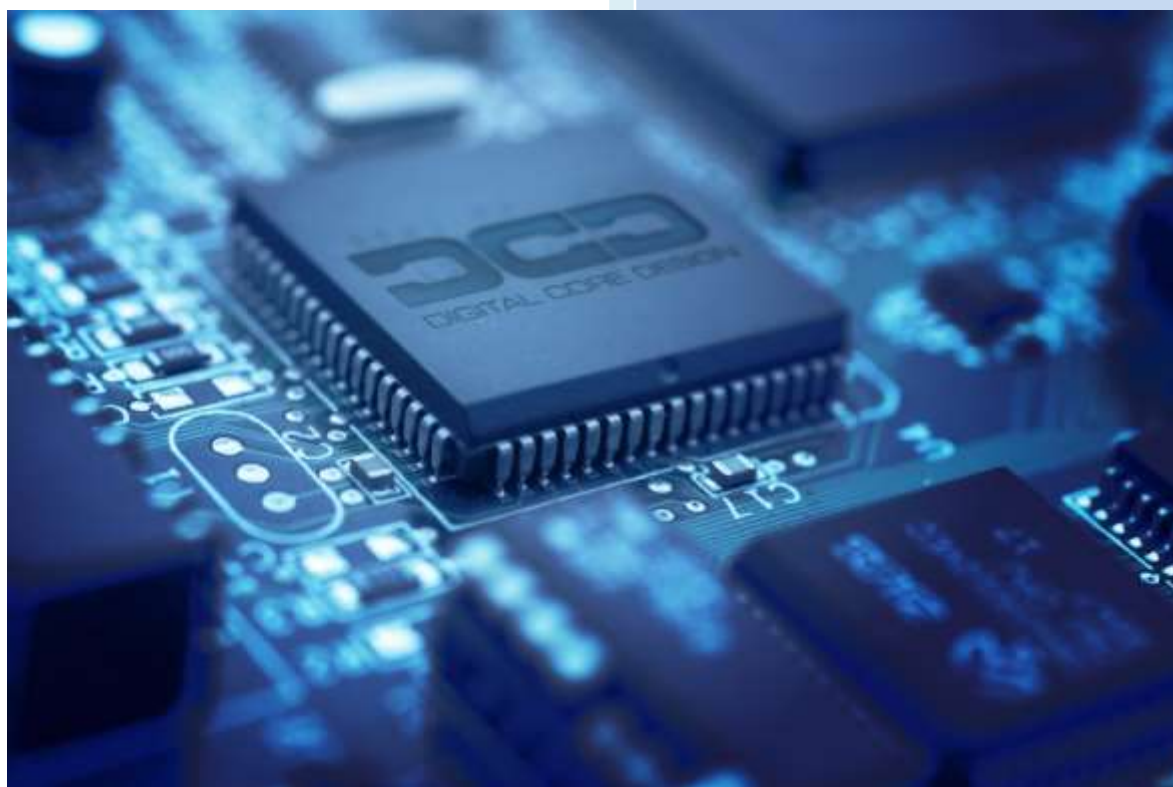




2017

DP80C51 IP Core



Pipelined High Performance 8-bit Microcontroller v. 4.01

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 micro-controllers and SoCs, we are designing solutions tailored to your needs.

IP CORE OVERVIEW

The DP80C51 is an **ultra-high performance, speed optimized** soft core of a single-chip 8-bit embedded controller, dedicated to operate with **fast** (typically on-chip) and **slow** (off-chip) memories. The core has been designed with a special concern about **performance to power consumption** ratio. This ratio is extended by an advanced power management unit - the **PMU**. The DP80C51 is 100% binary and **pin compatible** with the industry standard 8051 8-bit microcontroller. There are two configurations of the DP80C51: **Harvard**, where an external data and program buses are separated and **von Neumann**, with a common program and an external data bus. The DP80C51 has a Pipelined RISC architecture, up to **10 times faster** compared to the standard architecture - it executes **85-200 million instructions** per second. This performance can be also exploited to a great advantage in **low power** applications, where the core can be clocked over ten times slower than the original implementation, with no performance penalty. The DP80C51 is delivered with **fully automated test bench** and **complete set of tests**, allowing easy package validation at each stage of SoC design flow.

