LUBISEDA

Bringing CI Into Formal Verification

Dr. Tobias Ludwig, CEO

Semiconductor Family Feud

We have asked 100 hardware engineers: "What's notoriously hard to verify?"

Rank	IP Block
1	CPU / Processor Cores
2	DDR / DRAM Controllers
3	PCIe / High-Speed I/O
4	GPU / Graphics Units
5	Cache Coherency Units
6	AI/ML Accelerators
7	Network Interface (Ethernet, etc.)
8	Security / Crypto Engines
9	SoC Interconnect / NoC
10	Power Management Units (PMU)



What makes verifying caches so difficult?



What do we do in formal to get it done?



The setup

Most important property of a cache?

read |-> right data





Zooming into the FV cache



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Cache Miss Case



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Cache Hit Case



Bug Example



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What makes verifying caches so difficult?





Sounds good ?

Let's see how we can get this done ASAP



The Original Flow





Make it less tedious step #1





Al assisted setup



Al assisted setup

Verification Wrapper Ambiguous DUT module wrapper #(parameter num_reqs = 2 What does it do? input logic [1:0] a,) (input clk, input a, logic [1:0] x = 2'b00; output b always_ff @(posedge clk) begin); if (a != 2'b00) begin fv_lubis_rr_arbiter_vapp if (x == 2'b10)#(Large Language .num_reqs(num_reqs) fv_lubis_rr_arbiter_vapp_inst Model assign b = (a & (x == 2'b00)) | ((a >> 1) & (x == 2'b01));(LLM) .clk(clk), .reqs(a), .grant(b) design_x design_x_inst .clk(clk), .a(a), .b(b) endmodule Smart Prompt



module design_x (input logic clk,

);

output logic b

 $x \le x + 1'b1;$

x <= 2'b00;

