Small soft core uP Inventory

Opencore and other soft core processors

Only cores in the "usable" category included

Most Prolific Authors (alpha or better status)		©2018 James Brakefield
Robert Finch	bc6502, butterfly, ft816, klc32, raptor64, rtf68ksys, rft6809, rtf8088, rtf65002, table887, table888, thor	12
John Kent	micro8a, micro16b, system05, system09, system11, system68	6
Daniel Wallner	ax8, ppx16 (16C55 & 16F84), t65 (6502, 65C02 & 65C816), t80 (8080 & z80)	5
Shawn Tan	ae18, aeMB, k68, DCPU16, T3RAS	4
Ulrich Riedel	68hc05, 68hc08, tiny64, tiny8	4
C.H. Ting	ep16, eP32, ep8080, p16b, p24e	4
Stephan Nolting	atlas_core, storm_core, neo430	3
Aleksander Osman	ao486, ao68000, aor3000	3
Hans Tiggeler	cpu86, recore54, uTTA	3
Jose Ruiz	ion, light52, light8080	3
Lazaridis Dimitris	mips_fault_tolerant, mipsr2000, mips_enhanced	3
James Brakefield	lem1_9, lem4_9ptr, rois24_24, lem16_18, the12X_12uP, alt430, torso, quad_iw	3

Most Clones		©2018 James Brakefield		
MIPS	32-bit_MIPS, aor3000, edge, hf-risc, f32c, ion, mais, minimips, mips_fault_tolerant, mips32, mips32r1, mips789, mipsr2000, mipsfpga, oops, plasma, r4000, sweet32, ucore, yacc, yari, yellowstar, ztachip	25	RISC	90
risc-v	f32c, riscv_clarvi, riscv_fpga_zynq, riscv_GRVI, riscv_microsemi, riscv_orca, riscv_picorv32, riscv_pulpino, riscv_rocket, riscv_rv01_core, riscv_rv12, riscv_sodor, riscv_taiga, riscv_urv-core, riscv_vexriscv, riscv_vhdl, riscv_zscale, vexriscv, vscale, yarvi	22	RISC	
6502	6502_verilog, 6502vhdl, af65k, ag_6502, apple2fpga, bc6502, c65gs, cpu6502_true_cycle, fpga-64, free6502, lattice6502, m65, m65c02, mcl65, pet_fpga, t65, t6507lp, verilog_6502	19	accum	80
PIC16	altium/TSK165x, cqpic, free_risc8, jmr16f84, m16c5x, minirisc, p16c5x, pic_coonan, ppx16, recore54, risc16f84, risc5x, risc8	14	accum	
openrisc	altor32, altor32_lite, minsoc, **mor1kx**, or10, **or1200**, or1200_hp, or1200_soc, or1200mp, or1k_soc, or1k-cf, or1knd	12	RISC	
x86	ao486, cpu86, mcl86, next186, next186_soc, rtf8088, s80186, sp-i586, sub86, v586, zet86	11	CISC	27
8051	8051, altium/TSK51x, dalton_8051, light52, mc8051, mcl51, oms8051mini, pulserain, r8051, t51, turbo8051	11	accum	
avr	avr_core, avr_hp, avt_sauerman, avr8, avrtinyx61core, ax8, cpu_lecture, navre, pavr, riscmcu	10	RISC	
z80	altium/TSK80x, a-z80, nextz80, reverse=u16, socz80, t80, tv80, wb_z80, y80e, z80soc	10	accum	
68000	ao68000, aoocs, k68, mc68kods, minimig, rtf68ksys, suska-III, tg68, v1_coldfire	9	CISC	
microblaze	aeMB, an-noc-mpsoc, mblite, mb-lite-plus, microblaze, myblaze, openfire_core, openfire2, secretblaze	9	RISC	
6800	hd63701, system68, system6801, 68hc05, df6805, system05, 68hc08	7	accum	
picoblaze	copyblaze, mike_pico6, nanoblaze, pacoblaze, picoblaze, riscuval, wb4pb	7	accum	
SPARC	leon, mips_enhanced, openpiton, s1_core, sparc64soc, sparcv8coprocessor, temlib	7	RISC	
ARM7	amber, arm4u, oks8, storm_core, zap	5	RISC	
8080	am9080, cpu8080, ep8080, light8080, t80	5	accum	
6809	6809_6309, system09, mc6809e, rtf6809	4	accum	
PDP-11	pdp11-34verilog, pdp2011, pop11-40, w11	4	CISC	
PDP-8	pdp8, pdp8l, pdp8verilog	3	accum	
MSP430	msp430_vhdl, neo430, openmsp430	3	CISC	
other clones	1802, 4004, 3X 68HC11, 8085, 9900, AGC, CARDIAC, COP400, Cray1, DLX, MCS-48, MMIX, N32032, PDP-1, PDP-10, PIC12, PIC18, Saturn HP calculator uP, 2X SH-2, Z8	22		
total		219		

