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i n t e r o f f i c e

m e m o r a n d u m

To: FPA interest list

Date: 20 Apr 83
From: Mike Uhler
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Loc/Mail stop: MR01-2/E85
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Subject: Thoughts on the FPA functional interface

1.0 Introduction

The following is my attempt at reconstructing the significant pieces of a conversation that Rich and I had about functional interfaces to the FPA. It's intended to provoke some additional thought and not intended to be the final (or even preliminary) design for the interfaces.

2.0 Prefetch of operands

In all the conversations I've had about the FPA, we've always assumed that the IBOX does no significant (i.e., multi-instruction) fetch-ahead for the FPA. The implication of this assumption is that the FPA makes a standing start on the instruction with the only overlap being with the execution of the previous instruction in the EBOX. The assumption here is that the previous instruction in sequence is indeed processed by the EBOX and is not an FPA instruction.

Whether this scheme is viable is somewhat a function of the raw compute speed of the FPA. If the performance goals can be met with an FPA standing start, then it may be a moot point. If not, we'll have to consider some prefetch schemes.

An additional factor that may impact the ability to fetch ahead is the chance that a conflict will occur on one of the operands of the instruction. The farther the IBOX is fetching ahead, the more likely that a conflict will occur. This needs more study.

3.0 Unbiased rounding

Several months ago, the Architecture Committee decided that we should use unbiased rounding in any instruction to which it is applicable. Although the current EBOX microcode implements both the old biased rounding scheme and the unbiased rounding scheme (via conditional assembly), the FPA should implement only unbiased rounding, where applicable.

4.0 Implications of XCT

An XCT of an instruction that is processed by the FPA has some interesting implications. Somehow, the FPA has to be told that an instruction other than the XCT exists so that it can process it. The same problem exists with an XCT of an instruction that is processed by the EBOX.

With the exception of PXCT, which we haven't really thought about yet, there appears to be no reason that XCT ever has to be seen by the EBOX or the FPA. One possible way around the problem is to have the IBOX totally process the XCT and load the ultimate instruction into the instruction register. This scheme has the advantage that there is no longer any special-case code in the FPA or the EBOX to handle the case.

One problem is how to let the FPA know that an instruction exists. In the past, we've used schemes that monitor the MBOX data bus and kick things off based on returned data that is marked as an instruction. If the IBOX processes the XCT on its own, there must be another mechanism to convince the FPA (and the EBOX) that an instruction is ready to be processed. This needs more thought.

5.0 Architectural use of G floating

If one looks at the percentage of use of the G floating instructions on any KL10 today, one might conclude that the G floating instructions aren't very important. On most machines, the number of G floating instructions that are executed closely approximates the empty set.

Taking that data at face value would be a mistake. The reason that G floating instructions were added to the architecture (and the KL10 instruction set) was because we (Digital) were at a competitive disadvantage with other companies with respect to the range of our floating point exponents. It's only been in the last six months or so that a version of FORTRAN has had G floating support.

If one looks at the relative merits of D floating (the old kind) and G floating, there appears to be no reason why anyone wouldn't use G floating in the future. The range of the floating exponents has gone up by an order of magnitude, with the loss of only 3 bits of the mantisa. Using the corresponding D floating counts for the G floating instructions is probably a good indication of the future use of G floating.

6.0 Implications of the EXTEND G float conversion instructions

If one begins to use G floating, one will also use some of the G floating conversion instruction. Unfortunately, the G floating conversions are buried under EXTEND, which makes them a bit harder to process.

On the other hand, EXTEND can, in many cases, be treated very much like XCT when it comes to the G floating conversion instructions. If the IBOX were to process EXTEND and load the EXTENDed opcode into the instruction register, much as if it were an XCT, it could use the same protocols as for XCT.

The nice thing about the EXTEND conversion instructions is that the EXTENDed opcode overlays the LUUOs and MUUOs at the bottom of the instruction set. Therefore, as long as the FPA doesn't process LUUOs or MUUOs (and the conversion instructions under EXTEND are mutually exclusive the the FPA-processed instruction set), one can use the first 64 (or so) opcodes of the normal instruction set to handle the EXTEND conversion opcodes.

7.0 EBOX synchronization with the FPA

There seem to be two options for synchronizing the FPA with the EBOX to store results. In the first scheme, the EBOX starts to process the instruction as it would any other instruction. It then sits in a test loop waiting for the FPA to finish so that it can store results. The disadvantage is that it wastes microcode to implement the test loops. Also, the synchronization may not be as efficient as it might be if the FPA finishes just after the EBOX did the test.

The second scheme leaves the EBOX clocks stopped until just before the FPA finishes, at which point the EBOX starts. This seems to be preferable because it makes the synchronization interface much sharper. The disadvantage is that the valid logic to start the EBOX at the right time is more complex.

