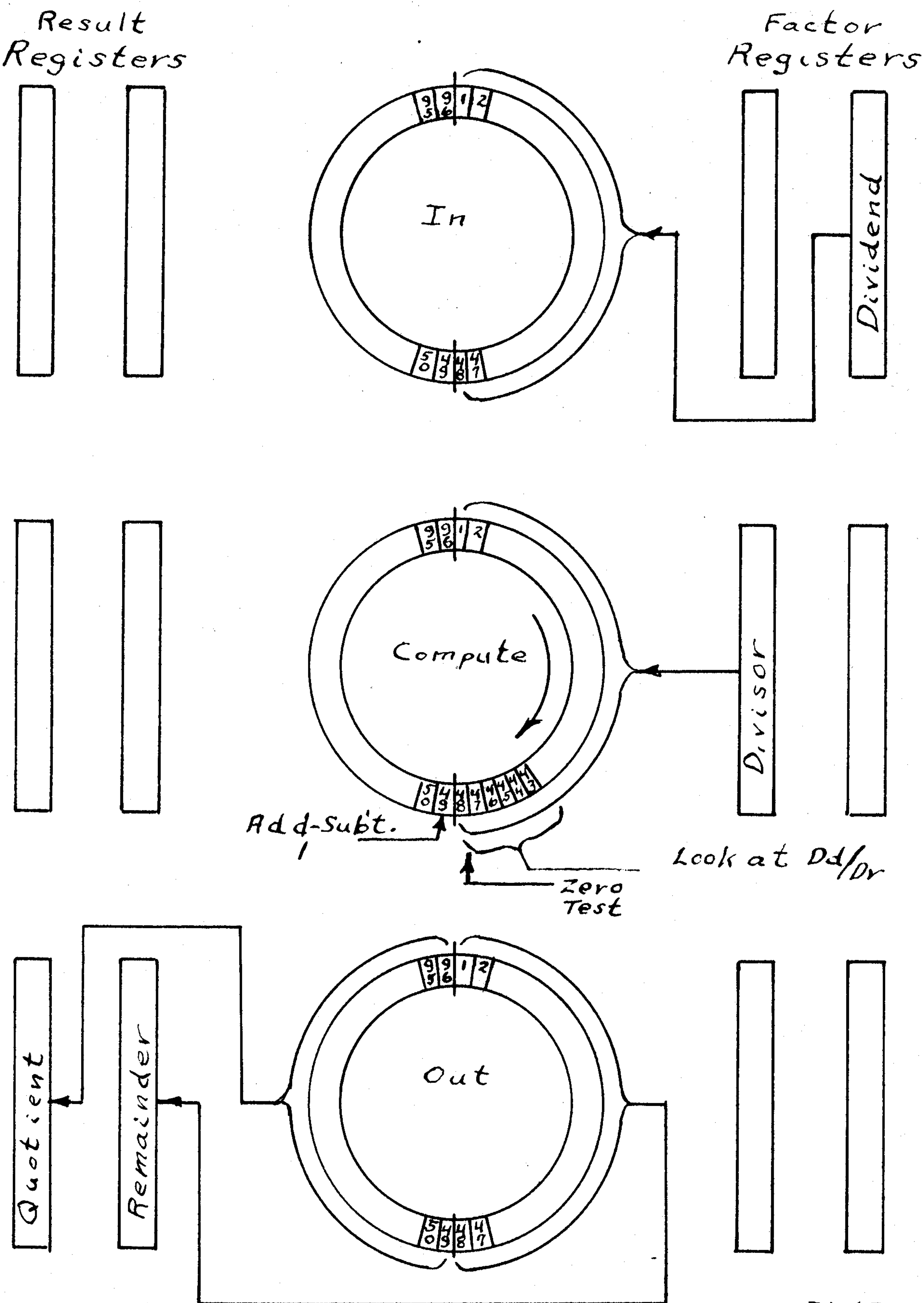
Diagram 4
Division



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