Most Numerous Original Processor Type	©2018 James Brakefield	
RISC	a2z, aizup, altium/TSK3000A, alwcpu, atlas_2k, atlax_core, ba22, c-nit, c0or1k, c16too, carpe, cole_c16, dcpu16, dgb16, diongenes, dlx, eco32, edu_3bus_architecture, eight_bit_uc, embedded_risc, erp, fisa32, fisa64, fluid_core, gumnut, hicovec, hpc-16, iDEA, jam, jane_nn, jpu16, klc32, kraken2, latticemicro32, lc-2, lxp32, manik, marca, microcpu, micoriscii, mips_16, mist1032isa, moxie, mproz, myrisc1, natalius_8bit_risc, ncore, niloofar1, nocpu, oberon_sdram, oldland-cpu, open8_urisc, p8x32_propeller, patmos, potoato, qrisc32, qs5-rible, raptor64, risc_16bit, risc_core_i, risc0, risc-16, risc5, riscff, riscompatible, risc-processor, rise, rois24_24, s6soc, sayeh_processor, scarts, scott_cpu, spartanMC, suslik, sxp, table888, theia_gpu, thor, tiny64, tinycpu, totalcpu, ucode_cpu, ucos, up1232, xr16, cole_c16, diogenes, dragonfly, eco32, edge, eight_bit_uc, erp, fpgammix, hicovec, hpc-16, jam, manik, marca, myrosc1, raptor64, risc0, risc5, vexriscv, vscale, xgate, xr16, xtensa, xthundercore, xucpu, xulalx25soc, yasep, zipcpu	99
forth/stack	4stack, 8bit_chapman, b16, cpu16, dataflow_chapman, dfp, e16, eP16,ep24, ep32, eric5, f18a, f21, fc16, fefff, forth_kf532, forth-cpu, frisc-3, gullwing, ignite_ptsc, J1, J1a, J1a32, J1b, J1b_16, j1sc, jop, kestrel-2, microcore, misc_halverson, msl16, myforthprocessor, nc4016, nige_machine, nybbleForth, p16, p16b, p24e, rtx2000, sc20, sod32, ssbcc, stundurd_fmite, tf2216yafc, x32, xpu, yafc, zpu, zpuino	51
accumulator	agcnorm, blue, c88, classic_HP_calculator, hmta, inst_list_processor, lem1_9, lem1_9min, lem4_9ptr, lem16_18min, lem4_9, lem4_9ptr, leros, leros32, lwrisc, mano_machine, mcpu, micro8a, micro16b, morell_cpu, mycpu, nod4, popcorn, rtf65002, t180-cpu, td4, tiny8, tisc, usimplez	30
other	lutiac, c16, ensilica, octavo, lemberg, vtach, bobcat, uTTA, x32	9
total		189

Usage beyond original author		©2018 James Brakefield
amber	Amber ARM-compatible core	OCCP
leon	SPARC clone, commerical product, 50 FPGA boards supported	
latticemicro32	used as the processor in milkymist	
minsoc	OpenRISC implementation of OR1200 SOC	OCCP
openMSP430	Clone of Texas Instruments MSP430 family	OCCP
or1k	OpenRISC 1000	OCCP
plasma	Plasma - most MIPS I opcodes: used in ~20 academic papers	OCCP
risc-v	several FPGA implementations, several ASIC implementations, UC Berkeley	
system09	Color Computer, arcade games, SWTPC	
t400	T400 uController	OCCP
t48	T48 uController	OCCP
t80	8080, Z80 & gameboy inst sets; several usages	
zpu	Zylin CPU, commercial product	

Commercial product	©2018 James Brakefield	Known For
Synopsys ARC	Targets ASIC designs, very little public information: en.wikipedia.org/wiki/ARC_(processor)	CAD tools

