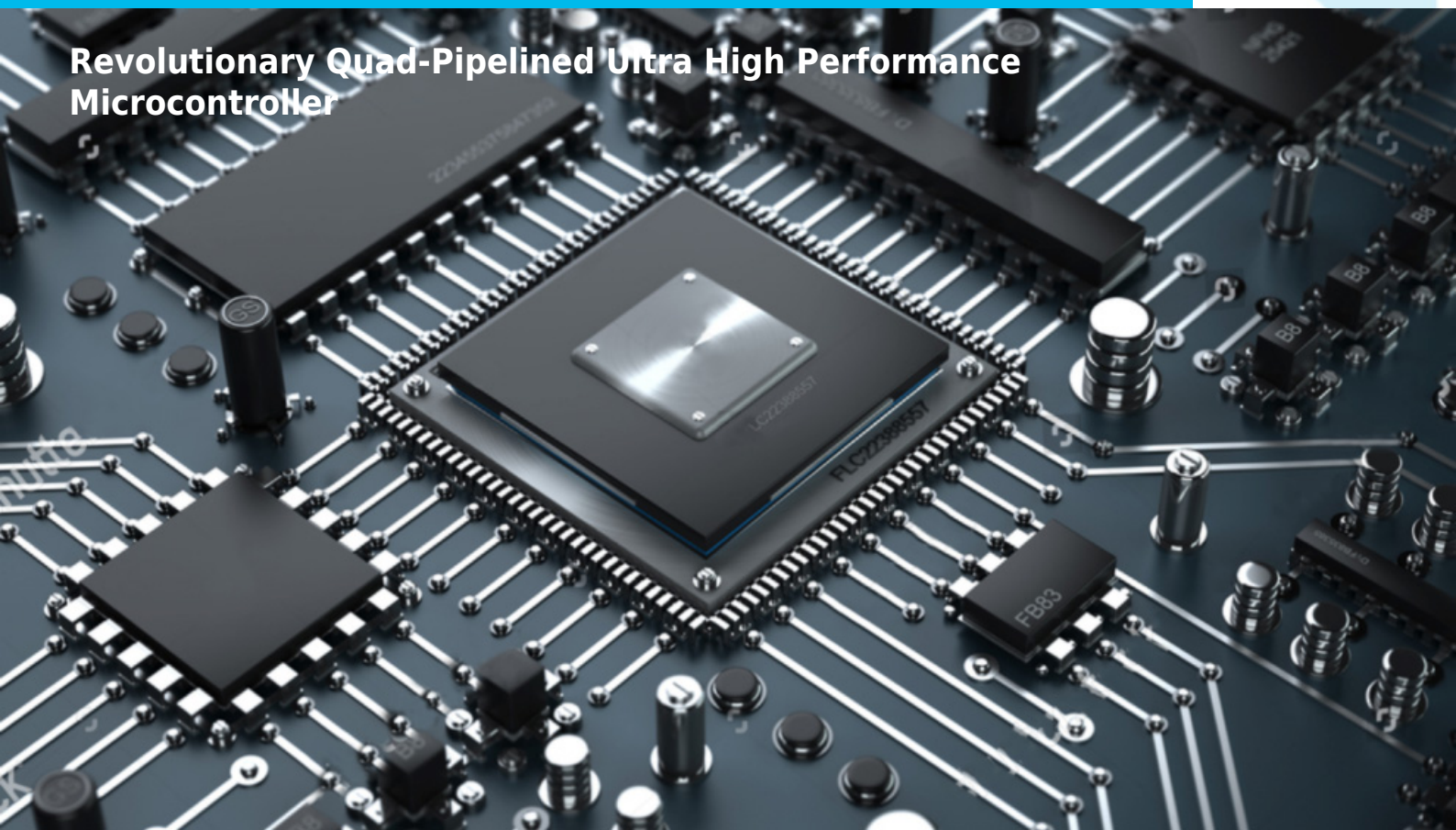
DIGITAL CORE DESIGN

DQ8051CPU

Revolutionary Quad-Pipelined Ultra High Performance 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

DQ8051CPU – ULTRA-HIGH PERFORMANCE 8051 CPU IP CORE

Overview

The **DQ8051CPU** is an **ultra-high performance, speed-optimized 8-bit 8051 CPU IP core**, designed as a **drop-in, binary-compatible replacement** for industry-standard 8051 microcontrollers. It delivers **massive performance gains, superior power efficiency, and full configurability**, making it an ideal choice for modern FPGA and ASIC-based System-on-Chip designs.