8.0 Calling the FPA as a subroutine

There are three instructions (ADJBP and EXTENDed CVTDBx and CVTBDx) which do integer multiply or divides as part of the instruction processing. Because these operations are very slow in the EBOX, there is an advantage in letting the EBOX call the FPA as a subroutine.

The EXTENDed CVTxxx instructions require a 72-bit integer multiply or divide. The ADJBP instruction requires a 6-bit divide and at least one 36-bit operation. The setup overhead may make it faster to continue to do the 6-bit divide in the EBOX, but the 36-bit and 72-bit operations are likely to be much faster in the FPA.

The real question is one of impact on the overall system performance. At present, we don't know if adding the logic to the FPA to do this is worth the performance gain that we could get. In fact, we don't even know what the performance gain really is. This needs more investigation.

9.0 Storing results and flags

Of all the functional interfaces, this seems to be the best understood. Previous schemes had the FPA put results on ABUS every other cycle for the EBOX to store. The exact timing of the first result is related to the synchronization between FPA and EBOX.

The flags-change interface seems to be fairly clean also. There are a finite number of flags that can change state as the result of an operation carried out in the FPA. The flags interface between the FPA and the EBOX should probably consist of a set of flags control lines that feed directly into the flags logic on SCA. The EBOX microcode would then enable a "Load FPA flags" decode to cause the FPA flags control lines to affect the PC flags.

APPENDIX A

FPA DATA FROM OPHIST

The following pages contain the post-processed OPHIST data from both internal and external sites. The data is sorted by KL runtime for each FPA-processed instruction. The "KL time" column gives the "typical" time in microseconds for the execution of that instruction. The "KL run time" column gives the total time in microseconds that the KL10 spent executing the instruction. The "Percent" column gives the percentage of total time that the KL10 spent processing the instruction.

[Summary data from all sites]

Opcode	Name	KL time	KL run time	Percent
231	IDIVI	4.884	25449845.3	1.15
234	DIV	4.716	12276111.1	0.55
221	IMULI	2.043	9979307.4	0.45
112	DFMP	4.548	7851685.4	0.35
164	FMPR	2.809	7817017.2	0.35
230	IDIV	5.014	7326908.1	0.33
220	IMUL	2.172	4632411.2	0.21
144	FADR	1.608	4518898.1	0.20
113	DFDV	8.633	4482745.7	0.20
174	FDVR	4.582	4394202.2	0.20
110	DFAD	2.208	3751910.9	0.17
111	DFSB	2.275	2671471.1	0.12
132	FSC	1.739	1253584.2	0.06
140	FAD	1.569	1136147.4	0.05
154	FSBR	1.775	1054089.1	0.05
145	FADRI	1.540	668187.5	0.03
146	FADRM	1.771	649269.9	0.03
127	FLTR	1.938	568758.4	0.03
170	FDV	4.543	538236.5	0.02
175	FDVRI	4.515	426739.7	0.02
224	MUL	2.140	411941.4	0.02
235	DIVI	4.586	379335.6	0.02
122	FIX	0.904	306184.8	0.01
117	DDIV	9.590	292341.6	0.01
160	FMP	2.776	260399.9	0.01
225	MULI	2.010	174701.2	0.01
150	FSB	1.743	152718.2	0.01
114	DADD	1.075	138271.9	0.01
172	FDVM	4.715	127804.8	0.01
165	FMPRI	2.375	107739.5	0.00
222	IMULM	2.342	97785.5	0.00
126	FIXR	0.904	77402.3	0.00
147	FADRB	1.769	55942.9	0.00
166	FMPRM	2.976	49348.0	0.00
232	IDIVM	5.083	46046.9	0.00
223	IMULB	2.341	35906.3	0.00
142	FADM	1.740	28445.5	0.00
156	FSBRM	1.944	21197.4	0.00
167	FMPRB	2.976	16034.7	0.00
116	DMUL	4.511	6956.0	0.00
143	FADB	1.739	5470.9	0.00
226	MULM	2.208	3139.8	0.00
176	FDVRM	4.743	1641.1	0.00
157	FSBRB	1.944	338.3	0.00
115	DSUB	1.075	40.8	0.00
177	FDVRB	4.743	37.9	0.00
102	GFAD	6.420	19.3	0.00
155	FSBRI	1.840	12.9	0.00

[Data from KL2102]