CPU FEATURES

- 100% pin compatible with the 8051 industry standard
- 100% software compatible with 8051 industry standard
- Pipelined RISC architecture enables to execute instructions up to 10 times faster compared to a standard 8051
- 24 times faster multiplication
- 12 times faster addition
- Up to 256 bytes of internal (on-chip) Data Memory
- Up to 64K bytes of internal (on-chip) or external (off-chip) Program Memory
- User programmable Program Memory Wait States solution, for a wide range of memories speed
- User programmable External Data Memory Wait States solution, for a wide range of memories speed
- Dedicated signal for Program Memory writes
- Interface for additional Special Function Registers
- Fully synthesizable, static synchronous design, with positive edge clocking and no internal tri-states
- Scan test ready
- **2.0 GHz virtual** clock frequency in a 0.25u technological process

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 OP CODE breakpoints
 - Hardware execution watch-point
 - one at Internal (direct) Data Memory
 - one at Special Function Registers (SFRs)
 - one at External Data Memory
 - Hardware watch-points activated at a certain
 - address by any write into memory
 - address by any read from memory
 - address by write into memory required data
 - address by read from memory required data
 - Unlimited number of software watch-points
 - Internal (direct) Data Memory
 - Special Function Registers (SFRs)
 - External Data Memory
 - Unlimited number of software breakpoints
 - Program Memory(PC)
 - 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

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 in one place.

Multi-Site license option – dedicated to corporate customers, who operate at several locations. The licensed product can be used in selected company branches.

In all cases the number of IP Core instantiations within a project and the number of manufactured chips are unlimited. The license is royalty-per-chip free. There are no restrictions regarding the time of use.

There are two formats of the delivered IP Core:

- VHDL or Verilog RTL synthesizable HDL Source code
- FPGA EDIF/NGO/NGD/QXP/VQM Netlist

CONFIGURATION

The following parameters of the DP80C51 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
- **Interrupts**
 - subroutines location
- Power Management Mode
 - used
 - unused
- Stop mode
 - used
 - unused
- **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.

DESIGN FEATURES

◆ PROGRAM MEMORY:

The DP80C51 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 $0x0000 \div (ROM_{size}-1)$
- RAM located in address range between $(RAM_{size}-1) \div 0xFFFF$

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

◆ INTERNAL DATA MEMORY:

The DP80C51 can address Internal Data Memory of up to 256 bytes. The Internal Data Memory can be implemented, as a Single-Port synchronous RAM.

◆ EXTERNAL DATA MEMORY:

The DP80C51 soft core can address up to 64 kB of External Data Memory.

◆ USER SPECIAL FUNCTION REGISTERS:

Up to 104 External (user) Special Function Registers (ESFRs) may be added to the DP80C51 design. ESFRs are memory mapped into Direct Memory, between addresses 0x80 and 0xFF, in the same manner, as core SFRs. They may occupy any address that is not occupied by a SFR core.

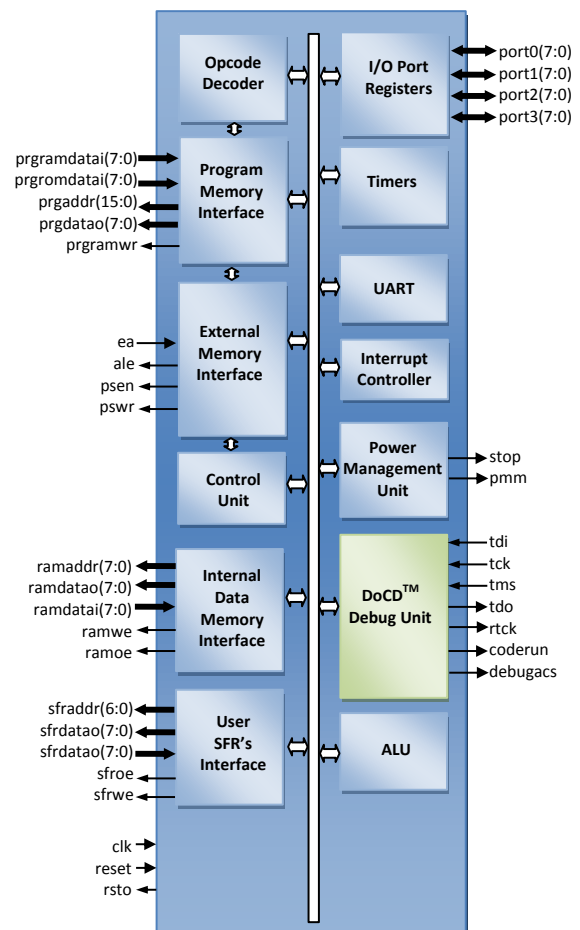
◆ WAIT STATES SUPPORT:

The DP80C51 soft core is dedicated for operation with a 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.