TSK3000A	32-bit RISC, Altium core, free with tools	CAD tools
ESi-1600, Esi-3200	Ensilica 16-bit & 32-bit , targets both FPGAs & ASICs: en.wikipedia.org/wiki/ESi-RISC	design services
Manik	32-bit RISC, Nitech core, free source	design services
MC8051	8051 clone from Oregano Systems, source is free	design services
ZPU	opensource.Zylin, "ZPU the worlds smallest 32 bit CPU with GCC toolchain"	design services
latticemicro8 & 32	8 & 32-bit Lattice Semiconductor cores, open source	FPGA chips
MicroBlaze	32-bit Xilinx core, free with tools, clones available	FPGA chips
NIOS II	32-bit Altera core, free with tools	FPGA chips
PicoBlaze	8-bit Xilinx core, free with tools, clones available	FPGA chips
Eric-5	Entner Electronics, 9-bit Forth	FPGA design
BA21-25	32-bit RISCs by CAST Inc., targets ASICs	IP
ColdFire	68000 clone by ip-extreme, free for Altera Cyclone 3	IP
MCL86	Low LUT count (308 LUTs, 4 BlkRAM) 8088 from MicroCore Labs	IP
OpenRISC 1000	32-bit from people at Beyond Semiconductor who target ASICs with BA12-25 series	IP
S8051XC3	highest performance 8051 clone, by CAST Inc., targets ASICs	IP
LEON	SPARC clone from Aeroflex Gaisler, LEON 2 & 3 source is free	SPARC IP
ARM Cortex A53	Incorporated into Altera Stratix X and Xilinx Zynq US+	uP IP
ARM Cortex A9	Incorporated into Altera Cyclone V and Xilinx Zynq	uP IP
ARM Cortex M0	Targets FPGAs and very low cost 32-bit processors	uP IP
ARM Cortex M1	Targets FPGAs, available for Actel, Altera & Xilinx	uP IP
ARM Cortex M3	Incorporated into MicroSemi SmartFusion1 & 2	uP IP

FPGA based Legacy Processor Emulation	http://en.wikipedia.org/wiki/Home_computer_remake	
Sun Sparc	http://en.wikipedia.org/wiki/LEON	
Cray-1 (cray1)	www.chrisfenton.com/homebrew-cray-1a/	
PDP	http://www.aracnet.com/~healyzh/pdp_fpga.html	
PDP-8	http://www.emeritus-solutions.com/pdp8onanfpga.htm	
PDP-11/70 (w11)	http://opencores.org/project,w11	
Amiga (68000)	http://en.wikipedia.org/wiki/Minimig	
MIST(minimig)	http://harbaum.org/till/mist/index.shtml	
m32632(N32032)	http://cpu-ns32k.net/index.html	
jcore_aka_sh2	http://j-core.org/	
SWTPC 6809	http://members.optusnet.com.au/jekent/system09/	
Color Computer	http://8littlebits.wordpress.com/category/coco3fpga/	
Commodore Pet	http://www.skibo.net/projects/pet2001fpga/	
generic	http://fpgaarcade.com/	
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Other Insights ©2018 James Brakefield

For small micro-controllers with small memory needs, some soft cores are competitive with ASIC cores
- For a good figure of merit must keep LUT count low and fmax high
- Floating-point will add at least 2K LUTs, except Altera now provides 32-bit floating-point in their series-10 DSP blocks

Both microBlaze and NIOS-2 have very good figure-of-merit numbers
- If RAM area removed from ARM Cortex A9 ASIC, it has the highest figure of merit

There are "wrinkles" in CAD tools:
- For ISE, Quartus and Vivado: success in inferring RAM and multipliers varies across vendor families & between vendors
- For ISE, Quartus and Vivado: Fmax can vary in unpredicable ways across vendor families & between vendors
- The tools vary in their reporting of LUTs used for route-thrus

Two high performance ideas that work
- Multi-threading or pipeline "barrel" increase performance without adding complexity: octavo, hive, or1200_hp
- State machine with program as logic for programs under 200 instructions: iDEA, Lutiac, C-to-Hardware (HLS)

No one architecture dominates in performance, size or speed
- Many clone and legacy designs have relatively poor figure of merit, usually due to high LUT counts
  - SoC designs usually have higher LUT counts, often 2X greater
- For usable original designs the numbers are RISC is 47%, stack 20%, accumulator 15%, other 11%, OpenRisc 7%

Some opencores "alpha" phase designs are system designs where core is stable and working

For those barrel designs with adjustable barrel length, intermediate barrel length gives best KIPS/LUT (sample size of 2)

Only 28nm part families in webpack tools are Cyclone V, Spartan-7, Atrix-7, Kintex-7 and Zynq-7

Only 16nm part family in webpack tools is Zynq-US+

No parts from highest performance FPGA families available in "webpack" tools (Arria X, Stratix X, Virtex-US+)

