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(71) Applicant: ARC INTERNATIONAL PLC [GB/US]; ARC House - Waterfront Business Park, Elstree Road, Elstree, Herts WD6 3BS (GB).

(72) Inventor: WARNES, Peter; 12a Walpole Road, East Ham, London E6 1AR (GB).

(74) Agent: GAZDZINSKI, Robert, F.; Gazdzinski & Associates, Suite A232, 3914 Murphy Canyon Road, San Diego, CA 92123 (US).

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WO 01/69376 A3

(54) Title: METHOD AND APPARATUS FOR PROCESSOR CODE OPTIMIZATION USING CODE COMPRESSION

(57) Abstract: An improved method of optimizing the instruction set of a digital processor using code compression. In one embodiment, the method comprises obtaining an assembly language program to be used for the optimization process; calculating the static frequency of each instruction type from the base instruction set; sorting the instruction types by frequency; determining the number and type of instructions necessary for correct program execution; creating a compressed instruction set encoding; re-evaluating the compressed instruction according to the foregoing steps; and generating an instruction set encoding for the compressed instruction set. Improved compressed instruction formats and register structures useful in a processor are also disclosed. A computer program and apparatus for synthesizing logic implementing the aforementioned data cache and pipeline performance enhancements are further disclosed.

'ERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/08175

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06F9/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 00 29938 A (TENSILICA INC) 25 May 2000 (2000-05-25)	1,8,14
P,A	column 17, line 29 -column 18, line 12	2-4,6,9, 19
A		18

X	US 5 848 255 A (KONDO YOSHIKAZU) 8 December 1998 (1998-12-08)	1-4,8, 14,15
Y	abstract	5,10, 16-18, 20,25,26
A		18
	column 2, line 19 - line 42 column 5, line 66 -column 6, line 26	
A	column 10, line 15 -column 11, line 21	9,19

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 January 2002	01 03 2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Moraiti, M

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Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	KARL GUTTAG: "microP's on-chip macrocode extends instruction set" ELECTRONIC DESIGN , vol. 31, no. 5, March 1983 (1983-03), pages 157-161, XP000211560 Denville, NJ, USA the whole document	5,10,16, 17,20
Y	US 5 884 057 A (BRASHEARS CHERYL SENTER ET AL) 16 March 1999 (1999-03-16) abstract column 6, line 37 - line 54	25,26
Y	BEREKOVIC M ET AL: "A core generator for fully synthesizable and highly parameterizable RISC-cores for system-on-chip designs" IEEE WORKSHOP ON SIGNAL PROCESSING SYSTEMS. SIPS. DESIGN AND IMPLEMENTATION, XX, XX, 8 October 1998 (1998-10-08), pages 561-568, XP002137267 the whole document	18
P,A	EP 1 050 798 A (ST MICROELECTRONICS SA) 8 November 2000 (2000-11-08) paragraph '0018! - paragraph '0022!	25,26
A	US 5 819 058 A (SMITH ERIC R ET AL) 6 October 1998 (1998-10-06) abstract column 2, line 64 - line 15 column 5, line 8 - line 53	1,8,14, 19
A	EP 0 843 253 A (SGS THOMSON MICROELECTRONICS) 20 May 1998 (1998-05-20) abstract column 3, line 1 - line 13	1,8,14, 19
A	DOLLE M ET AL: "A32-B RISC/DSP MICROPROCESSOR WITH REDUCED COMPLEXITY" IEEE JOURNAL OF SOLID-STATE CIRCUITS, IEEE INC. NEW YORK, US, vol. 32, no. 7, 1 July 1997 (1997-07-01), pages 1056-1066, XP000729365 ISSN: 0018-9200 page 4, column 2, paragraph 2 - paragraph 3; figure 2	27-29
A	US 5 812 416 A (GUPTE VILAS V ET AL) 22 September 1998 (1998-09-22)	

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 01/08175

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

see additional sheet

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 01/08175

The International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-4,6-9,11-15,19
   Method and apparatus of processor optimization code compression

2. Claims: 5,10,16,17,20-24
   Extension logic unit

3. Claim: 18
   Method of synthesizing the design of an intergrated circuit digital processor

4. Claims: 25-30
   Compressed instruction set with status register

The applicant has received the invitation pursuant to Rule 40.1 PCT and has paid all additional search fees.

The International Searching Authority considers that for the invention

2. Claims: 5,10,16,17,20-24
   Extension logic unit

a further lack of unity in view of the prior art as disclosed in document 'microP's on-chip macrocode extends instruction set', 2328 Electronic Design, Vol.31(1983), has been revealed during the search for those parts of the International Application, which relate to inventions in respect of which additional fees have been paid.

Only subject matter related to the first invention (main invention) in those parts, notably claims:5,10,16,17,20; subject matter Extension logic unit,
thus identified has been the subject of a search.

The International Search Report has therefore been limited to:

1. Claims: 1-4,6-9,11-15,19
   Method and apparatus of processor optimization code compression

2. Claims: 5,10,16,17,20
   Extension logic unit

3. Claim: 18
   Method of synthesizing the design of an intergrated circuit digital processor

4. Claims: 25-30
   Compressed instruction set with status register

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT).

The applicant is advised that the EPO policy when acting as International Preliminary Examining Authority is normally not to carry out preliminary examination of non-unitary

matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the international search report or during any preliminary examination procedure.

'ERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 01/08175

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0029938 A	25-05-2000	US 6282633 B1	28-08-2001
		AU 1346500 A	05-06-2000
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US 5812416 A	22-09-1998	NONE	