

## Appendix: Detailed Results

This document includes the detailed results for the paper “High-Bandwidth Address Translation for Multiple-Issue Processors”, by Todd M. Austin and Gurindar S. Sohi in ISCA-23, May 1996.

Program	Inputs/Options	Insts (Mil.)	Loads (Mil.)	Stores (Mil.)	Inst/Cycle		(Ld+St)/Cycle		Br Pred Rate (%)
					Issue	C <sup>mit</sup>	Issue	C <sup>mit</sup>	
Compress	in	62.0	15.8	6.1	3.65	1.96	1.30	0.69	89.7
Doduc	doducin	1,375.1	330.4	130.2	2.16	1.76	0.71	0.59	86.6
Espresso	-t cps.in	517.5	116.5	32.7	4.48	2.90	1.32	0.84	90.2
GCC	-O 1stmt.i	110.6	26.4	16.5	3.56	1.87	1.32	0.72	80.2
Ghostscript	-dNOPAUSE -sDEVICE=ppm fast-addr.ps -c quit	625.2	109.1	53.3	2.76	2.18	0.73	0.55	93.3
MPEG_play	coil.mpg	529.6	114.9	47.9	4.10	2.82	1.19	0.87	85.9
Perl	tests.pl	231.5	57.7	37.2	2.85	1.43	1.10	0.57	81.2
TFFT	MEXPONENT=20, ITER=1	959.8	136.6	89.4	2.69	1.79	0.62	0.42	79.9
Tomcatv	N=129	359.7	90.9	18.3	3.64	2.72	1.00	0.83	86.6
Xlisp	li-input.lsp	962.7	289.2	171.6	4.17	2.52	1.86	1.21	87.9

Table 1: Program Execution Performance. Instruction, load, and store counts include only non-speculative operations. The columns labeled *Issue* and *C<sup>mit</sup>* indicate the average number of operations issued and committed per cycle, respectively, on the baseline 8-way out-of-order issue processor simulator.

Program	Multi-ported				Multi-level/Pretranslated				Interleaved			Piggybacked		
	T4-IPC	T4	T2	T1	M16	M8	M4	P8	I8	I4	X4	PB2	PB1	I4/PB
Compress	1.962	1.000	0.941	0.683	0.908	0.891	0.871	0.953	0.879	0.861	0.862	0.998	0.943	0.994
Doduc	1.757	1.000	0.962	0.848	1.000	0.994	0.985	0.984	0.935	0.929	0.934	0.997	0.974	0.996
Espresso	2.900	1.000	0.934	0.699	1.000	1.000	0.981	0.983	0.893	0.868	0.874	0.994	0.916	0.986
GCC	1.869	1.000	0.910	0.660	1.000	0.977	0.925	0.990	0.883	0.857	0.851	0.990	0.888	0.984
Ghostscript	2.178	1.000	0.959	0.819	0.999	0.990	0.972	0.943	0.931	0.921	0.954	0.999	0.974	0.989
MPEG_play	2.822	1.000	0.908	0.692	0.958	0.937	0.850	0.880	0.876	0.846	0.843	0.972	0.865	0.980
Perl	1.434	1.000	0.937	0.734	0.997	0.972	0.925	0.976	0.939	0.905	0.906	0.992	0.904	0.983
TFFT	1.790	1.000	0.957	0.847	0.991	0.989	0.986	1.000	0.954	0.950	0.946	0.990	0.969	0.989
Tomcatv	2.721	1.000	0.960	0.787	1.000	0.994	0.955	0.908	0.935	0.934	0.974	0.998	0.965	0.996
Xlisp	2.523	1.000	0.876	0.551	0.999	1.000	0.972	0.987	0.834	0.806	0.815	0.992	0.861	0.986
RTW Avg	2.094	1.000	0.940	0.767	0.994	0.988	0.965	0.972	0.916	0.902	0.909	0.993	0.939	0.990

Table 2: Relative Performance on Baseline Simulator. Results shown are run-time weighted average IPCs normalized to the performance of design T4. All experiments were run on an 8-way out-of-order issue processor simulator with 32 registers and 4k pages.

Program	Fully-Associative						Set-Associative (128 entries)			
	4 entries	8 entries	16 entries	32 entries	64 entries	128 entries	8-way	16-way	32-way	64-way
Compress	18.8	16.0	13.4	9.8	4.0	0.0	0.0	0.0	0.0	0.0
Doduc	7.7	3.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Espresso	3.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GCC	11.5	3.7	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Ghostscript	8.0	3.3	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0
MPEG_play	37.7	14.4	12.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Perl	12.8	5.4	1.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0
TFFT	23.3	5.3	0.1	0.1	0.1	0.1	2.7	0.1	0.1	0.1
Tomcatv	15.8	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xlisp	4.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RTW Avg	13.8	4.6	1.4	0.2	0.1	0.0	0.6	0.0	0.0	0.0

Table 3: TLB miss rates. All values shown indicate percent of all references that miss. The row labeled RTW Avg is the run-time weighted average miss rate over all the benchmarks (weighted by the run-time of configuration T4). The 4, 8, and 16 entry TLBs are managed with LRU replacement, and the 32, 64, and 128 entry TLBs are managed with random replacement.