DELIVERABLES

- ◆ Source code:
 - VHDL Source Code or/and
 - VERILOG Source Code or/and
 - Encrypted, or plain text EDIF
- ◆ VHDL & VERILOG 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
- ◆ Technical support
 - IP Core implementation support
 - 3 months maintenance
 - Delivery of the IP Core and documentation updates, minor and major versions changes
 - Phone & email support

BLOCK DIAGRAM



UNITS SUMMARY

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 – Performs the core synchronization and data flow control. This module is directly connected to Opcode Decoder and manages 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 Memory Interface - Contains memory access related registers, such as Data Page High (DPH), Data Page Low (DPL). It 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.

Internal Data Memory Interface – Interface controls access into 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 control module is responsible for the interrupt manage system, for the external and internal interrupt sources. It contains interrupt related registers, such as Interrupt Enable (IE), Interrupt Priority (IP) and (TCON) registers. Please note, that external pins of this module are connected to appropriate pins of P3 port.

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 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 a clock source for UARTs. Please note, that external pins of this module are connected to appropriate pins of P3 port.

UART0 – Universal Asynchronous Receiver and Transmitter module is full duplex, which means that it can transmit and receive concurrently. Includes Serial Configuration register (SCON), serial receiver and transmitter buffer (SBUF) registers. Its receiver is double-buffered, meaning, 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. Please note, that external pins

of this module are connected to appropriate pins of P3 port.

Ports - Block contains 8051's general purpose I/O ports. Each of port's pin can be read/written as a single bit or as an 8-bit bus P0, P1, P2, P3. The P0, P2, P3 are multi-functional ports. When used with External memory P0 works as a multiplexed Data/LSB address to memory, and P2 works as a MSB address to external memory, P3.6 is a write signal and P3.7 is a read signal. Functionality of port is the same as in legacy 80C51 microcontroller.

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 is highly desirable, when microcontroller is planned to be used in portable and power critical applications.

DoCD™ Debug Unit – It is 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 CPU is executing an instruction. DEBUGACS pin is active, when any access is performed by **DoCD™** debugger. The **DoCD™** system includes **TTAG** or **JTAG interface** and complete set of tools, to communicate and work with 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 debugger is not used, it is automatically switched to power save mode. Finally, when debug option is no longer used, whole debugger is turned off.

DP8051 FAMILY OVERVIEW

Main features of each DP80C51 family member have been summarized in the table below. It gives a brief member characteristic, helping you to select the most suitable IP Core for your application. You can specify your own peripheral set (including listed below and others) and requests the core modifications.

| Design | Architecture speed grade | Program Memory space | | | Stack space size | Internal Data Memory space | External Data Memory space | External Data / Program Memory Wait States | Power Management Unit Interface for additional SFRs | Interrupt sources | Interrupt levels | Data Pointers | Timer/Counters | UART | I/O Ports | Compare/Capture | Watchdog | Master I ² C Bus Controller | Slave I ² C Bus Controller | SPI | Fixed Point Coprocessor | Floating Point Coprocessor |
|-----------|--------------------------|----------------------|-------------|----------|------------------|----------------------------|----------------------------|--|---|-------------------|------------------|---------------|----------------|------|-----------|-----------------|----------|--|---------------------------------------|-----|-------------------------|----------------------------|
| | | on-chip RAM | on-chip ROM | off-chip | | | | | | | | | | | | | | | | | | |
| DP8051CPU | 10 | 64k | 64k | 64k | 256 | 256 | 16M | ✓ | ✓ | ✓ | 2 | 2 | 1 | - | - | - | - | - | - | - | - | - |
| DP8051 | 10 | 64k | 64k | 64k | 256 | 256 | 16M | ✓ | ✓ | ✓ | 5 | 2 | 1 | 2 | 1 | 4 | - | - | - | - | - | - |
| DP8051XP | 10 | 64k | 64k | 64k | 256 | 256 | 16M | ✓ | ✓ | ✓ | 15 | 2 | 2 | 3 | 2 | 4 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

