Overlapping Pipeline Stages with a Cache Miss

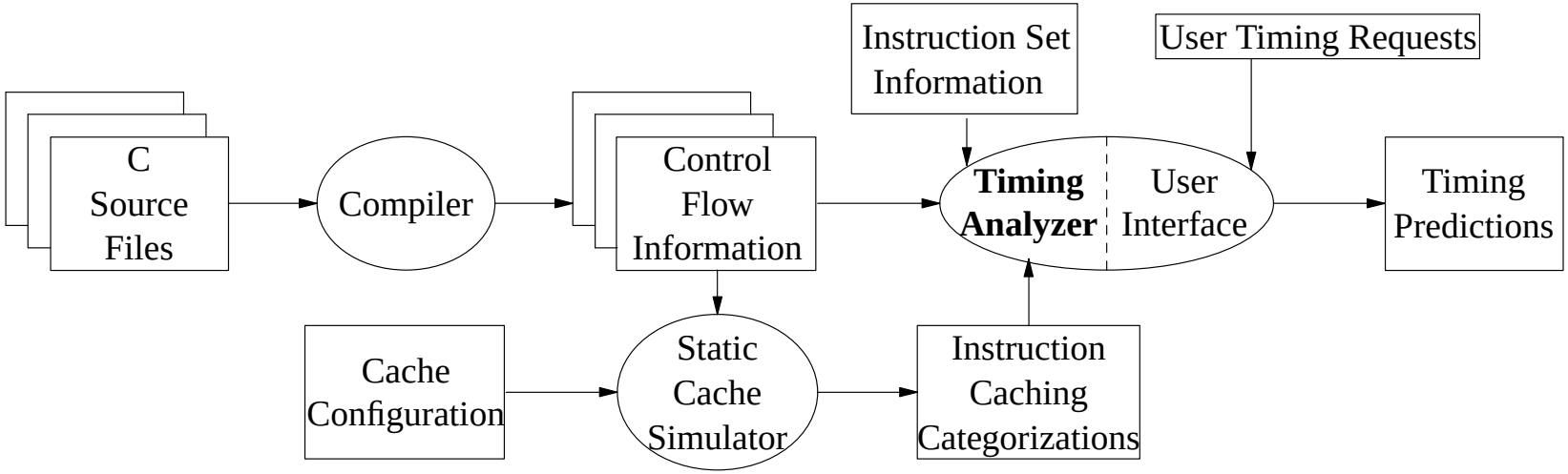
SPARC Instructions

```
inst 1: faddd  %f2,%f0,%f2
inst 2: sub    %o4,%g1,%i2
inst 3: std    %f2,[%o0+8]
```

Pipeline Diagram

		cycle																	
		1	2	3	4	5	...	11	12	13	14	15	16	17	18	19	20	21	22
stage	IF	**1**	2	2	2	2	...	2	**3**										
	ID		**1**						2	**3**									
	EX									**2**	3	3	3	3	3	**3**			
	FEX			**1**	1	1	...	1	1	1	1	1	1	1	1	**1**			
	MEM										**2**						3	3	**3**
	WB											**2**							
	FWB																**1**		

Overview of Bounding Pipeline and Cache Performance



Worst-Case Union of Two Paths

Path 1

		stage						
		IF	ID	EX	FEX	CA	WB	FWB
cycle	1	**10**						
	2	11	**10**					
	3	16	11					
	4	17	16	**11**				
	5	18	17	16		**11**		
	6	19	18	17		16	**11**	
	7	19	18			17	16	
	8	20	19	18			17	
	9	21	20	19		18		
	10	22	21	20		19	18	
	11	23	22	21		20	19	
	12	24	23	22		21	20	
	13	25	24	23		22	21	
	14	25	24	23		22		
	15	26	25	24		23		
	16	**27**	26	25		24	23	
	17		**27**			25	24	
	18			**27**			25	
	19					**27**		
	20						**27**	
	...							
	32							
	33							

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Path 2

		stage						
		IF	ID	EX	FEX	CA	WB	FWB
cycle	1	**10**						
	2	11	**10**					
	3	12	11					
	4	13	12	**11**				
	5	14	13	12		**11**		
	6	15	14	13		12	**11**	
	7	24	15			13	12	
	8	25	24		**15**			**13**
	9	26	25	24	15			
	10	**27**	26	25	15	24		
	11		**27**	**27**	15	25	24	
	12				15	**27**	25	
	13				15		**27**	
	14				15			
	15				15			
	16				15			
	17				15			
	18				15			
	19				15			
	20				15			
	...				...			
	32				**15**			
	33							**15**

=

Worst-Case Union

		stage						
		IF	ID	EX	FEX	CA	WB	FWB
cycle	1	**10**						
	2		**10**					
	3							
	4			**11**				
	5					**11**		
	6						**11**	
	7							
	8				**15**			**13**
	9							
	10							
	11							
	12							
	13							
	14							
	15							
	16	**27**						
	17		**27**					
	18			**27**				
	19					**27**		
	20						**27**	
	...							
	32				**15**			
	33							**15**

Worst-Case Loop Example

- Path 1's First Misses are Instructions 16, 20, 24
- Path 2's First Misses are Instructions 12, 24

Iteration	Path 1	Path 2	fm encountered
1	20+27=47	**33+18=51**	12, 24
2	**16+18=34**	26	16, 20
3	16	**29**	
4-9		**26**	
10	16	**26**	

Test Programs

Name	Num Bytes	Hit Ratio	Description or Emphasis
Des	2,240	81.41%	Encrypts and Decrypts 64 Bits
Matcnt	812	81.81%	Counts, Sums Values in Matrix
Matmul	768	99.24%	Multiplies 2 50x50 Matrices
Matsum	644	88.22%	Sums Values in 100x100 Matrix
Sort	556	83.99%	Bubblesort of 500 Numbers
Stats	1,428	88.41%	Sum, Mean, StdDev., & Corr. Coef.

