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A High Speed Josephson 2-bit ALU Circuit Fabricated with Nb/Al-Oxide/Nb Junctions

Hiroshi NAKAGAWA, Itaru KUROSAWA, Susumu TAKADA
Electrotechnical Laboratory
1-1-4 Umezono, Sakuramura, Ibaraki, 305 Japan

In this paper, we present a Josephson 2-bit arithmetic logic unit(ALU) which consists of a 4JL-gate family(1). The circuit was fabricated using a Nb/Al-oxide/Nb junction process(2).

The circuit configuration of the ALU is shown in Fig.1. The ALU was designed to perform 16 arithmetic functions and 16 logic functions for two binary data of (A_0,A_1) and (B_0,B_1). Each function is performed by selecting external control signals of M and S_0, S_1, S_2 and S_3. Circuit parameters were determined based on the characteristics of 3μm-Nb/Al-oxide/Nb junctions(V_m=50mV, V_g=2.8mV). In this design, an operating time of the ALU was calcurated to be 180ps at a power dissipation of 267μW.

The Nb/Al-oxide/Nb junction was made by forming a junction sandwich which consists of base electrode, Al-oxide barier and counter electrode on a whole Si wafer. Each junction was defined by dry-etching process(3). Wirings and resisters were made of Pb-In and Au-In alloys, respectively. Figure 2 shows a photograph of the ALU circuit fabricated. The ALU circuit consists of 174 4JL-gates. To measure a real operating time, four 4JL-gates were integrated in the same circuit. The circuit has a size of about 0.85mm X 2mm. A Josephson regulator is connected to the power line as is seen in the top of the figure.

Testing was carried out in liquid He for various functions of the ALU. Figure 3 shows oscilloscope traces of the ALU operations which mean coincident(logic) and add(arithmetic) functions. The logic and the arithmetic were carried out for the first 8-bit pulse pattern and last one, respectively. These results mean consistent operations of the ALU.

A critical delay time was measured for the logic mode of $\overline{A}$*B. The critical pass includes 12 4JL-family gates(six OR, four AND, two AMP). In Fig.4, the operating time is plotted as a function of the current which was fed to the power line. The operating time is constant at 220ps up to 70mA. The operating time decreases with increasing the current. The fastest operating time of 157ps was achieved at the current of 92.5mA. Taking account of 12 4JL-gates in the critical pass, an average gate delay time is 13 ps/gate.

In conclusion, we have designed and fabricated the Josephson 2-bit ALU circuit with the 3μm-Nb/Al-oxide/Nb junction technology. The ALU was successfuly operated

for 16 logic and 16 arithmetic function modes. The fastest operating time of 157ps has been achieved.

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References: (1)H.Nakagawa et al., Extended Abstracts of 15th Conf. Solid State Devices and Materials, Tokyo, 137 (1983). (2)H.Nakagawa et al., Jpn. J. Appl. Phys. 25, L70 (1986). (3) A.Shoji et al., Appl. Phys. Lett. 41, 1097 (1982).

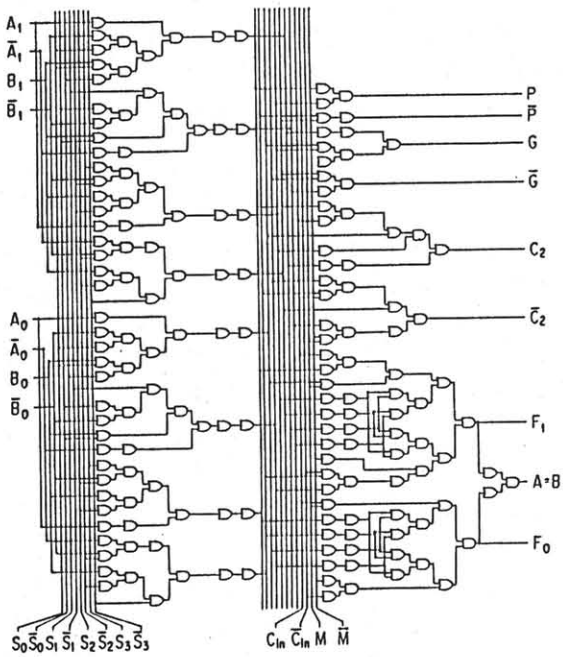

Fig.1 Layout of 2-bit ALU.

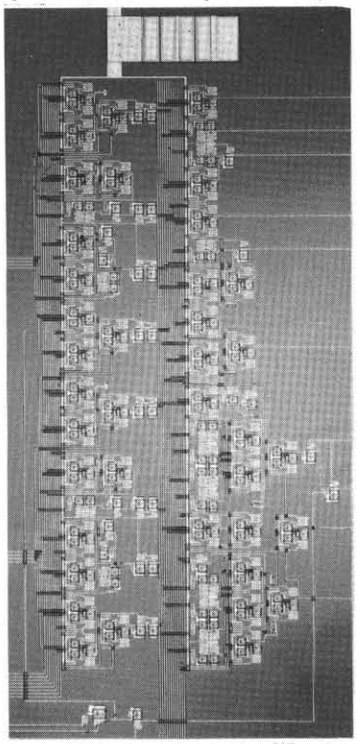

Fig.2 Photograph of the ALU circuit.

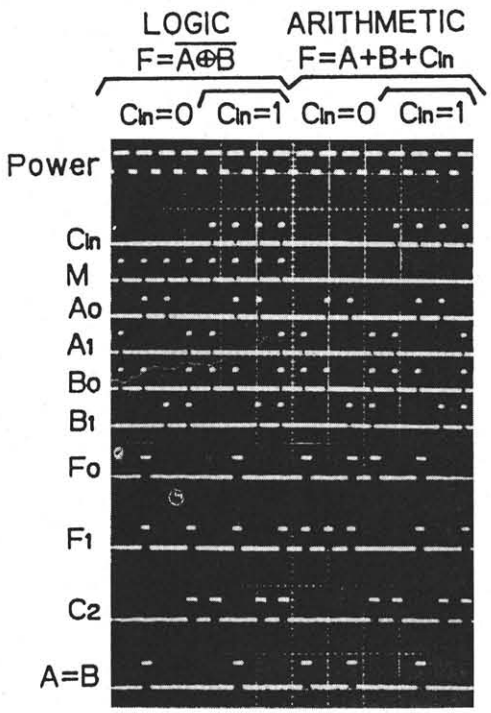

Fig.3 ALU testing.

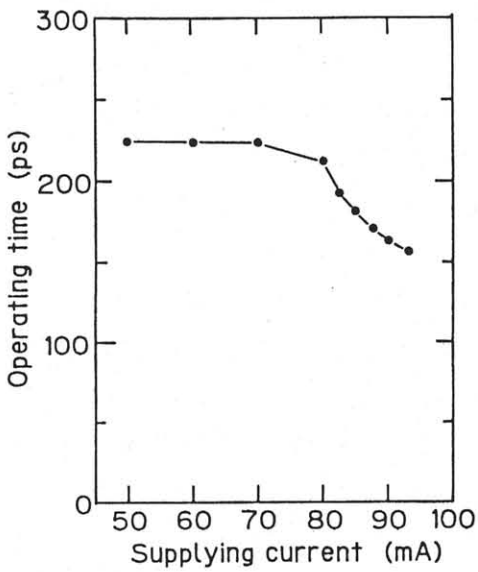

Fig.4 Operating time dependence on supplying current.