Engineered to operate efficiently with both **fast on-chip memories** and **slower off-chip memories**, the DQ8051CPU combines a deeply optimized architecture with an **advanced Power Management Unit (PMU)** to achieve an outstanding **performance-to-power ratio**.

Key Performance Advantages

Thanks to its highly optimized microarchitecture, the **DQ8051CPU executes real-world embedded workloads dramatically faster than legacy 8051 implementations**:

- **26.67× to 29.01× faster** than the original 80C51 at the same clock frequency (Dhrystone 2.1)
- Enables **over 10× lower clock frequency** operation with **no performance penalty**
- Ideal for **low-power, always-on, and energy-constrained applications**

This performance headroom allows designers to **reduce power consumption, simplify timing closure, or increase system throughput**—without rewriting legacy firmware.

100% 8051 Compatibility – Zero Software Risk

The DQ8051CPU is **100% binary-compatible with industry-standard 8051 microcontrollers**, ensuring:

- Immediate reuse of existing firmware
- Full compatibility with established toolchains
- Minimal migration effort from legacy 8051 designs

It is a **true drop-in CPU replacement** that modernizes classic 8051-based systems without disrupting software ecosystems.

Advanced Debug & Development Support

To accelerate development and reduce bring-up risk, the DQ8051CPU integrates **DCD's DoCD™ Hardware Debug System**, delivering **non-intrusive, real-time SoC-level debugging**:

- Built-in **configurable DoCD-JTAG debugger**
- Full support for **Keil µVision**
- Standalone **DoCD™ Debug Software**
- Halt, run, single-step, and instruction skip
- Read/write access to:
  - All CPU registers
  - Internal and external program/data memory
  - All SFRs, including user-defined peripherals

Unlike traditional on-chip debuggers, **DoCD™ operates without disturbing real-time system behavior**.

Fully Customizable & Silicon-Efficient

The DQ8051CPU is **fully configurable** and delivered in an **exact configuration tailored to your SoC requirements**:

- No unused features

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- No wasted silicon
- Optimized area, power, and performance

This makes it an excellent choice for **cost-sensitive**, **power-constrained**, and **high-volume designs**.

SoC-Ready & Production-Proven

- Technology-independent IP
- Compatible with **FPGA and ASIC** design flows
- Delivered with a **fully automated testbench**
- Comprehensive regression test suite
- Easy validation at every stage of the SoC design lifecycle

Typical Applications

- Legacy 8051 system modernization
- Low-power embedded controllers
- Industrial and automotive subsystems
- IoT and always-on devices
- FPGA-based embedded systems
- Cost-optimized ASIC designs

WHY CHOOSE DQ8051CPU?

- ⚙ **Fully customizable, no wasted silicon**
- ✅ **Production-ready with full verification**

The **DQ8051CPU** is not just an 8051 replacement—it is a **modern, high-performance evolution of the 8051 architecture**, built for today's SoC designs.

DQ8051CPU VS CLASSIC 8051 – MODERN PERFORMANCE WITHOUT SOFTWARE CHANGES

Engineers still relying on classic 8051 microcontrollers often face **performance bottlenecks, power limitations, and limited debug visibility**. The **DQ8051CPU** was created to remove these constraints—**without breaking compatibility**.

Side-by-Side Comparison

Feature	Classic 8051 MCU	DQ8051CPU IP Core
CPU Architecture	Single-cycle, legacy 8-bit core	Deeply optimized, high-performance 8-bit core
Binary Compatibility	Native 8051	**100% binary-compatible**
Firmware Migration	Not applicable	**Zero changes required**
Performance (Dhrystone 2.1)	Baseline (1×)	**26.67×–29.01× faster**
Clock Frequency Requirement	High	**Up to 10× lower for same performance**
Power Efficiency	Limited	**Advanced PMU, ultra-low-power capable**
Debug Capabilities	Basic / intrusive	**DoCD™ non-intrusive real-time debug**
Memory Support	Limited optimization	Optimized for **fast on-chip & slow off-chip memory**
Customization	Fixed silicon	**Fully configurable, no wasted logic**
SoC Integration	External MCU	**Native FPGA / ASIC IP core**
Verification & Testbench	Vendor-dependent	**Fully automated testbench included**

Why Replace a Classic 8051?