Opcode	Name	KL time	KL run time	Percent
234	DIV	4.716	3550657.6	2.27
231	IDIVI	4.884	3020265.6	1.93
221	IMULI	2.043	964459.4	0.62
230	IDIV	5.014	478676.6	0.31
220	IMUL	2.172	395721.0	0.25
140	FAD	1.569	100711.0	0.06
174	FDVR	4.582	66892.6	0.04
164	FMPR	2.809	50048.0	0.03
235	DIVI	4.586	28066.3	0.02
224	MUL	2.140	21817.3	0.01
154	FSBR	1.775	21053.3	0.01
144	FADR	1.608	12560.1	0.01
175	FDVRI	4.515	9856.2	0.01
225	MULI	2.010	9535.4	0.01
127	FLTR	1.938	4182.2	0.00
122	FIX	0.904	3399.0	0.00
117	DDIV	9.590	1448.1	0.00
112	DFMP	4.548	1264.3	0.00
146	FADRM	1.771	580.9	0.00
232	IDIVM	5.083	579.5	0.00
113	DFDV	8.633	543.9	0.00
126	FIXR	0.904	524.3	0.00
110	DFAD	2.208	417.3	0.00
222	IMULM	2.342	414.5	0.00
160	FMP	2.776	211.0	0.00
116	DMUL	4.511	112.8	0.00
132	FSC	1.739	86.9	0.00
165	FMPRI	2.375	59.4	0.00
170	FDV	4.543	59.1	0.00
114	DADD	1.075	53.8	0.00
115	DSUB	1.075	40.8	0.00
223	IMULB	2.341	30.4	0.00

[Data from KL2116]

Opcode	Name	KL time	KL run time	Percent
231	IDIVI	4.884	2709604.1	1.78
221	IMULI	2.043	1249719.5	0.82
230	IDIV	5.014	1063860.5	0.70
112	DFMP	4.548	1048978.0	0.69
234	DIV	4.716	904396.8	0.59
113	DFDV	8.633	723540.4	0.48
220	IMUL	2.172	570315.1	0.37
117	DDIV	9.590	275098.7	0.18
140	FAD	1.569	133112.4	0.09
224	MUL	2.140	116837.6	0.08
110	DFAD	2.208	106547.0	0.07
174	FDVR	4.582	101101.8	0.07
235	DIVI	4.586	97824.0	0.06
114	DADD	1.075	70701.7	0.05
164	FMPR	2.809	69278.4	0.05
225	MULI	2.010	62408.5	0.04
144	FADR	1.608	54176.7	0.04
154	FSBR	1.775	45235.9	0.03
150	FSB	1.743	18346.8	0.01
175	FDVRI	4.515	11928.6	0.01
127	FLTR	1.938	5263.6	0.00
160	FMP	2.776	2648.3	0.00
116	DMUL	4.511	793.9	0.00
165	FMPRI	2.375	662.6	0.00
232	IDIVM	5.083	447.3	0.00
126	FIXR	0.904	411.3	0.00
146	FADRM	1.771	285.1	0.00
170	FDV	4.543	199.9	0.00
145	FADRI	1.540	112.4	0.00
132	FSC	1.739	76.5	0.00
111	DFSB	2.275	66.0	0.00
122	FIX	0.904	53.3	0.00
222	IMULM	2.342	35.1	0.00

[Data from 3M, machine A]

Opcode	Name	KL time	KL run time	Percent
231	IDIVI	4.884	994660.8	0.62
234	DIV	4.716	421242.6	0.26
221	IMULI	2.043	409905.5	0.26
230	IDIV	5.014	253437.6	0.16
164	FMPR	2.809	183107.5	0.11
220	IMUL	2.172	119436.1	0.07
174	FDVR	4.582	72010.7	0.05
144	FADR	1.608	66606.6	0.04
146	FADRM	1.771	27691.4	0.02
127	FLTR	1.938	26622.3	0.02
175	FDVRI	4.515	21008.3	0.01
154	FSBR	1.775	19500.2	0.01
140	FAD	1.569	14342.2	0.01
147	FADRB	1.769	13529.3	0.01
122	FIX	0.904	12197.7	0.01
145	FADRI	1.540	9292.4	0.01
160	FMP	2.776	8805.5	0.01
170	FDV	4.543	6964.4	0.00
224	MUL	2.140	6362.2	0.00
235	DIVI	4.586	6026.0	0.00
132	FSC	1.739	5383.9	0.00
166	FMPRM	2.976	4562.2	0.00
225	MULI	2.010	4498.4	0.00
165	FMPRI	2.375	2992.5	0.00
222	IMULM	2.342	1690.9	0.00
232	IDIVM	5.083	1326.7	0.00
150	FSB	1.743	1214.9	0.00
172	FDVM	4.715	707.2	0.00
112	DFMP	4.548	664.0	0.00
126	FIXR	0.904	616.5	0.00
110	DFAD	2.208	587.3	0.00
113	DFDV	8.633	250.4	0.00
167	FMPRB	2.976	98.2	0.00
117	DDIV	9.590	95.9	0.00
223	IMULB	2.341	65.5	0.00
116	DMUL	4.511	40.6	0.00
143	FADB	1.739	24.3	0.00
176	FDVRM	4.743	23.7	0.00
111	DFSB	2.275	4.6	0.00
156	FSBRM	1.944	3.9	0.00
114	DADD	1.075	2.2	0.00