DP8051 family of Pipelined High Performance Microcontroller Cores

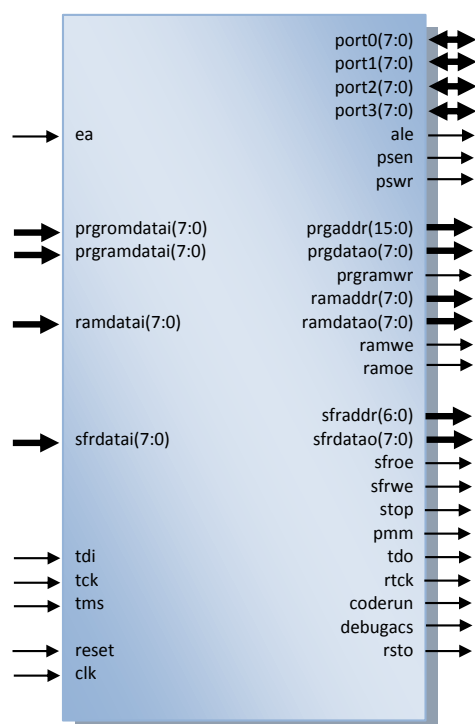
DP80390 FAMILY OVERVIEW

Main features of each DP80390 family member have been summarized in the table below. It gives a brief member characteristic, helping you to select the most suitable IP Core for your application. You can specify your own peripheral set (including listed below and others) and requests the core modifications.

| Design | Architecture speed grade | Program Memory space | | | Stack space size | Internal Data Memory space | External Data Memory space | External Data / Program Memory Wait States | Power Management Unit Interface for additional SFRs | Interrupt sources | Interrupt levels | Data Pointers | Timer/Counters | UART | I/O Ports | Compare/Capture | Watchdog | Master I ² C Bus Controller | Slave I ² C Bus Controller | SPI | Fixed Point Coprocessor | Floating Point Coprocessor |
|------------|--------------------------|----------------------|-------------|----------|------------------|----------------------------|----------------------------|--|---|-------------------|------------------|---------------|----------------|------|-----------|-----------------|----------|--|---------------------------------------|-----|-------------------------|----------------------------|
| | | on-chip RAM | on-chip ROM | off-chip | | | | | | | | | | | | | | | | | | |
| DP80390CPU | 10 | 64k | 64k | 8M | 256 | 256 | 16M | ✓ | ✓ | ✓ | 2 | 2 | 1 | - | - | - | - | - | - | - | - | - |
| DP80390 | 10 | 64k | 64k | 8M | 256 | 256 | 16M | ✓ | ✓ | ✓ | 5 | 2 | 1 | 2 | 1 | 4 | - | - | - | - | - | - |
| DP80390XP | 10 | 64k | 64k | 8M | 256 | 256 | 16M | ✓ | ✓ | ✓ | 15 | 2 | 2 | 3 | 2 | 4 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

DP80390 family of Pipelined High Performance Microcontroller Cores

SYMBOL



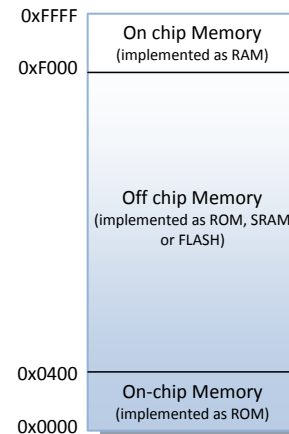
PINS DESCRIPTION

| PIN | TYPE | DESCRIPTION |
|-----------------|-------|---|
| clk | input | Global clock |
| reset | input | Global reset input |
| port0[7:0] | bidir | I/O Port 0, multifunctional Data/LSB address of external memory |
| port1[7:0] | bidir | I/O Port 1 |
| port2[7:0] | bidir | I/O Port 2, multifunctional MSB address of external memory |
| port3[0] | bidir | I/O Port 3.0 Serial receiver input/output port |
| port3[1] | bidir | I/O Port 3.1 Serial transmitter output port |
| port3[2] | bidir | I/O Port 3.2, multifunctional Interrupt 0 input/timer 0 gate |
| port3[3] | bidir | I/O Port 3.3, multifunctional Interrupt 1 input/timer 1 gate |
| port3[4] | bidir | I/O Port 3.4, multifunctional Timer 0 external clock line |
| port3[5] | bidir | I/O Port 3.5, multifunctional Timer 1 external clock line |
| port3[6] | bidir | I/O Port 3.6 External Data Memory write |
| port3[7] | bidir | I/O Port 3.7 External Data Memory read |
| ea | input | Enable all external program memory |
| rgramdatai[7:0] | input | Data bus from int. RAM prog. memory |
| rgromdatai[7:0] | input | Data bus from int. ROM prog. memory |
| ramdatai[7:0] | input | Data bus from internal data memory |
| sfrdatai[7:0] | input | Data bus from user SFR's |
| tdi | input | DoCD™ TAP data input |
| tck | input | DoCD™ TAP clock input |

