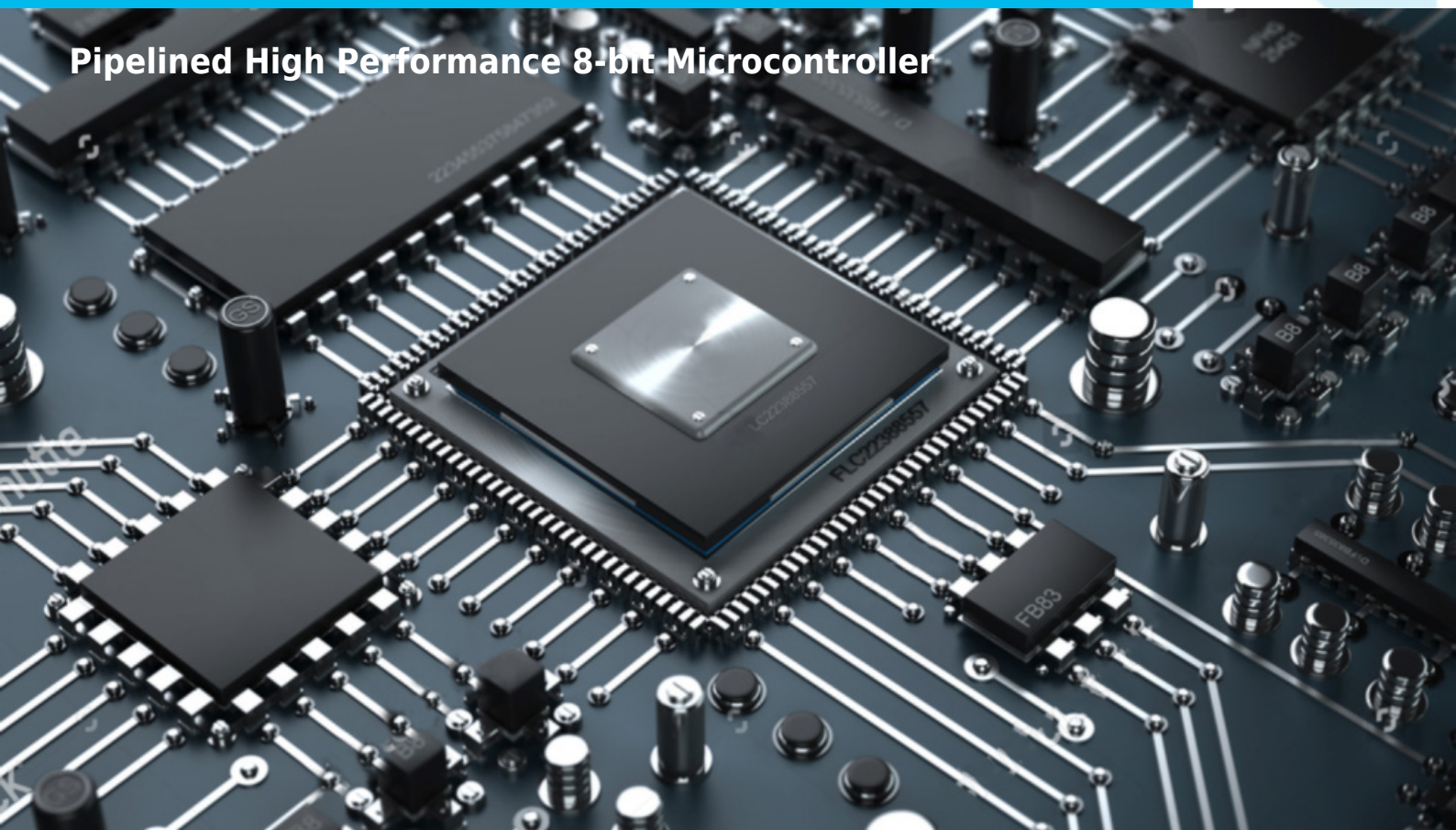
DIGITAL CORE DESIGN

DP8051

Pipelined High Performance 8-bit Microcontroller



COMPANY OVERVIEW

Digital Core Design is a leading IP Core provider and a System-on-Chip design house. The company was founded in 1999 and since the very beginning has been focused on IP Core architecture improvements. Our innovative, silicon proven solutions have been employed by over 300 customers and with more than 500 hundred licenses sold to companies like Intel, Siemens, Philips, General Electric, Sony and Toyota. Based on more than 70 different architectures, starting from serial interfaces to advanced microcontrollers and SoCs, we are designing solutions tailored to your needs.