[Data from 3M, machine B]

Opcode	Name	KL time	KL run time	Percent
231	IDIVI	4.884	941049.1	0.59
164	FMPR	2.809	505499.2	0.32
234	DIV	4.716	488355.9	0.31
230	IDIV	5.014	409312.9	0.26
221	IMULI	2.043	400517.9	0.25
140	FAD	1.569	172994.8	0.11
144	FADR	1.608	162218.3	0.10
220	IMUL	2.172	157923.9	0.10
160	FMP	2.776	147447.2	0.09
174	FDVR	4.582	112749.3	0.07
175	FDVRI	4.515	67431.5	0.04
146	FADRM	1.771	53091.0	0.03
127	FLTR	1.938	34955.7	0.02
154	FSBR	1.775	31745.9	0.02
170	FDV	4.543	31342.2	0.02
145	FADRI	1.540	16975.4	0.01
122	FIX	0.904	14533.6	0.01
225	MULI	2.010	12411.8	0.01
110	DFAD	2.208	10684.5	0.01
147	FADRB	1.769	10274.4	0.01
166	FMPRM	2.976	9663.1	0.01
132	FSC	1.739	9286.3	0.01
224	MUL	2.140	7793.9	0.00
165	FMPRI	2.375	6438.6	0.00
150	FSB	1.743	5872.2	0.00
235	DIVI	4.586	5232.6	0.00
112	DFMP	4.548	4552.5	0.00
222	IMULM	2.342	2730.8	0.00
172	FDVM	4.715	1886.0	0.00
113	DFDV	8.633	1864.7	0.00
232	IDIVM	5.083	1530.0	0.00
156	FSBRM	1.944	841.8	0.00
223	IMULB	2.341	791.3	0.00
111	DFSB	2.275	509.6	0.00
167	FMPRB	2.976	380.9	0.00
126	FIXR	0.904	352.6	0.00
143	FADB	1.739	111.3	0.00
116	DMUL	4.511	49.6	0.00
176	FDVRM	4.743	23.7	0.00
177	FDVRB	4.743	4.7	0.00
114	DADD	1.075	3.2	0.00

[Data from 3M, machine C]

Opcode	Name	KL time	KL run time	Percent
231	IDIVI	4.884	1731622.2	1.10
221	IMULI	2.043	722392.5	0.46
230	IDIV	5.014	704176.2	0.45
234	DIV	4.716	566240.7	0.36
220	IMUL	2.172	472883.5	0.30
164	FMPR	2.809	412293.8	0.26
144	FADR	1.608	188473.7	0.12
174	FDVR	4.582	102774.3	0.07
146	FADRM	1.771	64653.9	0.04
175	FDVRI	4.515	55764.8	0.04
154	FSBR	1.775	42316.0	0.03
140	FAD	1.569	39101.0	0.02
127	FLTR	1.938	34841.4	0.02
132	FSC	1.739	27996.2	0.02
170	FDV	4.543	24677.6	0.02
122	FIX	0.904	23810.5	0.02
145	FADRI	1.540	16223.9	0.01
222	IMULM	2.342	15412.7	0.01
224	MUL	2.140	12917.0	0.01
166	FMPRM	2.976	12359.3	0.01
225	MULI	2.010	10192.7	0.01
235	DIVI	4.586	10006.7	0.01
147	FADRB	1.769	9954.2	0.01
165	FMPRI	2.375	7866.0	0.00
160	FMP	2.776	7470.2	0.00
172	FDVM	4.715	3281.6	0.00
232	IDIVM	5.083	3192.1	0.00
110	DFAD	2.208	1821.6	0.00
167	FMPRB	2.976	1818.3	0.00
112	DFMP	4.548	1096.1	0.00
150	FSB	1.743	765.2	0.00
126	FIXR	0.904	482.7	0.00
113	DFDV	8.633	414.4	0.00
223	IMULB	2.341	180.3	0.00
116	DMUL	4.511	112.8	0.00
176	FDVRM	4.743	47.4	0.00
111	DFSB	2.275	27.3	0.00
156	FSBRM	1.944	19.4	0.00
117	DDIV	9.590	9.6	0.00
142	FADM	1.740	1.7	0.00

[Data from 3M, machine D]

