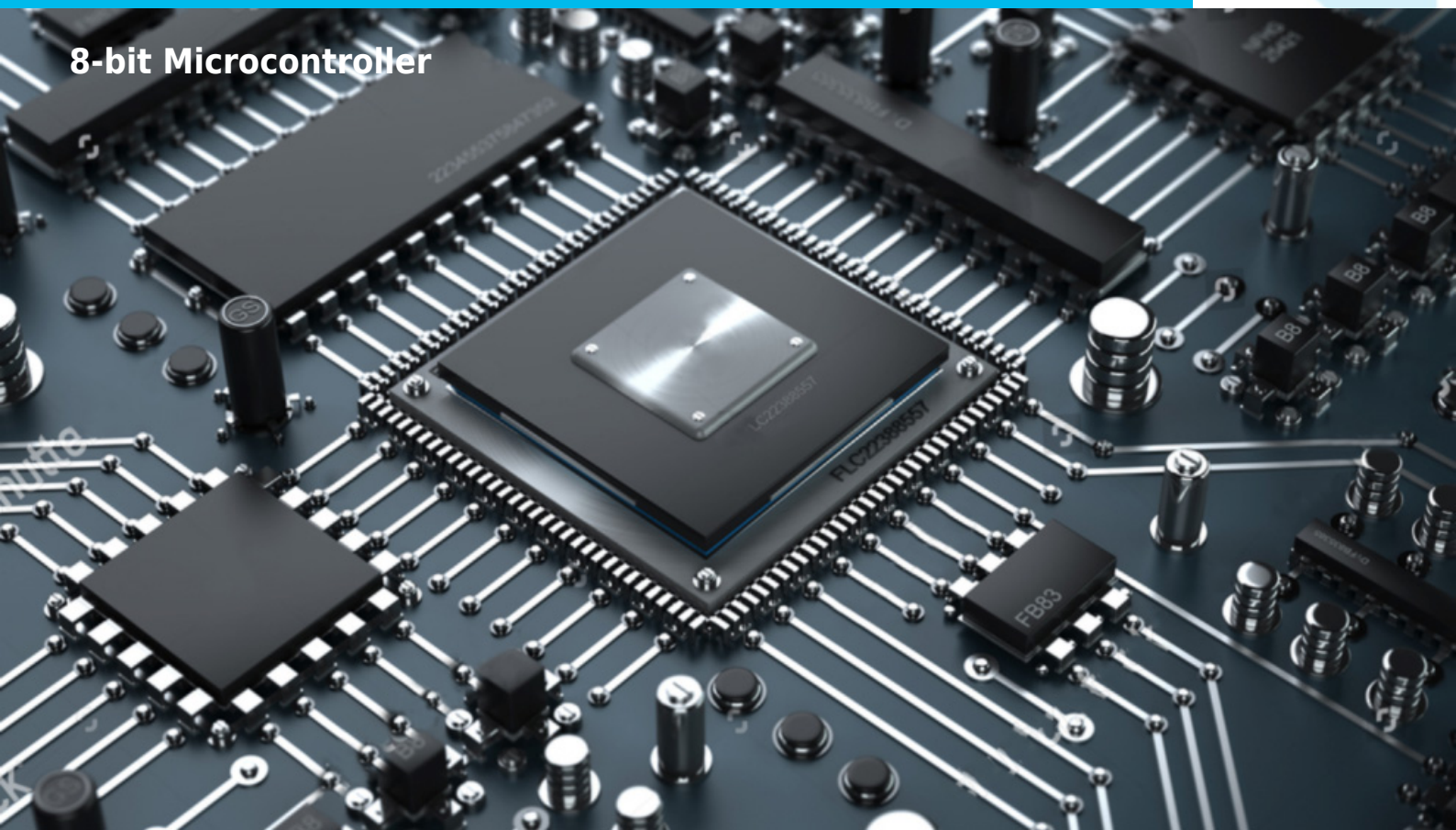
DIGITAL CORE DESIGN

D68HC11E

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

D68HC11E MICROCONTROLLER IP CORE

Fully Compatible 68HC11E Soft MCU for Modern SoC Integration

The **D68HC11E** is a fully synthesizable **8-bit soft microcontroller IP Core**, designed as a drop-in replacement for the **Motorola 68HC11E** family. It maintains full binary and functional compatibility with **68HC11E**, as well as legacy **68HC11A** and **68HC11D** microcontrollers, enabling seamless migration of existing hardware and software designs into modern System-on-Chip (SoC) implementations.