end

end

endmodule

Make it less tedious step #2





Its on the web

Al.mem_addr ()		witness	Proof Runtin	ne V	itness Runtime	Proof Memory [MB]	Witness Memory [MB]	Run Management	Actions
Al.mem data (i)	\odot	0	8m 52s		1m 30s	4661	5104	Start Run	Show witness
	\odot	Ø	8m 55s		1m 30s	4661	5104	Start Run	Show witness
ALDC	\odot	Ø	14m 22s		1m 31s	4661	5104	Start Run	Show witness
	0	0	2m 27c		1m 21c	4661	5104	Start Run	
	Ŭ	Ŭ	Sinore			-1001	0101	Start Kull	counterexample
Counterexample f	for pro	operty: S	RAI.regfile						Hide
Signal			Time (ns)	Expected Va	lue Actual Value				
ibex_top.gen_regfile_ff.re	egister_fi	ile_i.rf_reg[1	2] 57	0xffffffff	0x3				
Bug description									^
Instruction sequence le	eading to	bug Cloc	cycle						
SRAI r12, r4, -1		14							
Clock 14: Instruction: SRAI r12 Expected Value: 0x1f Actual Value: 0x3	2, r4, –1 fffffff								
Clock 14: Instruction: SRAI r12 Expected Value: &rff Actual Value: &rff Clock 14: Clock 14: C	2, r4, -1 fffffff AI (Shift Ri ate value. eegative nu Med ≪e	ight Arithmeti However, if w umber. The ac	c Immediate) instr e consider the imm tual value remains	uction shifts th nediate value a 0x3, indicating	e value in r4 right by as 31 (since -1 in 5-bi g the shift operation o	y the immediate value. The i it immediate is 31), the ope did not execute correctly.	immediate value is -1, which ration would be 0x8000003	is not valid for the SRAI in >> 31, resulting in 0xffff	nstruction as it expects a
Clock 14: Instruction: SRAT_r12 Explanation: The SRAT Actual Value: %3 Explanation: The SRAT non-negative immedia arithmetic shift of a ner File View Settings Help Copes bactops bactops	2, r4, -1 fffffff al (Shift Ri ate value. egative nu ke et	ight Arithmeti However, if w umber. The ac	c Immediate) instr e consider the imm tual value remains	uction shifts th nediate value a ex3, indicating	e value in r4 right by s 31 (since -1 in 5-b) g the shift operation of	r the immediate value. The i it immediate is 31), the ope did not execute correctly.	immediate value is -1, which ration would be 0x8000003	is not valid for the SRAI in >> 31, resulting in 0xffff	nstruction as it expects a fffff due to the
Clock 14: Instruction: SRAT_r12 Explanation: The SRAT Actual Value: exd Explanation: The SRAT non-negative immedia arithmetic shift of a ne	2, r4, -1 fffffff AI (Shift Ri ate value. wegative nu	ight Arithmeti However, if w umber. The ac bec_top ric_ ibec_top ric_ instr_rotag(0) instr_rotag(1)	c Immediate) instr e consider the imm tual value remains	uction shifts th mediate value a 0x3, indicating	e value in r4 right by as 31 (since -1 in 5-bi the shift operation of the shift operation of the shift operation of the shift operation of the shift operation of the shift operation of the shift operation of the shift operation of the shift operation of the shift operation of the shift operation op	y the immediate value. The i it immediate is 31), the ope did not execute correctly.	immediate value is -1, which ration would be 9x89999993	is not valid for the SRAI in >> 31, resulting in 0xfff	nstruction as it expects a fffff due to the
Clock 14: Instruction: SRAI r12 Expected Value: exf Actual Value: exf Stual Value: exact Content of the SRAI Content of the State	2, r4, -1 fffffff AI (Shift Ri ate value. legative nu	ight Arithmeti However, if w umber. The ac Iber.toocit, Iber.toocit, Iber.toocit, Instorden Instorden Instorden Karen, o dea_ke-o	c Immediate) instr e consider the imr tual value remains	uction shifts th mediate value a sea, indicating sea control of the sea control of the se	e value in r4 right by as 31 (since -1 in 5-bi the shift operation of the shift operation shift operation shift operation	y the immediate value. The it immediate is 31), the ope did not execute correctly.	immediate value is -1, which ration would be 0x80000003	is not valid for the SRAI in >> 31, resulting in 0xffff	nstruction as it expects a rffff due to the
Clock 14: Instruction: SRAI r12 Expected Value: 0x1 Actual Value: 0x3 Instruction: The SRAI Department of the start arithmetic shift of a ne	2, r4, -1 fffffff AI (Shift Ri ate value, egative nu K≪ ≪	ight Arithmeti However, if w umber. The ac low_took! liber_took! liber_took! liber_took! liber_took!	c Immediate) instr e consider the imm tual value remains	uction shifts the mediate value a s.a., indicating control of the control of the	e value in r4 right by as 31 (since -1 in 5-b) as 31 (since -1 in 5-b) g the shift operation of the shift operation of the shift operation of the shift operation opera	y the immediate value. The i it immediate is 31), the ope did not execute correctly.	immediate value is -1, which ration would be 0x8000003	is not valid for the SRAI in >> 31, resulting in 0xffff	nstruction as it expects a fffff due to the