Opcode	Name	KL time	KL run time	Percent
221	IMULI	2.043	1170827.0	0.73
231	IDIVI	4.884	1167823.0	0.73
234	DIV	4.716	457730.2	0.29
230	IDIV	5.014	374676.2	0.23
164	FMPR	2.809	198245.2	0.12
220	IMUL	2.172	164933.0	0.10
144	FADR	1.608	69060.4	0.04
146	FADRM	1.771	65734.2	0.04
174	FDVR	4.582	54136.3	0.03
175	FDVRI	4.515	28900.5	0.02
110	DFAD	2.208	24557.4	0.02
127	FLTR	1.938	22399.4	0.01
122	FIX	0.904	18360.2	0.01
222	IMULM	2.342	17522.8	0.01
154	FSBR	1.775	16951.3	0.01
145	FADRI	1.540	12806.6	0.01
224	MUL	2.140	9084.3	0.01
140	FAD	1.569	7939.1	0.00
112	DFMP	4.548	7326.8	0.00
235	DIVI	4.586	7241.3	0.00
160	FMP	2.776	5441.0	0.00
166	FMPRM	2.976	5377.6	0.00
147	FADRB	1.769	5292.8	0.00
132	FSC	1.739	3676.2	0.00
165	FMPRI	2.375	3662.3	0.00
170	FDV	4.543	3052.9	0.00
225	MULI	2.010	2506.5	0.00
232	IDIVM	5.083	1768.9	0.00
150	FSB	1.743	864.5	0.00
223	IMULB	2.341	692.9	0.00
156	FSBRM	1.944	600.7	0.00
172	FDVM	4.715	556.4	0.00
113	DFDV	8.633	500.7	0.00
126	FIXR	0.904	141.9	0.00
167	FMPRB	2.976	116.1	0.00
142	FADM	1.740	48.7	0.00
111	DFSB	2.275	47.8	0.00
116	DMUL	4.511	27.1	0.00
176	FDVRM	4.743	23.7	0.00
117	DDIV	9.590	19.2	0.00
143	FADB	1.739	7.0	0.00
114	DADD	1.075	2.2	0.00
155	FSBRI	1.840	1.8	0.00

[Data from 3M, machine E]

Opcode	Name	KL time	KL run time	Percent
231	IDIVI	4.884	972336.0	0.61
221	IMULI	2.043	478168.2	0.30
230	IDIV	5.014	427568.9	0.27
234	DIV	4.716	417748.0	0.26
164	FMPR	2.809	344897.4	0.22
220	IMUL	2.172	178093.1	0.11
144	FADR	1.608	117387.2	0.07
174	FDVR	4.582	74512.5	0.05
175	FDVRI	4.515	68451.9	0.04
146	FADRM	1.771	38809.7	0.02
127	FLTR	1.938	28924.6	0.02
154	FSBR	1.775	26255.8	0.02
145	FADRI	1.540	14394.4	0.01
132	FSC	1.739	13652.9	0.01
122	FIX	0.904	11439.2	0.01
110	DFAD	2.208	9286.8	0.01
140	FAD	1.569	8359.6	0.01
224	MUL	2.140	8061.4	0.01
225	MULI	2.010	7977.7	0.01
147	FADRB	1.769	7937.5	0.00
113	DFDV	8.633	7657.5	0.00
166	FMPRM	2.976	6818.0	0.00
160	FMP	2.776	6556.9	0.00
222	IMULM	2.342	6365.6	0.00
235	DIVI	4.586	5026.3	0.00
112	DFMP	4.548	4793.6	0.00
165	FMPRI	2.375	3921.1	0.00
170	FDV	4.543	3334.6	0.00
232	IDIVM	5.083	2048.4	0.00
150	FSB	1.743	1458.9	0.00
172	FDVM	4.715	881.7	0.00
167	FMPRB	2.976	735.1	0.00
223	IMULB	2.341	283.3	0.00
126	FIXR	0.904	116.6	0.00
156	FSBRM	1.944	95.3	0.00
111	DFSB	2.275	68.3	0.00
176	FDVRM	4.743	42.7	0.00
116	DMUL	4.511	27.1	0.00
143	FADB	1.739	22.6	0.00
157	FSBRB	1.944	9.7	0.00
114	DADD	1.075	5.4	0.00
177	FDVRB	4.743	4.7	0.00

[Data from 3M, machine F]

