Studies in Josephson Supercomputers

Advances in QUANTUM FLUX PARAMETRON COMPUTER DESIGN

Editors

E Goto

Y Wada

K F Loe

World Scientific

Advances in

QUANTUM FLUX PARAMETRON COMPUTER DESIGN

STUDIES IN JOSEPHSON SUPERCOMPUTERS

D C Flux Parametron — A New Approach to Josephson Junction Logic
by E Goto and K F Loe

Fluxoid Josephson Computer Technology — Proceedings of the 3rd, 4th and 5th RIKEN-ERATO Symposia
Eds. E Goto, T Soma and K F Loe

Issues in Josephson Supercomputer Design — Proceedings of the 6th and 7th RIKEN Symposia on Josephson Electronics
Eds. E Goto and K F Loe

Quantum Flux Parametron — A Single Quantum Flux Superconducting Logic Device
by W Hioe and E Goto

Advances in Quantum Flux Parametron Computer Design
Eds. E Goto, Y Wada and K F Loe

Studies in
Josephson
Supercomputers

Advances in
QUANTUM FLUX PARAMETRON COMPUTER DESIGN

Editors

E Goto
Kanagawa University and
Research Development Corporation of Japan (JRDC)

Y Wada
Research Development Corporation of Japan (JRDC)

K F Loe
National University of Singapore

World Scientific
Singapore • New Jersey • London • Hong Kong

Published by

World Scientific Publishing Co. Pte. Ltd.
P O Box 128, Farrer Road, Singapore 9128
USA office: Suite 1B, 1060 Main Street, River Edge, NJ 07661
UK office: 73 Lynton Mead, Totteridge, London N20 8DH

Library of Congress Cataloging-in-Publication data is available.

ADVANCES IN QUANTUM FLUX PARAMETRON COMPUTER DESIGN

ISBN 981-02-0826-X

Printed in Singapore by World Publications Printers Pte. Ltd.

PREFACE

The Quantum Flux Parametron (QFP) is a circuit device consisting of a pair of Josephson junctions. The polarities of the flux in the device are used to represent binary information. The study of the Quantum Flux Parametron was initiated in 1983. It took about two years to complete the preliminary study of the device. In the preliminary study the characteristics of the device, such as the limit of the clocking speed and the junction current, noise problems and the device coupling problems which affect the operation of the device were analysed. Since QFPs couple to each other through inductance flux signals which can be inductively transferred, it is possible to have three dimensional packaging. Thus three dimensional packaging and the computation of three-dimensional inductance became new issues which needed to be studied. Three dimensional packaging and the use of the parametron to realise logic and memory design have set a new direction for computer architecture design. The cyclic pipeline computer was conceived to take advantage of this technology.

Theoretical studies and some experiments being done in Hitachi Central Research Lab have shown that QFP is a promising technology. The QFP project was supported by the Research Development Corporation of Japan (JRDC) as an Exploratory Research for Advanced Technology Project (ERATO) from October 1986 for a period of five years. Being an ERATO project, it is regarded as a technology which can go beyond the horizon of the current technology and it is expected to find practical solutions to the problems of the technology. Three research groups were formed for this purpose. They are the fundamental research group, the computer architecture group and the magnetic shielding group.

The fundamental research group studied the properties of the QFP as a logic element and a memory element. It also looked into the three dimensional integration of the QFP into the computer system. The computer architecture group studied a new architecture based on the QFP. The magnetic shielding group studied the proper shielding of magnetic interference, the technique of removing trapped flux, and the efficient helium liquefier which provides the proper environment in running the Josephson computer. In the last four years of the project, under the support of JRDC, the project has made much improvement on how to control the QFP to realise better performance in terms of speed, integration and reliability. The technological development of the project included the fabrication of logic components for high speed operation, the development of a prototype computer system for the new architecture and the exploring of feasible technology for three dimensional integration of the computer system, removal of trapped flux, shielding of magnetic interference and the building of a helium liquefier.

Much of the above work was reported in the previous four volumes of the series *Studies in Josephson Supercomputers*. The volumes are *DC Flux Parametron — A New Approach to Josephson Junction Logic* written by E. Goto and K. F. Loe, *Fluxoid Josephson Computer Technology* edited by E. Goto, T. Soma and K. F. Loe, *Quantum Flux Parametron — A Single Quantum Flux Superconducting Logic Device* written by W. Hioe and E. Goto, and *Issues in Josephson Supercomputer Design* edited by E. Goto and K. F. Loe.

By September 1991, the QFP project will conclude its work on the study of the QFP. The purpose of this volume is to capture the new developments which were not reported in the last four volumes, and some new improvements of the work reported earlier.

Computer technology is being stretched to its physical limit in this decade, and there does not seem to be much scope for new computer technology in the next decade. Further, it is even more difficult to find a new technology which has been advancing to the stage as what the QFP project has achieved so far. We hope that these five volumes of studies on the Josephson Supercomputer will serve as a precursor for the advancement of the QFP for future computer technology.

E. Goto, Y. Wada and K. F. Loe
August 1, 1991

CONTENTS

2. COMPUTER ARCHITECTURE GROUP

Cyclic Pipeline Architecture (CPC)

FLATS2

3. MAGNETIC SHEILDING GROUP

New Approaches for Reliable and High Efficiency Refrigerator