Integrated Peripherals and System Control

In its standard configuration, the D68HC11E integrates all major peripheral functions on-chip. It includes an **asynchronous Serial Communications Interface (SCI)** and a dedicated **Serial Peripheral Interface (SPI)**, supporting reliable communication in embedded and industrial systems.

A **16-bit free-running timer system** provides input capture, output compare channels, and real-time interrupt functionality. Additionally, an **8-bit pulse accumulator subsystem** enables accurate counting of external events or precise measurement of external signal periods.

Reliability, Safety, and Low-Power Operation

The D68HC11E incorporates built-in self-monitoring and protection mechanisms to ensure robust system operation. A **Computer Operating Properly (COP) watchdog** safeguards against software failures, while **illegal opcode detection** triggers a non-maskable interrupt to protect against unexpected execution errors.

For power-sensitive applications, the core offers two software-controlled low-power modes—**WAIT** and **STOP**—making it especially suitable for **automotive electronics**, **battery-powered systems**, and energy-efficient embedded designs.

Optional ADC Support and Full Customization

The D68HC11E can be equipped with an **ADC Controller**, enabling seamless use of external ADC hardware with standard 68HC11 ADC software. External ADCs appear as internal peripherals, preserving full software compatibility with original 68HC11E microcontrollers.

The IP Core is **fully customizable** and delivered in an exact configuration tailored to project requirements. This approach eliminates unnecessary features, reduces silicon area, and avoids paying for unused functionality.

Verification and Advanced Debugging

To simplify SoC integration and validation, the D68HC11E is delivered with a **fully automated test bench** and a comprehensive verification suite, supporting validation at every stage of the design flow.

Each D68HC11E Core includes built-in support for **DoCD™**, DCD's advanced **real-time hardware debugging system**. DoCD™ enables **non-intrusive debugging** of a running application, allowing developers to halt, run, step through code, and read or write all system resources—including registers, SFRs, program memory, data memory, and user-defined peripherals—across the entire SoC.

Typical Applications

- Automotive control systems
- Battery-powered embedded devices
- Industrial automation and control
- Legacy 68HC11 system migration to SoC

D68HC11E VS CLASSIC 68HC11 – IP CORE COMPARISON

While the original **Motorola 68HC11** microcontrollers defined an industry standard for automotive and industrial control, modern SoC designs demand higher flexibility, easier integration, and advanced debug capabilities. The **DCD-SEMI D68HC11E IP Core** preserves full compatibility while removing the limitations of legacy silicon.

Feature	Classic 68HC11 MCU	DCD-SEMI D68HC11E IP Core
Binary Compatibility	✔ Yes	✔ 100% compatible
Synthesizable IP	✖ No	✔ Yes
Technology Node	Fixed, legacy	✔ Any modern CMOS process
Peripheral Set	Fixed	✔ Fully configurable
Silicon Utilization	Fixed die size	✔ Optimized – only required logic

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Feature	Classic 68HC11 MCU	DCD-SEMI D68HC11E IP Core
Power Modes	WAIT / STOP	✔ WAIT / STOP (software compatible)
ADC Integration	Fixed on-chip ADC	✔ Optional external ADC mapped as internal
Debugging	Limited / intrusive	✔ DoCD™ non-intrusive SoC-level debug
Verification	Not available	✔ Fully automated testbench
SoC Integration	Not possible	✔ Designed for SoC environments

Key Advantage:
The D68HC11E allows engineers to **reuse proven 68HC11 software and know-how**, while gaining **SoC scalability, lower power consumption, reduced silicon cost, and professional-grade debugging**—none of which are possible with legacy discrete MCUs.

WHY CHOOSE D68HC11E INSTEAD OF ARM CORTEX-M?

ARM Cortex-M microcontrollers dominate new designs—but they are not always the best choice, especially when **legacy software, deterministic behavior, or long product lifecycles** matter.

When D68HC11E Is the Better Choice

✔ Zero Software Migration Risk
D68HC11E is fully compatible with existing 68HC11 codebases. No recompilation, no revalidation, no functional regressions—critical for safety-related and long-lifecycle products.