Opcode	Name	KL time	KL run time	Percent
231	IDIVI	4.884	1571617.5	0.99
234	DIV	4.716	1077558.8	0.68
221	IMULI	2.043	1008998.9	0.64
230	IDIV	5.014	909765.2	0.58
220	IMUL	2.172	254152.2	0.16
164	FMPR	2.809	57340.1	0.04
222	IMULM	2.342	26495.0	0.02
174	FDVR	4.582	25553.8	0.02
144	FADR	1.608	23592.6	0.01
224	MUL	2.140	11521.8	0.01
175	FDVRI	4.515	10352.9	0.01
235	DIVI	4.586	9305.0	0.01
117	DDIV	9.590	9263.9	0.01
146	FADRM	1.771	9127.7	0.01
154	FSBR	1.775	9033.0	0.01
225	MULI	2.010	5839.0	0.00
127	FLTR	1.938	5800.4	0.00
122	FIX	0.904	5424.9	0.00
232	IDIVM	5.083	4391.7	0.00
132	FSC	1.739	3241.5	0.00
116	DMUL	4.511	2629.9	0.00
160	FMP	2.776	2262.4	0.00
140	FAD	1.569	2223.3	0.00
145	FADRI	1.540	1787.9	0.00
110	DFAD	2.208	1360.1	0.00
166	FMPRM	2.976	1220.2	0.00
147	FADRB	1.769	1178.2	0.00
112	DFMP	4.548	1105.2	0.00
170	FDV	4.543	731.4	0.00
165	FMPRI	2.375	695.9	0.00
150	FSB	1.743	582.2	0.00
172	FDVM	4.715	325.3	0.00
114	DADD	1.075	310.7	0.00
113	DFDV	8.633	302.2	0.00
126	FIXR	0.904	214.2	0.00
111	DFSB	2.275	66.0	0.00
167	FMPRB	2.976	20.8	0.00
157	FSBRB	1.944	19.4	0.00
177	FDVRB	4.743	9.5	0.00
143	FADB	1.739	5.2	0.00
176	FDVRM	4.743	4.7	0.00
223	IMULB	2.341	2.3	0.00

[Data from 3M, machine G]

Opcode	Name	KL time	KL run time	Percent
231	IDIVI	4.884	824458.3	0.52
221	IMULI	2.043	477496.1	0.30
230	IDIV	5.014	409663.9	0.26
234	DIV	4.716	348040.8	0.22
220	IMUL	2.172	178342.9	0.11
164	FMPR	2.809	170815.3	0.11
144	FADR	1.608	70920.8	0.04
110	DFAD	2.208	66094.3	0.04
174	FDVR	4.582	58800.8	0.04
175	FDVRI	4.515	29677.1	0.02
112	DFMP	4.548	27688.2	0.02
146	FADRM	1.771	25583.9	0.02
113	DFDV	8.633	20244.4	0.01
140	FAD	1.569	15746.5	0.01
127	FLTR	1.938	15538.9	0.01
222	IMULM	2.342	13970.0	0.01
154	FSBR	1.775	13277.0	0.01
145	FADRI	1.540	12517.1	0.01
132	FSC	1.739	12343.4	0.01
160	FMP	2.776	11750.8	0.01
224	MUL	2.140	9525.1	0.01
122	FIX	0.904	9323.0	0.01
225	MULI	2.010	6717.4	0.00
235	DIVI	4.586	5847.2	0.00
170	FDV	4.543	5624.2	0.00
166	FMPRM	2.976	5568.1	0.00
147	FADRB	1.769	5533.4	0.00
150	FSB	1.743	5415.5	0.00
165	FMPRI	2.375	4859.3	0.00
172	FDVM	4.715	4224.6	0.00
232	IDIVM	5.083	2231.4	0.00
143	FADB	1.739	344.3	0.00
111	DFSB	2.275	270.7	0.00
167	FMPRB	2.976	181.5	0.00
223	IMULB	2.341	98.3	0.00
126	FIXR	0.904	82.3	0.00
176	FDVRM	4.743	52.2	0.00
157	FSBRB	1.944	21.4	0.00
177	FDVRB	4.743	14.2	0.00
116	DMUL	4.511	13.5	0.00
156	FSBRM	1.944	7.8	0.00
114	DADD	1.075	1.1	0.00

[Data from Columbia]

Opcode	Name	KL time	KL run time	Percent
231	IDIVI	4.884	3003503.7	1.90
234	DIV	4.716	981173.2	0.62
221	IMULI	2.043	796980.4	0.51
230	IDIV	5.014	633584.1	0.40
220	IMUL	2.172	563015.0	0.36
112	DFMP	4.548	263483.8	0.17
110	DFAD	2.208	212776.1	0.13
174	FDVR	4.582	157098.5	0.10
144	FADR	1.608	105086.0	0.07
164	FMPR	2.809	104365.6	0.07
224	MUL	2.140	78719.9	0.05
127	FLTR	1.938	59868.7	0.04
113	DFDV	8.633	56140.4	0.04
154	FSBR	1.775	35634.9	0.02
223	IMULB	2.341	32909.8	0.02
142	FADM	1.740	28375.9	0.02
235	DIVI	4.586	24425.0	0.02
175	FDVRI	4.515	17382.8	0.01
122	FIX	0.904	16444.7	0.01
140	FAD	1.569	15664.9	0.01
111	DFSB	2.275	13656.8	0.01
170	FDV	4.543	13251.9	0.01
225	MULI	2.010	11728.3	0.01
145	FADRI	1.540	8443.8	0.01
132	FSC	1.739	8079.4	0.01
146	FADRM	1.771	3942.2	0.00
232	IDIVM	5.083	2424.6	0.00
114	DADD	1.075	2230.6	0.00
222	IMULM	2.342	1135.9	0.00
126	FIXR	0.904	769.3	0.00
160	FMP	2.776	741.2	0.00
165	FMPRI	2.375	503.5	0.00
150	FSB	1.743	329.4	0.00
167	FMPRB	2.976	190.5	0.00
116	DMUL	4.511	185.0	0.00
166	FMPRM	2.976	136.9	0.00
147	FADRB	1.769	81.4	0.00
172	FDVM	4.715	42.4	0.00
176	FDVRM	4.743	28.5	0.00
155	FSBRI	1.840	5.5	0.00
143	FADB	1.739	5.2	0.00