While the original 8051 architecture remains popular due to its massive software ecosystem, it was **never designed for modern SoC constraints**. The DQ8051CPU preserves everything engineers value about the 8051—**while eliminating its limitations**.

1. Massive Performance Headroom

The DQ8051CPU executes the same 8051 binaries **up to 29× faster**, enabling:

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- Higher system throughput
- Faster interrupt handling
- Headroom for additional software features

2. Lower Power Without Compromise

Thanks to its advanced PMU and architectural efficiency:

- The core can run **over 10× slower** for the same workload
- Ideal for **always-on**, **battery-powered**, and **energy-harvesting** systems

3. Professional-Grade Debugging

Classic 8051 debugging is often intrusive and limited. DQ8051CPU integrates **DoCD™ Hardware Debug**, offering:

- Real-time, non-intrusive debugging
- Full visibility into CPU, memory, and peripherals
- Support for **Keil µVision** and standalone DoCD tools

4. True SoC Integration

Unlike discrete 8051 MCUs, the DQ8051CPU:

- Integrates directly into **FPGA and ASIC designs**
- Eliminates external MCU components
- Reduces BOM, latency, and power consumption

Drop-In Replacement, Future-Proof Design

The **DQ8051CPU is a drop-in CPU replacement for classic 8051 microcontrollers**, delivering:

- Zero firmware rewrite
- Higher performance
- Lower power
- Better debug
- Full SoC integration

It enables engineers to **extend the life of proven 8051 software** while moving confidently into **modern silicon platforms**.

Best Fit Applications

- Legacy 8051 system upgrades
- Industrial and automotive controllers
- Low-power embedded systems
- FPGA-based designs replacing discrete MCUs
- Cost-optimized ASIC SoCs

ALL DCD'S IP CORES ARE TECHNOLOGY AGNOSTIC, ENSURING 100% COMPATIBILITY WITH ALL FPGA AND ASIC VENDORS.

For further details, email info@dcd-semi.com

CPU FEATURES

- software is 100% compatible with 8051 industry standard
- Quad-Pipelined architecture enables to run 28.40 times faster, than the original 80C51 at the same frequency
- Up to 26.721 VAX MIPS at 100 MHz
- 24 times faster multiplication
- 12 times faster division
- 2 Data Pointers (DPTR) – for faster memory blocks copying
  - Advanced INC & DEC modes
  - Auto-switch of current DPTR
- Up to 256 bytes of internal (on-chip) Data Memory – IDM
- Up to 64k bytes of Program Memory
- Up to 16 MB of external (off-chip) Data Memory – XDM
  - Synchronous interface – for up to 64K bytes of (on-chip) fast external Data Memory – (SXDM)
- User programmable Program Memory Wait States solution – for wide range of memories' speed
- User programmable External Data Memory Wait States solution – for wide range of memories' speed
- De-multiplexed Address/Data bus – to allow easy memory connection
- Interface for additional Special Function Registers
- Fully synthesizable
- Static synchronous design
- No internal tri-states
- Scan test ready
- USB, Ethernet, I2C, SPI, UART, CAN, LIN, HDLC, Smart Card

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interfaces available

DESIGN FEATURES

PROGRAM MEMORY:
The DQ8051CPU soft core is dedicated for operation with Internal or External Program Memory. Program Memory can be implemented as ROM, RAM or FLASH.

INTERNAL DATA MEMORY:
The DQ8051CPU can address Internal Data Memory of up to 256 bytes The Internal Data Memory can be implemented as synchronous RAM.

EXTERNAL DATA MEMORY:
The DQ8051CPU soft core can address up to 16 MB of External Data Memory. Extra DPX (Data Pointer eXtended) register is used for segments swapping.

SYNCHRONOUS XDM:
The DQ8051CPU soft core can address up to 64kB of fast on-chip Synchronous External Data Memory. All reads and writes are executed in one clock cycle.

USER SPECIAL FUNCTION REGISTERS:
Up to 60 External (user) Special Function Registers (ESFRs) may be added to the DQ8051CPU 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 core SFR.

WAIT STATES SUPPORT:
The DQ8051CPU 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.