Program	Insts (Mil.)	Loads (Mil.)	Stores (Mil.)	8-Way In-order Issue, 4k page				8-Way Out-of-Order Issue, 8k page					
				Inst/Cycle		(Ld+St)/Cycle		Br Pred Rate (%)	Inst/Cycle		(Ld+St)/Cycle		Br Pred Rate (%)
				Issue	C'mit	Issue	C'mit		Issue	C'mit	Issue	C'mit	
Compress	62.0	15.8	6.1	1.31	1.23	0.45	0.43	89.4	3.65	1.96	1.30	0.69	89.7
Doduc	1,375.1	330.4	130.2	1.01	0.97	0.33	0.32	86.4	2.16	1.76	0.71	0.59	86.7
Espresso	517.5	116.5	32.7	1.50	1.41	0.43	0.41	88.8	4.48	2.90	1.32	0.84	90.2
GCC	110.6	26.4	16.5	1.55	1.27	0.56	0.49	78.8	3.56	1.87	1.32	0.72	80.2
Ghostscript	625.2	109.1	53.3	1.36	1.30	0.35	0.33	94.3	2.76	2.18	0.73	0.55	93.3
MPEG_play	529.6	114.9	47.9	1.36	1.29	0.42	0.40	84.6	4.11	2.83	1.17	0.86	86.0
Perl	231.5	57.7	37.2	1.32	1.10	0.52	0.44	79.4	2.85	1.43	1.10	0.57	81.2
TFFT	959.8	136.6	89.4	1.17	1.04	0.27	0.24	84.5	2.70	1.79	0.62	0.42	79.0
Tomcatv	359.7	90.9	18.3	1.12	1.09	0.34	0.33	86.0	3.67	2.73	1.00	0.83	86.6
Xlisp	962.7	289.2	171.6	1.55	1.42	0.73	0.68	87.2	4.17	2.52	1.86	1.21	88.0

Table 4: Program Execution Performance. Instruction, load, and store counts include only non-speculative operations. The columns labeled *Issue* and *C'mit* indicate the average number of operations issued and committed per cycle, respectively.

Program	Multi-ported				Multi-level/Pretranslated				Interleaved			Piggybacked		
	T4-IPC	T4	T2	T1	M16	M8	M4	P8	I8	I4	X4	PB2	PB1	I4/PB
Compress	1.230	1.000	0.985	0.924	0.981	0.975	0.959	0.967	0.930	0.930	0.931	1.000	1.000	1.000
Doduc	0.966	1.000	0.992	0.945	0.997	0.981	0.937	0.960	0.964	0.963	0.974	0.996	0.994	0.995
Espresso	1.412	1.000	0.975	0.897	1.000	0.998	0.981	0.922	0.952	0.942	0.948	0.999	0.946	0.988
GCC	1.273	1.000	0.980	0.902	0.995	0.975	0.928	0.946	0.936	0.931	0.934	0.999	0.985	0.996
Ghostscript	1.303	1.000	0.992	0.952	0.998	0.984	0.961	0.964	0.961	0.959	0.961	1.000	0.993	0.995
MPEG_play	1.286	1.000	0.984	0.885	0.951	0.937	0.859	0.941	0.958	0.949	0.957	0.992	0.919	0.998
Perl	1.098	1.000	0.986	0.929	0.992	0.972	0.936	0.958	0.959	0.949	0.966	0.999	0.987	0.994
TFFT	1.040	1.000	0.991	0.983	0.999	0.996	0.968	0.984	0.984	0.977	0.982	1.000	0.992	1.000
Tomcatv	1.094	1.000	1.000	0.972	1.000	1.000	0.931	0.951	0.995	0.994	0.904	1.000	0.976	0.999
Xlisp	1.419	1.000	0.975	0.893	1.000	0.992	0.936	0.988	0.937	0.937	0.941	0.999	0.994	1.000
RTW Avg	1.156	1.000	0.988	0.937	0.994	0.984	0.935	0.959	0.963	0.959	0.960	0.998	0.982	0.997

Table 5: Relative Performance with In-order Issue.