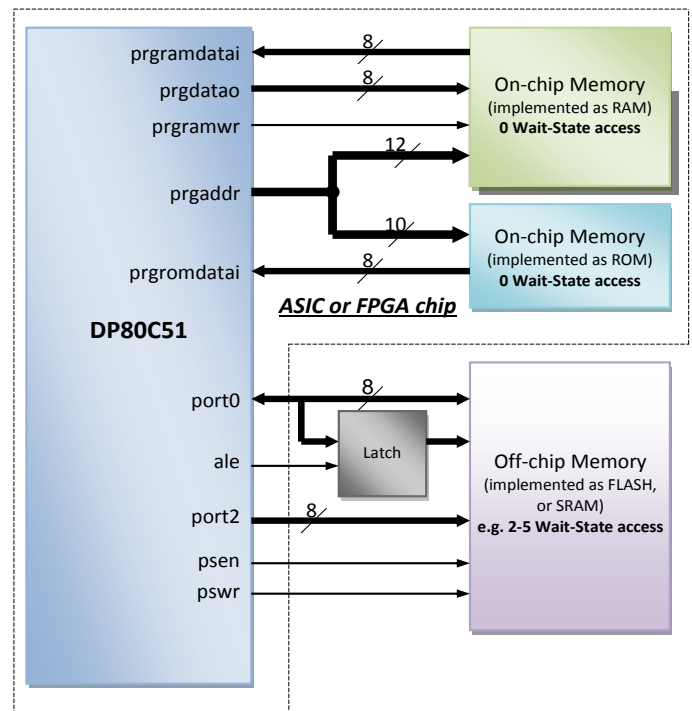
| | | |
|---------------|--------|--------------------------------------|
| tms | input | DoCD™ TAP mode select input |
| rsto | output | Reset output |
| prgaddr[15:0] | output | Internal program memory address bus |
| prgdatao[7:0] | output | Data bus for internal program memory |
| prgramwr | output | Internal program memory write |
| ale | output | Address Latch Enable |
| psen | output | Program Store (memory) read Enable |
| pswr | output | Program Store (memory) Write |
| ramaddr[7:0] | output | Internal Data Memory address bus |
| ramdatao[7:0] | output | Data bus for internal data memory |
| ramoe | output | Internal data memory output enable |
| ramwe | output | Internal data memory write enable |
| sfraddr[6:0] | output | Address bus for user SFR's |
| sfrdatao[7:0] | output | Data bus for user SFR's |
| sfroe | output | User SFR's read enable |
| sfrwe | output | User SFR's write enable |
| tdo | output | DoCD™ TAP data output |
| rtck | output | DoCD™ return clock line |
| debugacs | output | DoCD™ accessing data |
| coderrun | output | CPU is executing an instruction |
| pmm | output | Power management mode indicator |
| stop | output | Stop mode indicator |

PROGRAM CODE SPACE IMPLEMENTATION

The following figure shows an example Program Memory space implementation in systems with the DP80C51 Microcontroller core. The On-chip Program Memory located in address space between 0kB and 1kB, is typically used for BOOT code with system initialization functions. This part of the code is typically implemented as ROM. The on-chip Program Memory located in address space between 60kB and 64kB, is typically used for timing critical part of the code e.g. interrupt subroutines, arithmetic functions etc. This part of the code is typically implemented as RAM and can be loaded by the BOOT code during initialization phase, from off-chip memory or through a RS232 interface from an external device. The program code is executed from the two spaces mentioned above without wait-states and can achieve top performance, up to 200 million instructions per second (many instructions executed in one clock cycle). The off-chip Program Memory located in address space between 1kB and 60kB is typically used for main code and constants. This part of the code is usually implemented as ROM, SRAM or FLASH device. Due to relatively long access time, the program code executed from devices mentioned above must be fetched with additional Wait-States. The number of required Wait-States depends on memory access time and the DP80C51 clock frequency.



In most cases, the proper number of Wait-States cycles is between 2 and 5. The READY pin can be also dynamically modulated by e.g. SDRAM controller. The figure below shows typical Program Memories connections in a system with the DP80C51 Microcontroller Core.