Designs with floating point				©2018 James Brakefield
	cray1, fpgammix & s1_core are 64-bit, pdp2011 & oc54x 16-bit, others are 32-bit		LUT cnt	LUT type
ARM_Cortex_A9	ASIC, dual issue, includes fltg-pt & MMU & caches	std	4500	area equivalent
cray1	homebrew Cray1, double precision	std	13463	6LUT
fpgammix	clone of Knuth's MMIX, double precision	std	11605	ALUT
lemberg	upto 4 inst/clock	std	37459	4LUT
m32632	National 32032 with fltg-pt, cache & MMU	std	10167	6LUT
minsoc	minimal OR1200, vendor neutral, has caches	std	4945	6LUT
oberon_sdram	risc5 modified to use DRAM, has caches, serial multiply	std	2820	6LUT
or1200_hp	1 to 4 slot barrel version of OR1200	std	5602	6LUT
pdp2011	clone of PDP11/34	std	5060	6LUT
risc5	minimalist Wirth, part of Project Oberon 2013, fast multiply	std	2441	6LUT
s1_core	reduced version of OpenSPARC T1	std	52845	6LUT
leon	SPARC, customized for ~50 FPGA boards, configurable	opt		
microblaze	Xilinx RISC, fltg-pt, cache & MMU options	opt		
nios2	Altera RISC, fltg-pt, cache & MMU options	opt		
Altera X series DSP	Arria X & Stratix X provide single precision floating-point add & multiply	std		area equivalent
Altera IP	variable exponent and mantissa size, sqrt , exp/log & trig avail, no denorm support	IP		
several	OpenCores Arithmetic cores	IP		
VHDL 2008	variable exponent and mantissa size, sqrt avail, denorms opt, rounding modes opt	IP		
Xilinx IP	variable exponent and mantissa size, sqrt & exp/log avail, no denorm support	IP		

Highly micro-coded or serial arithmetic - e.g. area over speed					©2018 James Brakefield
		clks / inst	KIPS / LUT	LUT cnt	LUT type
light8080	Lightweight 8080 compatible core	9	59	154	6LUT
mcl51	MicroCore Labs AKA Ted Fried	8	24	312	6LUT
mcl65	MicroCore Labs AKA Ted Fried, cycle exact	4	50	252	6LUT
mcl86	MicroCore Labs AKA Ted Fried, matches original 8086 timing	20	20	308	6LUT
Nios2/E	serial arithmetic variant	~9	62	730	ALUT

Some of the designs with ROM or RAM initialization	©2018 James Brakefield
ROM/RAM inferred, MIF or other initialization	P&R on:
altor32	automatic use of either Altera LPMs or Xilinx primitives, no initialization	A&X
amber	generic_sram_byte_en.v: inferred byte enable RAM, also spartan-6 BRAM init	A&X
ao68000	MIF microcode file, see line 2130 of ao68000.v	A2
atlas_core	case statement in BOOT_MEM.vhd	X&A
c16	bit_vector constants in mem_conten.vhd, see memory.vhd: RAM4_S1_S1	S3
classic_HP_calc	three array ROM constants	K7
cray1	cray_rom.txt: xilinx MIF, see cray_sys_top.v line 111	K7
dalton_8051	constant in i8051_rom.vhd	K7
diogenes	MIF files , see pmem.vhd line 116	K7
eco32	large case based state "microcode" machine: cpu.v, no inferred RAM for Altera	X&A-
eP16, eP8080	Lattice memory IP, with init.	X
fpgammix	initmem.data: see progmem.v	A2
gumnut	source reads *.dat files, both VHDL & Verilog	A&X
gup	gucode.mif: see gucode.vhd line 89	A2
hd63701	*.i include files contain table definitions: see HD63701_MCROM.v	S3&6
lem1_9min	lem1_9min.vhd has array constant, for Quartus to infer block RAM, must be fully registered	X&A
leros	leros_rom.vhd: case statement with others	X&A
light52	light52_ucode_pkg.vhd has microcode table generator	C2&X
light8080	light808.vhdl has signal array init (instead of constant init)	X&A-
lwrisc	init_file.mif: see ramxxx.v files	A2
m1_core	*.vh initialization file	X&A
m16c5x, p16c5x	COE files	X&A
m32632	Verilog readmemf text file	K7,C4
marca	Altera memory IP & MIF files	A2
natalius_8bit_risc	inferred, MEM file	X
nige_machine	MIF files	K7
pdp8l	MIF files	C3
plasma	INIT text	K7
risc0	INIT text	K7
risc5	MEM file	X&A
rtf68ksys	case statement in bootrom.v	S3
system68	INIT in xilinx RAMB4_S8	S3
t51	case table	K7&A2
z80soc	COE files	S3&C3