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 into memory a required data
    - address by read from memory a required data
    - Instructions Smart Trace Buffer – configurable up to 8192 levels (optional)
    - Automatic adjustment of debug data transfer speed rate between HAD and Silicon
    - JTAG Communication interface
- Power Management Unit
  - Power management mode
  - Switchback feature
  - Stop mode
- Extended Interrupt Controller
  - 2 priority levels
  - 2 external interrupt sources

UNITS SUMMARY

ALU – Arithmetic Logic Unit performs the arithmetic and logic operations, during execution of an instruction. It 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 – It performs the core synchronization and data flow control. This module is directly connected to Opcode Decoder and it manages the execution of all microcontroller tasks.
Program Memory Interface – Program Memory Interface contains Program Counter (PC) and related logic. It 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 or DoCD™ module.
External Data Memory Interface – It contains memory access related registers, such as Data Pointer High (DPH), Data Pointer Low (DPL), Data Page Pointer (DPP), MOVX @Ri address register (MXAX) and STRETCH registers. It performs the memory addressing and data transfers. It also allows applications software to access up to 16MB of external data memory. The DPP register is used for segments swapping. STRETCH register allows flexible timing management, while accessing different speed system devices, by programming XDATAWR and XDATARD pulse width between 1 and 8 clock periods.
Synchronous eXternal Data Memory (SXDM) Interface – contains XDATA memory access related logic, allowing fast access to synchronous memory devices. It performs the external Data Memory addressing and data transfers. This memory can be used to store large variables frequently accessed by CPU, improving overall performance of application.
Internal Data Memory Interface – Interface controls access to the internal memory of size up to 256 bytes. It contains 8-bit Stack Pointer (SP) register and related logic.
User SFRs Interface – Special Function Registers interface controls access to the special registers. It 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 – Interrupt Controller module is responsible for the interrupt manage system of external and

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internal interrupt sources. It contains interrupt related registers, such as Interrupt Enable (IE), Interrupt Priority (IP) and (TCON) registers.

Power Management Unit – 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 full speed mode, if enabled. It's highly desirable, when the microcontroller is planned to be used in portable and power critical applications.

DoCD™ Debug Unit – it's a **real-time hardware debugger**, which provides debugging capability of a whole SoC system. Unlike other on-chip debuggers, **DoCD™** ensures **non-intrusive debugging** of running application. It can halt, run, step into or skip an instruction, read/write any contents of 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. CODERUN is active, when the CPU is executing an instruction. The DEBUGACS pin is active when any access is performed by **DoCD™** debugger. The **DoCD™** system includes **JTAG interface** and 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 DQ8051CPU 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.

- Second Data Pointer (DPTR1) – *used/unused*
- DPTR0 decrement – *used/unused*
- DPTR1 decrement – *used/unused*
- Data Pointers auto-switch – *used/unused*
- Data Pointers auto-update – *used/unused*
- Interrupts – *subroutines location*
- Power Management Mode – *used/unused*
- Stop mode – *used/unused*
- Synchronous XDM – *size*
- DoCD™ debug unit – *used/unused*

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

PERFORMANCE

One of the most important performance parameters is the real application speed improvement when compared to the well-known 80C51 architecture. The Dhrystone Benchmark Version 2.1 was used to measure the 80C51 and the DQ8051CPU core performance. The following table gives a survey about the DQ8051CPU performance in Dhrystone VAX MIPS per 1 MHz and its improvement vs. 80C51.

Device	DMIPS/MHz	Ratio
80C51	0,00941	1,00
DQ8051	0,18527	19,69
DQ8051+DPTRs	0,22369	23,77
DQ8051+DPTRs+SXDM	0,23650	25,13
DQ8051+DPTRs+SXDM+MDU32	0,25053	26,62

The following table gives a survey about the DQ8051CPU core area in **INTEL FPGA** Programmable Logic Devices after Place & Route (CPU features and peripherals included):

Device	Speed	Min area LE/ALM	F_{max}
CYCLONE-III	-6	2 550	60 MHz
CYCLONE-IV GX	-6	2 550	60 MHz
STRATIX-II	-3	1 700	70 MHz
STRATIX-III	-2	1 700 LUT	100 MHz
STRATIX-IV	-1	1 700 LUT	100 MHz
STRATIX-V	-2	1 700 LUT	90 MHz

Results given for working system with two DPTRs and 256B IDM, 8kB CODE and 2kB SXDM memories.

DELIVERABLES

- HDL Source Code
- Testbench environment
  - Automatic Simulation macros
  - Tests with reference responses
- Synthesis scripts
- Technical documentation
- 12 months of technical support

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.

– Remote Access license option – allows authorized users to access and use the licensed product from a remote location.

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.

The IP is delivered in HDL Source code suitable for ASIC and FPGA projects.

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