The implementation above should be treated as an example. All Program Memory spaces are fully configurable.

For timing-critical applications, the whole program code can be implemented as an on-chip ROM and (or) RAM and executed without Wait-States, but for some other applications, the whole program code can be implemented as an off-chip ROM or FLASH and executed with required number Wait-State cycles.

PERFORMANCE

The following tables give a survey about the Core area and performance in ASIC Devices (CPU features and peripherals included):

| Device | Optimization | F _{max} |
|---------------|--------------|------------------|
| 0.25u typical | area | 100 MHz |
| 0.25u typical | speed | 250 MHz |

Core performance in ASIC devices

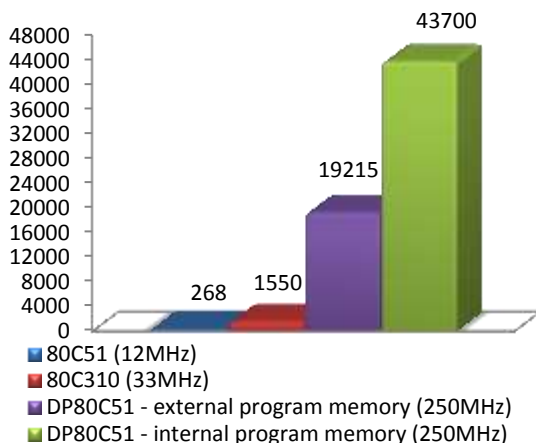
For the user, the most important aspect is an application speed improvement. The most commonly used arithmetic functions and their improvement, are shown in the table below. The improvement was computed as {80C51 clock periods}, divided by {DP80C51 clock periods}, required to execute an identical function for code, executed from internal (first column) and external (second column) program memory. More details are available in the core documentation.

| Function | Improvement | |
|--|--------------|-------------|
| 8-bit addition (<i>immediate data</i>) | 9,00 | 3,00 |
| 8-bit addition (<i>direct addressing</i>) | 9,00 | 3,00 |
| 8-bit addition (<i>indirect addressing</i>) | 9,00 | 3,60 |
| 8-bit addition (<i>register addressing</i>) | 12,00 | 4,00 |
| 8-bit subtraction (<i>immediate data</i>) | 9,00 | 3,00 |
| 8-bit subtraction (<i>direct addressing</i>) | 9,00 | 3,00 |
| 8-bit subtraction (<i>indirect addressing</i>) | 9,00 | 3,60 |
| 8-bit subtraction (<i>register addressing</i>) | 12,00 | 4,00 |
| 8-bit multiplication | 16,00 | 6,00 |
| 8-bit division | 9,60 | 4,80 |
| 16-bit addition | 12,00 | 4,00 |
| 16-bit subtraction | 12,00 | 4,00 |
| 16-bit multiplication | 13,60 | 5,47 |
| 32-bit addition | 12,00 | 4,00 |
| 32-bit subtraction | 12,00 | 4,00 |
| 32-bit multiplication | 12,60 | 4,89 |
| Average speed improvement: | 11,12 | 4,03 |

Dhrystone Benchmark Version 2.1 was used to measure the Core performance. The following table gives a survey about the DP80C51 performance in terms of Dhrystone/sec and VAX MIPS rating for testing code executed from external (1) and internal (2) program memory.

| Device | Target | Clock frequency | Dhry/sec (VAX MIPS) |
|----------------------|--------|-----------------|---------------------|
| 80C51 | - | 12 MHz | 268 (0.153) |
| 80C310 | - | 33 MHz | 1550 (0.882) |
| DP80C51 ¹ | 0.25u | 250 MHz | 19215 (10,938) |
| DP80C51 ² | 0.25u | 250 MHz | 43700 (24.872) |

Core performance in terms of Dhrystones



An area utilized by each unit of the DP80C51 core in vendor specific technologies is summarized in the table below.

| Component | Area | |
|-----------------------|-------------|------------|
| | [Gates] | [FFs] |
| CPU* | 6100 | 310 |
| Interrupt Controller | 450 | 40 |
| Power Management Unit | 50 | 5 |
| I/O ports | 400 | 35 |
| Timers | 550 | 50 |
| UART0 | 650 | 60 |
| Total area | 8200 | 500 |

*CPU – consisted of ALU, Opcode Decoder, Control Unit, Program & Internal & External Memory Interfaces, User SFRs Interface

Core components area utilization

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