[Data from Rome]

Opcode	Name	KL time	KL run time	Percent
112	DFMP	4.548	2922412.9	1.83
164	FMPR	2.809	2517041.0	1.58
231	IDIVI	4.884	2024789.2	1.27
144	FADR	1.608	1766116.3	1.11
113	DFDV	8.633	1760795.3	1.11
174	FDVR	4.582	1641043.3	1.03
110	DFAD	2.208	1489362.3	0.93
111	DFSB	2.275	1206430.2	0.76
234	DIV	4.716	776343.2	0.49
132	FSC	1.739	644407.3	0.40
221	IMULI	2.043	452847.3	0.28
154	FSBR	1.775	310781.2	0.20
230	IDIV	5.014	254124.6	0.16
140	FAD	1.569	235950.9	0.15
145	FADRI	1.540	215389.0	0.14
170	FDV	4.543	198883.5	0.12
220	IMUL	2.172	188479.6	0.12
127	FLTR	1.938	119078.5	0.07
122	FIX	0.904	92607.6	0.06
146	FADRM	1.771	57189.1	0.04
175	FDVRI	4.515	41321.3	0.03
165	FMPRI	2.375	40524.6	0.03
172	FDVM	4.715	29162.3	0.02
150	FSB	1.743	26324.5	0.02
235	DIVI	4.586	23934.3	0.02
126	FIXR	0.904	18945.1	0.01
224	MUL	2.140	15666.9	0.01
114	DADD	1.075	9226.7	0.01
160	FMP	2.776	9085.8	0.01
225	MULI	2.010	6828.0	0.00
222	IMULM	2.342	3384.2	0.00
156	FSBRM	1.944	1168.3	0.00
232	IDIVM	5.083	1057.3	0.00
226	MULM	2.208	733.1	0.00
147	FADRB	1.769	406.9	0.00
116	DMUL	4.511	311.3	0.00
223	IMULB	2.341	227.1	0.00
157	FSBRB	1.944	188.6	0.00
166	FMPRM	2.976	77.4	0.00
167	FMPRB	2.976	11.9	0.00
176	FDVRM	4.743	9.5	0.00

[Data from Rutgers]

Opcode	Name	KL time	KL run time	Percent
231	IDIVI	4.884	2565999.9	1.62
234	DIV	4.716	1001343.6	0.63
221	IMULI	2.043	680821.6	0.43
230	IDIV	5.014	575797.7	0.36
220	IMUL	2.172	435486.0	0.28
174	FDVR	4.582	133336.2	0.08
164	FMPR	2.809	95427.3	0.06
110	DFAD	2.208	59624.8	0.04
112	DFMP	4.548	53248.0	0.03
224	MUL	2.140	51182.4	0.03
145	FADRI	1.540	49009.0	0.03
127	FLTR	1.938	40701.9	0.03
144	FADR	1.608	38397.4	0.02
154	FSBR	1.775	32390.2	0.02
140	FAD	1.569	31753.4	0.02
132	FSC	1.739	28491.8	0.02
122	FIX	0.904	25839.9	0.02
235	DIVI	4.586	23994.0	0.02
175	FDVRI	4.515	17743.9	0.01
113	DFDV	8.633	9599.9	0.01
225	MULI	2.010	9284.2	0.01
111	DFSB	2.275	5528.3	0.00
117	DDIV	9.590	5111.5	0.00
116	DMUL	4.511	2124.7	0.00
232	IDIVM	5.083	1814.6	0.00
126	FIXR	0.904	1735.7	0.00
146	FADRM	1.771	1195.4	0.00
170	FDV	4.543	472.5	0.00
223	IMULB	2.341	201.3	0.00
165	FMPRI	2.375	175.8	0.00
222	IMULM	2.342	131.2	0.00
167	FMPRB	2.976	130.9	0.00
160	FMP	2.776	130.5	0.00
172	FDVM	4.715	127.3	0.00
150	FSB	1.743	116.8	0.00
114	DADD	1.075	100.0	0.00
166	FMPRM	2.976	38.7	0.00
176	FDVRM	4.743	37.9	0.00
102	GFAD	6.420	6.4	0.00
226	MULM	2.208	2.2	0.00
155	FSBRI	1.840	1.8	0.00
147	FADRB	1.769	1.8	0.00

