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# Dividing Device

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***Abstract* — This invention is related to the area of computing machinery and can be used to perform the division procedure. The invention allows for a significant increase in the performance of the existing device. The device consists of the multipliers and the adders forming a triangular cellular array, the converters of the binary code into the one's complement code, subtractors, and the converter of the redundant binary code to the non-redundant binary code.**

This invention is related to the area of computing machinery and can be used to perform the division procedure.

The purpose of the invention is to increase the performance of the existing division device.

Fig. 1 provides the internal structure of the device for the case of $n=p=8$, where $p$ is the number of the redundant quotient digits.

The division device consists of a total of 21 multipliers numbered 1 through 21, a total of 21 adders numbered 22 through 42, a total of 6 converters for converting the binary code to the one's complement code numbered 43 through 48, a total of 4 subtractors numbered 49 through 52, the converter of the redundant binary code to the binary code numbered 53, the dividend input numbered 54, the divisor input numbered 55, and the quotient output numbered 56.

The division device is based on the following idea. Assume that the dividend $C = 0.\ c_1\ c_2\ c_3\ c_4\ c_5\ c_6\ c_7\ c_8$ and the divisor $A = 0.\ a_1\ a_2\ a_3\ a_4\ a_5\ a_6\ a_7\ a_8$ are normalized binary fractions and the quotient $Q$ is represented as follows:

$$Q = C / A = q_0 \,.\, q_1\, q_2\, q_3\, q_4\, q_5\, q_6\, q_7\,,$$

where $q_i$ is $i$th redundant quotient digit and $0 \leq i \leq 7$.
The condition $A{\cdot}Q = C$ can be used to determine the redundant quotient digits by assigning the sums of the partial products with equal binary weights to the corresponding digits of the dividend $C$. The dividend $C$ is represented in the device in the following form:

$$C = 0.\ c_1c_2c_3c_4c_5c_6c_7c_8 = c_1{\cdot}2^{-1} + c_2{\cdot}2^{-2} + 0{\cdot}2^{-3} + (2c_3+c_4){\cdot}2^{-4} + 0{\cdot}2^{-5} + \\ +(2c_5+c_6){\cdot}2^{-6} + 0\cdot 2^{-7} + (2c_7+c_8){\cdot}2^{-8}.$$

As a result, the following system of linear equations can be obtained:

$$\begin{aligned}
&a_1q_0 = c_1\\
&a_1q_1 + a_2q_0 = c_2\\
&a_1q_2 + a_2q_1 + a_3q_0 = 0\\
&a_1q_3 + a_2q_2 + a_3q_1 + a_4q_0 = 2c_3 + c_4\\
&a_1q_4 + a_2q_3 + a_3q_2 + a_4q_1 + a_5q_0 = 0\\
&a_1q_5 + a_2q_4 + a_3q_3 + a_4q_2 + a_5q_1 + a_6q_0 = 2c_5 + c_6\\
&a_1q_6 + a_2q_5 + a_3q_4 + a_4q_3 + a_5q_2 + a_6q_1 + a_7q_0 = 0\\
&a_1q_7 + a_2q_6 + a_3q_5 + a_4q_4 + a_5q_3 + a_6q_2 + a_7q_1 + a_8q_0 = 2c_7 + c_8 \qquad (1)
\end{aligned}$$

Taking into account the fact that $A$ and $C$ are normalized binary fractions i.e. $a_1 = c_1 = 1$, equations (1) can be rewritten as follows:

$$\begin{aligned}
&q_0 = 1\\
&q_1 = c_2 - a_2\\
&q_2 = - a_2q_1 - a_3\\
&q_3 = 2c_3 + c_4 - a_2q_2 - a_3q_1 - a_4\\
&q_4 = - a_2q_3 - a_3q_2 - a_4q_1 - a_5\\
&q_5 = 2c_5 + c_6 - a_2q_4 - a_3q_3 - a_4q_2 - a_5q_1 - a_6\\
&q_6 = - a_2q_5 - a_3q_4 - a_4q_3 - a_5q_2 - a_6q_1 - a_7\\
&q_7 = 2c_7 + c_8 - a_2q_6 - a_3q_5 - a_4q_4 - a_5q_3 - a_6q_2 - a_7q_1 - a_8 \qquad (2)
\end{aligned}$$

The suggested division device forms the quotient digits according to the equations above. The redundant digit $q_1$ is formed on the output of subtractor 49. Subtractor 49 subtracts the value of $a_2$ from the value of $c_2$. The redundant digit $q_2$ is formed on the output of converter 44. The multiplier 1 forms the value of $a_2q_1$ . The output of the multiplier 1 is connected to the first input of adder 22, the second input of which is connected to the input $a_2$ of the divisor. The output of adder 22 forms the result of $a_3 + a_2q_1$ which is equal to $-q_2$ according to the third equation of (2). Converter 44, which converts the binary code to one's complement code, changes the sign of the value of $a_3 + a_2q_1$ to the opposite one and thus forms the value of $q_2 = -a_2q_1 - a_3$. The redundant quotient digit $q_3$ is formed on the output of adder 28 as follows. The value of $-a_3q_1$ from the output of multiplier 2 is supplied to the first input of adder 23, the second input of which is connected to the output of subtractor 50. Subtractor 50 formulates the value of $2c_3 + c_4 - a_4$ on its output based on the values of $c_3$, $c_4$, and $a_4$ supplied to its inputs. The value of $2c_3 + c_4 - a_4 - a_3q_1$ from the output of adder 23 is supplied to the second input of adder 28. The first input of adder 28 is connected to the output of multiplier 7 which formulates the value of $-a_2q_2$. Therefore, the output of adder 28 produces the value of $q_3 = 2c_3 + c_4 - a_2q_2 - a_3q_1 - a_4$. Like the above, the device formulates the quotient redundant digits $q_4$, $q_5$, $q_6$, and $q_7$. The value of $q_0 = 1$ is formulated explicitly in the device but its value is taken into account by converter 53 which is used to convert the quotient from the redundant binary code to the non-redundant binary form $Q = q_0'.\ q_1'\, q_2'\, q_3'\, q_4'\, q_5'\, q_6'\, q_7'$ which is provided on output 56 of the device.

In the case in which the number of bits of the dividend and the divisor is odd (for instance, $n=p=7$), the quotient $Q$ is formulated in the following form:

$$C = 0.\, c_1\, c_2\, c_3\, c_4\, c_5\, c_6\, c_7 = c_1 \cdot 2^{-1} + c_2 \cdot 2^{-2} + 0 \cdot 2^{-3} + (2c_3 + c_4) \cdot 2^{-4} + 0 \cdot 2^{-5} + \\ +(2c_5 + c_6) \cdot 2^{-6} + c_7 \cdot 2^{-7}.$$

This affects the formulation of the last quotient digit $q_6$ which in this case will be formulated as follows:

$$q_6 = c_7 - a_2q_5 - a_3q_4 - a_4q_3 - a_5q_2 - a_6q_1 - a_7\ .$$