Clock 14: Instruction: SRAI r12 Expected Value: &xf Actual Value: &xf Actual Value: &xf Structure: The SRAI non-negative immedia arithmetic shift of a ne File View Settings Hele Copes Ibec.loo	2, r4, -1 fffffff AI (Shift Ri ate value. egative nu	ight Arithmeti However, if w umber, The ac like,topack, inst. rokack, inst. rokack, dwa.gwc, dwa.gwc, dwa.gwc, dwa.gwc, dwa.gwc, dwa.gwc,	c Immediate) instr e consider the imm tual value remains	uction shifts the mediate value a sea, indicating to sea, indicating t	e value in r4 right by ss 31 (since -1 in 5-b) g the shift operation of seconde	y the immediate value. The i it immediate is 31), the ope did not execute correctly.	immediate value is -1, which ration would be exseences (60, 41-) (eccessors (50-) (eccessors)	is not valid for the SRAI in >> 31, resulting in 0xffff	nstruction as it expects a fffff due to the
Clock 14: Instruction: SRAI r12 Expected Value: exf Actual Value: exf Status: exf Instruction: The SRAI non-negative immedia arithmetic shift of a ne Fle Vew Settings Help Coopes Iber.too Modelblog: ERecorptat mean	2, r4, -1 fffffff at (Shift Ri ate value legative nu k≪ ≪	ight Arithmeti However, if w umber. The ac bec.too.cit. ib	c Immediate) instr e consider the imm tual value remains	uction shifts th mediate value : 0x3, indicatin	ee value in r4 right by as 31 (since -1 in 5-b) the shift operation of the shift operation of second	r the immediate value. The i it immediate is 31), the ope did not execute correctly.	immediate value is -1, which ration would be 0x60000003	is not valid for the SRAI in >> 31, resulting in 0xffff	nstruction as it expects a fffff due to the
Clock 14: Instruction: SRAI r12 Expected Value: exf Actual Value: exf Sexplanation: The SRAI non-negative immedia arithmetic shift of a ne rile View Settings Helo Copes Iber_top Variables Filter (context menu	2, r4, -1 fffffff AI (Shift Ri ate value. egative nu ket et	ight Arithmeti However, if w umber. The ac bec.too.ck. iber.too.ck. i	c Immediate) instr e consider the imm tual value remains	uction shifts th mediate value i ex3, indicatin	e value in r4 right by as 31 (since -1 in 5-b) the shift operation of the shift operation see 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	r the immediate value. The i it immediate is 31), the ope did not execute correctly.	immediate value is -1, which ration would be 0x60000003	is not valid for the SRAI in >> 31, resulting in 0xffff	nstruction as it expects a fffff due to the
Clock 14: Instruction: SRAI r12 Expected Value: exf Actual Value: exf Sexplanation: The SRAI non-negative immedia arithmetic shift of a ne rife View Settings Help Coopes Iber_too Variables Filter (context menu	2, r4, −1 fffffff atë value. gative n. Het ←	ight Arithmeti However, if w umber. The ac ber.top.ck. iber.top.top.ck. iber.top.ck. iber.top.ck. iber.top.ck. iber.top.ck. iber.top.ck. iber.top.ck. iber.top.top.ck. iber.top.top.top.top.top.top.top.top.top.top	c Immediate) instr e consider the imm tual value remains	uction shifts the mediate value is ex3, indicating ex3, indicating ex3 ex3 ex3 ex3 ex3 ex3 ex3 ex3 ex3 ex3	e value in r4 right by as 31 (since -1 in 5-b) the shift operation of the shift operation second	y the immediate value. The i it immediate is 31), the ope did not execute correctly.	immediate value is -1, which ration would be %x80000003	is not valid for the SRAI in >> 31, resulting in 0xffff	nstruction as it expects a fffff due to the
Clock 14: Instruction: SRAT_r12 Expected Value: exif Actual Value: oxif Explanation: The SRAT non-negative immedia arithmetic shift of a ne rile View Settings Hele Coopes Iber to Context mean Variables Filter (context mean	2, r4, −1 ffffff Li (Shift Ri egative nu leegative nu le	ight Arithmeti However, if w umber, The ac liber, topacki, liber, top	c Immediate) instr e consider the imm tual value remains	uction shifts the mediate value a sea, indicating to sea, indicating t	ee value in r4 right by ss 31 (since -1 in 5-b) g the shift operation of second	r the immediate value. The i it immediate is 31), the ope did not execute correctly.	immediate value is -1, which ration would be 0x80000003	is not valid for the SRAI in >> 31, resulting in 0xffff	nstruction as it expects a fffff due to the

Web-based control

Al generated debug information

Web-based debugging



Expand Popout

The Original Flow



Time for a conclusion



LUBIS Formal EDA Ecosystem

From an idea to tape-out





LUBIS EDA Fast. Reliable. Bug-free.



We help chip teams build confidence in their designs by combining expert formal verification services with automation that scales. From finding hidden bugs to verifying complex systems.





Kaiserslautern, Germany



We love formal



Tobias Ludwig

CEO



Web: <u>www.lubis-eda.com</u>