IP CORE OVERVIEW

The DP8051 is an **ultra-high performance**, **speed-optimized** softcore, of a single-chip 8-bit embedded controller, intended to operate with fast (typically on-chip) and slow (off-chip) memories. The core was designed with a special concern about the performance to power-consumption ratio. This ratio is extended by the **PMU –** an **advanced power management unit.** The DP8051 softcore is 100% binary-compatible with the industry standard 8051 8-bit microcontrollers. There are two configurations of the DP8051:

- Harvard, where internal data and program buses are separated and
- von Neumann, with a common program and external data bus.

The DP8051 has a Pipelined RISC architecture and executes 120-300 million instructions per second. **Dhrystone 2.1 benchmark program runs from 11.46 to 15.55 times faster than the original 80C51 at the same frequency.** The same C compiler was used for benchmarking of the core vs 80C51, with the same settings. This performance can also be exploited to great advantage in low-power applications, where the core can be clocked over **ten times slower** than the original implementation, without performance depletion. The DP8051 is delivered with a **fully automated test bench** and a **complete set of tests**, allowing easy package validation, at each stage of the SoC design flow. Each of DCD's 8051 Cores has built-in support for the Hardware Debug System called **DoCD™**. It is a **real-time hardware debugger**, which provides debugging capability of the whole System-on-Chip (SoC). Unlike other on-chip debuggers, the **DoCD™** provides non-intrusive debugging of a running application. It can halt, run, step into or skip an instruction, and read/write any contents of the microcontroller, including all registers, internal and external program memories, and all SFRs, including user-defined peripherals.

DESIGN FEATURES:

ALL DCD'S IP CORES ARE TECHNOLOGY INDEPENDENT WHICH MEANS THAT THEY ARE 100% COMPATIBLE WITH ALL FPGA & ASIC VENDORS E.G.

- ***Altera / Intel,***
- ***Xilinx / AMD,***
- ***Lattice,***
- ***Microsemi / Microchip, and others.***
- ***TSMC***
- ***UMC***
- ***SK Hynix and others.***

CPU FEATURES

- Software in 100% compatible with 8051 industry standard
- Pipelined RISC architecture enables to run 15.55 times faster, than the original 80C51 at the same frequency
- Up to 14.632 VAX MIPS at 100 MHz
- 24 times faster multiplication
- 12 times faster division
- Up to 256 bytes of internal (on-chip) Data Memory
- Up to 64 kB of internal (on-chip) or external (off-chip) Program Memory
- Up to 8MB linear code space (in 80390 mode)
- Up to 16 MB of external (off-chip) Data Memory
- User programmable Program Memory Wait States
- User programmable External Data Memory Wait States
- De-multiplexed Address/Data bus – to allow easy memory connection
- Interface for additional Special Function Registers
- Fully synthesizable
- Static synchronous design
- Positive edge clocking and no internal tri-states
- Scan test ready
- USB, Ethernet, I2C, SPI, UART, CAN, LIN, HDLC, Smart Card interfaces available

DESIGN FEATURES

PROGRAM MEMORY:

The DP8051 soft core is dedicated to operate with Internal and External Program Memory. Internal Program Memory can be implemented as:

- ROM located in address range between 0x0000 ¸ (ROM_{size}-1)
- RAM located in address range between (RAM_{size}-1) ¸ 0xFFFF

External Program Memory can be implemented as ROM or RAM located in address range between ROM_{size} ¸ RAM_{size}.