Program	Multi-ported				Multi-level/Pretranslated				Interleaved			Piggybacked		
	T4-IPC	T4	T2	T1	M16	M8	M4	P8	I8	I4	X4	PB2	PB1	I4/PB
Compress	1.962	1.000	0.941	0.682	0.928	0.900	0.874	0.955	0.879	0.833	0.805	0.998	0.944	0.992
Doduc	1.756	1.000	0.991	0.867	1.000	1.000	1.000	0.997	0.959	0.944	0.944	1.000	0.996	0.997
Espresso	2.899	1.000	0.934	0.699	0.997	1.000	1.000	0.984	0.885	0.863	0.868	1.000	0.952	0.996
GCC	1.868	1.000	0.911	0.660	1.000	0.990	0.939	0.992	0.873	0.847	0.844	0.992	0.891	0.982
Ghostscript	2.179	1.000	0.959	0.819	0.999	0.994	0.978	0.970	0.941	0.925	0.935	0.999	0.987	0.997
MPEG_play	2.827	1.000	0.907	0.691	0.978	0.974	0.872	0.898	0.875	0.852	0.849	0.994	0.886	1.000
Perl	1.435	1.000	0.936	0.733	1.000	0.980	0.933	0.990	0.939	0.914	0.921	0.993	0.907	0.981
TFFT	1.792	1.000	0.957	0.846	0.991	0.988	0.987	1.000	0.953	0.934	0.933	0.990	0.968	0.996
Tomcatv	2.734	1.000	0.958	0.783	1.000	0.992	0.959	0.943	0.939	0.937	0.972	0.994	0.987	0.997
Xlisp	2.523	1.000	0.875	0.551	0.999	0.999	0.977	0.989	0.839	0.707	0.707	0.992	0.862	0.969
RTW Avg	2.095	1.000	0.948	0.772	0.996	0.992	0.975	0.982	0.924	0.890	0.893	0.996	0.952	0.992

Table 6: Relative Performance with 8k Pages.

Program	Insts (Mil.)	Loads (Mil.)	Stores (Mil.)	8-Way Out-of-order Issue, 8 int/8 fp registers				
				Inst/Cycle		(Ld+St)/Cycle		Br Pred
				Issue	C'mit	Issue	C'mit	Rate (%)
Compress	72.9	18.6	6.1	3.64	2.12	1.22	0.72	90.2
Doduc	1,616.4	457.1	227.0	2.35	1.93	0.97	0.82	86.4
Espresso	621.1	182.2	65.1	4.46	3.38	1.78	1.33	92.5
GCC	119.5	33.1	19.8	3.64	1.96	1.57	0.87	80.8
Ghostscript	651.5	126.9	59.1	3.05	1.96	0.96	0.56	89.5
MPEG_play	704.3	225.1	101.6	4.31	2.80	1.83	1.30	81.1
Perl	241.0	61.6	42.4	2.86	1.46	1.23	0.63	81.4
TFFT	1,350.0	402.4	181.6	3.04	2.24	1.15	0.97	79.4
Tomcatv	1,969.8	355.3	131.7	5.47	5.44	1.35	1.35	89.3
Xlisp	946.6	280.0	165.3	4.22	2.59	1.87	1.20	89.3

Table 7: Program Execution Performance.

Program	Multi-ported				Multi-level/Pretranslated				Interleaved			Piggybacked		
	T4-IPC	T4	T2	T1	M16	M8	M4	P8	I8	I4	X4	PB2	PB1	I4/PB
Compress	2.120	1.000	0.947	0.698	0.932	0.913	0.887	0.967	0.900	0.883	0.888	0.997	0.929	0.994
Doduc	1.930	1.000	0.948	0.759	0.999	0.994	0.986	0.980	0.893	0.878	0.883	0.997	0.949	0.993
Espresso	3.383	1.000	0.841	0.540	1.000	0.997	0.949	0.815	0.814	0.728	0.731	0.964	0.799	0.946
GCC	1.956	1.000	0.885	0.610	1.000	0.979	0.924	0.890	0.855	0.827	0.819	0.985	0.857	0.980
Ghostscript	1.959	1.000	0.938	0.800	1.000	0.988	0.967	0.959	0.904	0.893	0.910	0.996	0.938	0.983
MPEG_play	2.796	1.000	0.854	0.566	0.984	0.971	0.922	0.910	0.811	0.749	0.742	0.962	0.811	0.961
Perl	1.455	1.000	0.927	0.708	1.000	0.977	0.936	0.941	0.938	0.896	0.893	0.991	0.897	0.983
TFFT	2.240	1.000	0.901	0.652	1.000	0.998	0.977	0.996	0.773	0.754	0.759	1.000	0.874	0.958
Tomcatv	5.445	1.000	0.940	0.631	1.000	0.998	0.984	0.677	0.723	0.710	0.713	0.998	0.879	0.974
Xlisp	2.590	1.000	0.869	0.543	1.000	0.999	0.964	0.890	0.842	0.815	0.822	0.981	0.862	0.974
RTW Avg	2.594	1.000	0.912	0.670	0.998	0.992	0.967	0.917	0.837	0.811	0.816	0.992	0.892	0.975

Table 8: Relative Performance with Fewer Registers (8 int/8 fp).