[Data from Stanford]

Opcode	Name	KL time	KL run time	Percent
112	DFMP	4.548	3462324.2	2.19
164	FMPR	2.809	2636232.4	1.66
231	IDIVI	4.884	2481702.0	1.57
113	DFDV	8.633	1877116.4	1.19
110	DFAD	2.208	1727159.4	1.09
144	FADR	1.608	1604488.1	1.01
174	FDVR	4.582	1425006.6	0.90
111	DFSB	2.275	1373126.3	0.87
234	DIV	4.716	854694.8	0.54
221	IMULI	2.043	697537.4	0.44
230	IDIV	5.014	504177.8	0.32
132	FSC	1.739	476444.3	0.30
220	IMUL	2.172	437006.4	0.28
154	FSBR	1.775	347048.0	0.22
140	FAD	1.569	343661.2	0.22
146	FADRM	1.771	248566.9	0.16
170	FDV	4.543	234732.3	0.15
145	FADRI	1.540	230753.6	0.15
127	FLTR	1.938	139224.0	0.09
150	FSB	1.743	91155.4	0.06
172	FDVM	4.715	86345.8	0.05
122	FIX	0.904	72540.6	0.05
235	DIVI	4.586	64969.9	0.04
160	FMP	2.776	57243.9	0.04
224	MUL	2.140	50745.8	0.03
114	DADD	1.075	37211.1	0.02
165	FMPRI	2.375	32639.6	0.02
126	FIXR	0.904	26310.0	0.02
225	MULI	2.010	21334.1	0.01
175	FDVRI	4.515	17649.1	0.01
222	IMULM	2.342	6878.5	0.00
143	FADB	1.739	4928.3	0.00
232	IDIVM	5.083	3451.4	0.00
156	FSBRM	1.944	2881.0	0.00
226	MULM	2.208	2404.5	0.00
166	FMPRM	2.976	2151.6	0.00
147	FADRB	1.769	1669.9	0.00
176	FDVRM	4.743	573.9	0.00
223	IMULB	2.341	414.4	0.00
116	DMUL	4.511	297.7	0.00
167	FMPRB	2.976	291.6	0.00
157	FSBRB	1.944	91.4	0.00
142	FADM	1.740	12.2	0.00
177	FDVRB	4.743	4.7	0.00

[Data from Utah]

Opcode	Name	KL time	KL run time	Percent
231	IDIVI	4.884	1440413.7	0.90
220	IMUL	2.172	516623.2	0.32
164	FMPR	2.809	472426.0	0.30
221	IMULI	2.043	468635.6	0.29
234	DIV	4.716	430584.9	0.27
174	FDVR	4.582	369185.5	0.23
230	IDIV	5.014	328086.1	0.21
144	FADR	1.608	239813.9	0.15
154	FSBR	1.775	102866.6	0.06
145	FADRI	1.540	80481.9	0.05
111	DFSB	2.275	71669.3	0.05
235	DIVI	4.586	67437.1	0.04
146	FADRM	1.771	52818.3	0.03
112	DFMP	4.548	52747.7	0.03
110	DFAD	2.208	41631.8	0.03
127	FLTR	1.938	31356.8	0.02
175	FDVRI	4.515	29270.7	0.02
126	FIXR	0.904	26699.6	0.02
113	DFDV	8.633	23775.3	0.01
132	FSC	1.739	20417.6	0.01
232	IDIVM	5.083	19783.0	0.01
114	DADD	1.075	18423.4	0.01
156	FSBRM	1.944	15579.2	0.01
170	FDV	4.543	14910.1	0.01
140	FAD	1.569	14587.0	0.01
167	FMPRB	2.976	12058.8	0.01
224	MUL	2.140	11705.8	0.01
225	MULI	2.010	3439.1	0.00
165	FMPRI	2.375	2738.4	0.00
222	IMULM	2.342	1618.3	0.00
166	FMPRM	2.976	1374.9	0.00
117	DDIV	9.590	1294.7	0.00
176	FDVRM	4.743	773.1	0.00
160	FMP	2.776	605.2	0.00
150	FSB	1.743	271.9	0.00
172	FDVM	4.715	264.0	0.00
116	DMUL	4.511	230.1	0.00
122	FIX	0.904	210.6	0.00
147	FADRB	1.769	83.1	0.00
143	FADB	1.739	22.6	0.00
102	GFAD	6.420	12.8	0.00
223	IMULB	2.341	9.4	0.00
157	FSBRB	1.944	7.8	0.00
142	FADM	1.740	7.0	0.00
155	FSBRI	1.840	3.7	0.00