INTERNAL DATA MEMORY:

The DP8051 can address Internal Data Memory of up to 256 bytes The Internal Data Memory can be implemented as Single-Port synchronous RAM.

EXTERNAL DATA MEMORY:

The DP8051 soft core can address up to 16 MB of External Data Memory. Extra DPX (*Data Pointer eXtended*) register is used for segments swapping.

USER SPECIAL FUNCTION REGISTERS:

Up to 104 External (user) Special Function Registers (ESFRs) may be added to the DP8051 design. ESFRs are memory mapped into Direct Memory between addresses 0x80 and 0xFF in the same manner, as core SFRs and may occupy any address that is not occupied by a SFR core.

WAIT STATES SUPPORT:

The DP8051 soft core is dedicated for operation with wide range of Program and Data memories. Slow Program and External Data memory may assert a memory WAIT signal to hold up CPU activity, for required period of time.

PERIPHERALS

- **DoCD™ debug unit**
  - Processor execution control
    - Run, Halt
    - Step into instruction
    - Skip instruction
  - Read-write all processor contents
    - Program Counter (PC)
    - Program Memory
    - Internal (direct) Data Memory
    - Special Function Registers (SFRs)
    - External Data Memory
  - Code execution breakpoints
    - up to eight real-time PC breakpoints
    - unlimited number of real-time OPCODE breakpoints
  - Hardware execution watchpoints at
    - Internal (direct) Data Memory
    - Special Function Registers (SFRs)
    - External Data Memory
  - Hardware watchpoints activated at a certain
    - address by any write into memory
    - address by any read from memory
    - address by write required data into memory
    - address by read required data from memory
  - Instructions Smart Trace Buffer – configurable up to 8192 levels (optional)
  - Automatic adjustment of debug data transfer speed rate between HAD and Silicon
  - TTAG or JTAG Communication interface
- **Power Management Unit**
  - Power management mode
  - Switchback feature
  - Stop mode
- **Interrupt Controller**
  - 2 priority levels
  - 2 external interrupt sources
  - 3 interrupt sources from peripherals
- **Four 8-bit I/O Ports**
  - Bit addressable data direction for each line
  - Read/write of single line and 8-bit group
- **Two 16-bit timer/counters**
  - Timers clocked by internal source
  - Auto reload 8-bit timers
  - Externally gated event counters
- **Full-duplex serial port**
  - Synchronous mode, fixed baud rate
  - 8-bit asynchronous mode, fixed baud rate
  - 9-bit asynchronous mode, fixed baud rate
  - 9-bit asynchronous mode, variable baud rate

UNITS SUMMARY

ALU – Arithmetic Logic Unit – performs the arithmetic and logic operations during execution of an instruction. Contains accumulator (ACC), Program Status Word (PSW), (B) registers and related logic, like arithmetic unit, logic unit, multiplier and divider.
Opcode Decoder – Performs an opcode decoding instruction and control functions for all other blocks.
Control Unit – Performs the core synchronization and data flow control. This module is directly connected to the Opcode Decoder and manages execution of all microcontroller tasks.
Program Memory Interface – Contains Program Counter (PC) and related logic. Performs the instructions code fetching. Program Memory can be also written. This feature allows usage of a small boot loader to load new program into ROM, RAM, EPROM or FLASH EEPROM storage via UART, SPI, I2C and DoCD™ module.
External Memory Interface – Contains memory access related registers, such as Data Page High (DPH), Data Page Low (DPL) and Data Page Pointer (DPP) registers. Performs the external Program and Data Memory addressing and data transfers. Program fetch cycle length can be programmed by the user. This feature is called Program Memory Wait States and it allows core to work with different speed program memories.
Synchronous eXternal Data Memory (SXDM) Interface – Contains XDATA memory access related logic, allowing fast access to synchronous memory devices. Performs the external Data Memory addressing and data transfers. This memory can be used to store large variables, frequently accessed by the CPU, improving overall performance of application.
Internal Data Memory Interface – Controls the access to the internal memory of size up to 256 bytes. Contains 8-bit Stack Pointer (SP) register and related logic.
User SFRs Interface – Special Function Registers interface controls access to the special registers. Contains standard and used defined registers and related logic. User defined external devices can be quickly accessed (read, written, modified) by using all direct addressing mode instructions.
Interrupt Controller – Responsible for the interrupt manage system of the external and internal interrupt sources. Contains interrupt related registers, such as Interrupt Enable (IE), Interrupt Priority (IP) and (TCON) registers.
Timers – System timers module. Contains two 16 bits configurable timers: Timer 0 (TH0, TL0), Timer 1 (TH1, TL1) and Timers Mode (TMOD) registers. In the timer mode, timer registers are incremented every 12 (or 4) CLK periods when appropriate timer is enabled. In the counter mode, the timer registers are incremented every falling transition on their corresponding input pins (T0, T1), if gates are opened (GATE0, GATE1). T0, T1 input pins are sampled every CLK period. It can be used as clock source for UARTs.
UART0 – Universal Asynchronous Receiver and Transmitter