Worst-Case Results for Pipeline-only Analysis

Name	Observed Cycles	Estimated Cycles	Estim. Ratio	Naive Ratio
Des	66,594	68,254	1.02	3.82
Matcnt	1,063,572	1,063,572	1.00	2.38
Matmul	4,347,806	4,347,806	1.00	2.13
Matsum	933,540	933,540	1.00	2.28
Sort	3,380,660	6,748,925	2.00	8.13
Stats	900,231	900,231	1.00	1.70

Worst-Case Results for Cache-only Analysis

Name	Observed Cycles	Estimated Cycles	Estim. Ratio	Naive Ratio
Des	142,956	163,015	1.14	3.86
Matcnt	1,169,055	1,259,055	1.08	3.79
Matmul	1,527,648	1,527,648	1.00	9.36
Matsum	707,219	707,219	1.00	4.85
Sort	7,639,611	15,253,902	2.00	8.17
Stats	372,410	372,410	1.00	4.90

Worst-Case Results for Pipeline and Cache Analysis

Name	Observed Cycles	Estimated Cycles	Estim. Ratio	Naive Ratio
Des	149,706	169,613	1.13	5.02
Matcnt	1,769,321	1,859,323	1.05	3.69
Matmul	4,444,911	4,445,413	1.00	4.98
Matsum	1,277,465	1,277,477	1.00	4.08
Sort	7,765,648	15,504,693	2.00	10.78
Stats	1,016,048	1,016,145	1.00	3.12

Structural and Data Hazard Information

Stage	IF	ID	EX	FEX	MEM	WB	FWB
Beg Inst	1	1	2	1	2	2	1
Cycles from Beg	**0**	**1**	**12**	**2**	**13**	**14**	**19**
End Inst	3	3	3	1	3	2	1
Cycles from End	**10**	**9**	**3**	**3**	**0**	**7**	**2**

Register	%g1	%o0	%o4	%i2	%f0	%f2
first needed	**12**	**13**	**12**	**N/A**	**2**	**2**
last produced	**N/A**	**N/A**	**N/A**	**9**	**N/A**	**3**

Figure 5 : Path Information

Path 1 Info	IF	ID	EX	FEX	MEM	WB	FWB
Cycles from Beg	0	1	3	N/A	4	5	N/A
Cycles from End	4	3	2	N/A	1	0	N/A
Adj End Cycles	17	16	15	N/A	14	13	N/A
Path 2 Info	**IF**	**ID**	**EX**	**FEX**	**MEM**	**WB**	**FWB**
Cycles from Beg	0	1	3	7	4	5	7
Cycles from End	15	14	13	1	12	11	0

Use of Child Loop Times

Child => Parent	Action to Adjust Child Loop Time
fm => fm	Use the child loop time for the first iteration. For all remaining iterations subtract the miss penalty from the child loop time.
m => fh	For the first iteration subtract the miss penalty from the child loop time. For all remaining iterations use the child loop time directly.

Best-Case Results for Pipeline-only Analysis

Name	Observed Cycles	Estimated Cycles	Estim. Ratio	Naive Ratio
Des	34,837	15,684	0.45	0.36
Matcnt	1,013,307	1,013,207	1.00	0.38
Matmul	4,347,541	4,347,541	1.00	0.33
Matsum	913,275	913,175	1.00	0.35
Sort	11,158	4,174	0.37	0.32
Stats	447,478	447,477	1.00	0.41

Best-Case Results for Cache-only Analysis

Name	Observed Cycles	Estimated Cycles	Estim. Ratio	Naive Ratio
Des	59,998	19,345	0.32	0.21
Matcnt	929,073	929,073	1.00	0.41
Matmul	1,527,648	1,527,648	1.00	0.94
Matsum	687,219	687,219	1.00	0.47
Sort	10,439	3,901	0.37	0.35
Stats	372,410	372,410	1.00	0.49

Best-Case Results for Pipeline and Cache Analysis

Name	Observed Cycles	Estimated Cycles	Estim. Ratio	Naive Ratio
Des	65,615	22,247	0.34	0.19
Matcnt	1,549,095	1,548,798	1.00	0.25
Matmul	4,444,666	4,420,068	0.99	0.32
Matsum	1,257,239	1,157,240	0.92	0.26
Sort	19,957	4,428	0.22	0.18
Stats	607,399	601,406	0.99	0.30

Benefit of Overlapping Analysis

Name	Ratio With Overlapped Analysis	Ratio With Independent Analysis
Des	1.133	1.174
Matcnt	1.051	1.057
Matmul	1.000	1.000
Matsum	1.000	1.016
Sort	1.997	2.029
Stats	1.000	1.082
average	1.197	1.226