module is full duplex, meaning, it can transmit and receive concurrently. Includes Serial Configuration register (SCON), serial receiver and transmitter buffer (SBUF) registers. Its receiver is double-buffered, it can commence reception of a second byte before the previously received byte has been read from the receive register. Writing to SBUF0 loads the transmit register and reading SBUF0 reads a physically separate receive register. Works in 3 asynchronous and 1 synchronous modes. UART0 can be synchronized by Timer 1 or Timer 2 (if present in the system).

Ports – Contains 8051's general purpose I/O ports. Each of port's pins can be read/written as a single bit or as an 8-bit bus P0, P1, P2, P3.

Power Management Unit – Contains advanced power saving mechanisms with switchback feature, allowing external clock control logic to stop clocking (Stop mode) or run core in lower clock frequency (Power Management Mode), to significantly reduce power consumption. Switchback feature allows UARTs and interrupts to be processed in a full speed mode, if enabled. It is highly desirable when the microcontroller is planned to be used in portable and power critical applications.

DoCD™ Debug Unit – A **real-time hardware debugger** which provides debugging capability of a whole SoC system. Unlike other on-chip debuggers, the **DoCD™** ensures **non-intrusive debugging** of running application. It can halt, run, step into or skip an instruction, read/write any contents of the microcontroller, including all registers, internal and external program memories and all SFRs, including user defined peripherals. Hardware breakpoints can be set and controlled on program memory, internal and external data memories, as well as on SFRs. Hardware watchpoints can be set and controlled on internal and external data memories and also on SFRs. Hardware watchpoints are executed, if any write/read occurs at particular address, with certain data pattern or without pattern. Two additional pins: CODERUN and DEBUGACS, indicate the state of the debugger and CPU. The CODERUN is active when the CPU is executing an instruction. The DEBUGACS pin is active when any access is performed by the **DoCD™** debugger. The **DoCD™** system includes **TTAG** or **JTAG interface** and a complete set of tools, to communicate and work with the core in real time debugging. It is built, as a scalable unit and some features can be turned off by the user, to save silicon and reduce power consumption. When the debugger is not used, it is automatically switched to a power save mode. Finally, when the debug option is no longer used, the whole debugger is turned off.

CONFIGURATION

The following parameters of the DP8051 core can be easily adjusted to requirements of a dedicated application and technology. The configuration of the core can be effortlessly done, by changing appropriate constants in the package file. There is no need to change any parts of the code.

- Internal Program Memory type: *synchronous / asynchronous*
- Internal Program ROM Memory size: *0 – 64kB*
- Internal Program RAM Memory size: *0 – 64kB*
- Internal Program Memory fixed size: *true / false*
- Interrupts: *subroutines location*
- Power Management Mode: *used / unused*
- Stop mode: *used / unused*
- DoCD™ debug unit: *used / unused*

Except parameters mentioned above, all available peripherals and external interrupts can be excluded from the core, by changing appropriate constants in the package file.

PERFORMANCE

The following table gives a survey about the Core area and performance in Programmable Logic Devices after Place & Route (CPU features and peripherals included):

Device	Speed grade	Area	F_{max}
SPARTAN-II	-6	1 100 Slices	53 MHz
SPARTAN-IIE	-7	1 100 Slices	64 MHz
SPARTAN-III	-5	1 100 Slices	73 MHz
VIRTEX	-6	1 100 Slices	53 MHz
VIRTEX-E	-8	1 100 Slices	67 MHz
VIRTEX-II	-6	1 100 Slices	99 MHz
VIRTEX-IIP	-7	1 100 Slices	123 MHz
VIRTEX-4	-11	1 100 Slices	107 MHz
VIRTEX-5	-3	1 699 LCells	200 MHz

Core performance in XILINX® devices – results given for working system with IDATA, CODE and XDATA memories

For the user, the most important aspect is an application speed improvement. The most commonly used arithmetic functions and their improvement are shown in the following table. The improvement was computed as {80C51 clock periods} divided by {DP8051 clock periods} required to execute an identical function. More details are available in the core documentation.

Function	Improvement
8-bit addition (*immediate data*)	**9,00**
8-bit addition (*direct addressing*)	**9,00**
8-bit addition (*indirect addressing*)	**9,00**
8-bit addition (*register addressing*)	**12,00**
8-bit subtraction (*immediate data*)	**9,00**
8-bit subtraction (*direct addressing*)	**9,00**
8-bit subtraction (*indirect addressing*)	**9,00**
8-bit subtraction (*register addressing*)	**12,00**
8-bit multiplication	**16,00**
8-bit division	**9,60**
16-bit addition	**12,00**
16-bit subtraction	**12,00**
16-bit multiplication	**13,60**
32-bit addition	**12,00**
32-bit subtraction	**12,00**
32-bit multiplication	**12,60**
Average speed improvement:	**11,12**

Dhrystone Benchmark Version 2.1 was used to measure the core performance. The following table shows the DP8051

performance in VAX MIPS per 1 MHz rating.

Device	DMIPS/MHz	Ratio
80C51	0,00941	1,00
DP8051	0,10787	11,46
DP8051+DPTRs	0,13722	14,58
DP8051+DPTRs+SXDM	0,14457	15,36
DP8051+DPTRs+SXDM+MDU32	0,14632	15,55

DELIVEVERABLES

- Source code:
  - VERILOG or VHDL Source Code
  - VERILOG or VHDL test bench environment
    - Active-HDL automatic simulation macros
    - ModelSim automatic simulation macros
    - Tests with reference responses
  - Technical documentation
    - Installation notes
    - HDL core specification
    - Datasheet
  - Synthesis scripts
  - Example application
- Netlist
  - Netlist for selected FPGA family
  - Sample FPGA project
  - Technical documentation
    - HDL core specification
    - Datasheet
- Technical support
  - IP Core implementation
  - 12 months maintenance
    - Delivery of the IP Core and documentation updates
    - Phone & email support
- Design consulting

LICENSING

Comprehensible and clearly defined licensing methods without royalty-per-chip fees make use of our IP Cores easy and simple.
– Single-Site license option – dedicated to small and middle sized companies which run their business at one place.
– Multi-Site license option – dedicated to corporate customers which operate at several locations. The licensed product can be used at selected company branches.
In all cases the number of IP Core instantiations within a project and the number of manufactured chips are unlimited. There are no restrictions regarding the time of use.

There are two formats of the delivered IP Core that you can choose from:
– VHDL or Verilog RTL synthesizable source code (called HDL Source code)
– FPGA EDIF/NGO/NGD/QXP/VQM (called Netlist)

HDL Source code is suitable for ASIC and FPGA projects. The Netlist license is intended for FPGA projects only.

CONTACT

Digital Core Design Headquarters:
Wroclawska 94, 41-902 Bytom, POLAND
E-mail: info@dcd.pl
tel.: +48 32 282 82 66
fax: +48 32 282 74 37
Distributors:
Please check: dcd.pl/contact-us/