✔ Predictable, Deterministic Execution
Unlike Cortex-M systems with complex pipelines, caches, and bus matrices, the 68HC11 architecture delivers **fully deterministic timing**, ideal for real-time control and automotive logic.

✔ Smaller, Leaner Silicon Footprint
Cortex-M cores often include unused features (NVIC, SysTick, MPU). D68HC11E is **configured exactly to your needs**, minimizing area and power.

✔ No Vendor Lock-In
ARM cores require licenses, toolchains, and ecosystem dependencies. D68HC11E is a **license-clear, fully controllable IP**, ideal for proprietary and long-term industrial designs.

✔ Superior SoC Debug Visibility
With **DoCD™**, D68HC11E provides **non-intrusive, full-system debugging**, including custom peripherals—capabilities often limited or intrusive in Cortex-M implementations.

Ideal Use Cases vs Cortex-M

- Automotive body electronics
- Industrial controllers with certified software
- Battery-powered embedded systems
- Legacy MCU replacement inside modern 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

- Cycle compatible with original implementation
- Software compatible with 68HC11 industry standard
- I/O Wrapper making it pin-compatible core
- SFR registers remapped to any 4KB memory page
- Two power saving modes: STOP, WAI
- Fully synthesizable
- Static synchronous design
- No internal tri-states
- Scan test ready
- USB, Ethernet, I2C, SPI, UART, CAN, LIN, HDLC, Smart Card interfaces available

DESIGN FEATURES

- One global system clock
- Synchronous reset
- All asynchronous input signals are synchronized before internal use

PERIPHERALS

Peripherals listed below are implemented in a standard configuration of D68HC11E.

- **DoCD™ On-Chip Debugger**
  - Processor execution control
  - Read, write all processor contents
  - Hardware execution breakpoints
  - Three wire communication interface
- **I/O Ports**
- **Interrupt Controller**
  - Dedicated vector and interrupt priority for each interrupt source
- **Main16-bit timer/counter system**
  - 16 bit free running counter
  - Four stage programmable prescaler
  - Real Time Interrupt
- **16-bit Compare/Capture Unit**
  - Three independent input-capture

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- Five output-compare channels
- Events capturing
- Pulses and digital signals generation
- Gated timers
- Sophisticated comparator
- Pulse width modulation and measuring

- **8-bit Pulse accumulator**
  - Two major modes of operation
  - Simple event counter
  - Gated time accumulation
  - Clocked by internal source or external pin
- **SPI – Master and Slave Serial Peripheral Interface**
  - Software selectable polarity and phase of serial clock SCK
  - System errors detection
  - Allows operation from a wide range of system clock frequencies (built-in 5-bit timer)
  - Interrupt generation

- **Full-duplex UART – SCI**
  - Standard non-return-to-zero format
  - 8 or 9 bit data transfer
  - Integrated baud rate generator
  - Noise, Overrun and Framing error detection
  - IDLE and BREAK characters generation
  - Wake-up block to recognize UART wake-up from IDLE condition
  - Three SCI related interrupts

OPTIONAL PERIPHERALS

Optional peripherals (not included in the presented D68HC11E Microcontroller Core) can be implemented upon customer's request:

- **PWM – Pulse Width Modulation Timer/Counter with up to four 8-bit or two 16-bit PWM channels**
- **Memory extension unit and Chip select**
- **I2C Master & Slave bus controllers**
  - Master operation
  - Multi-master systems supported
  - Performs arbitration and clock synchronization
  - Interrupt generation
  - Supports speed up to 3,4Mb/s (standard, fast & HS modes)
  - Allows operation from a wide range of clock frequencies (built-in 8-bit timer)
  - User-defined timing
- **Floating-Point Arithmetic Coprocessor (DFPAU) IEEE-754 standard single precision**
  - FADD, FSUB – addition, subtraction
  - FMUL, FDIV- multiplication, division
  - FSQRT- square root
  - FUCOM – compare
  - FCHS – change sign
  - FABS – absolute value
- **Floating-Point Math Coprocessor (DFPMU) – IEEE-754 standard single precision real, word and short integers**
  - FADD, FSUB- addition, subtraction
  - FMUL, FDIV- multiplication, division
  - FSQRT- square root
  - FUCOM- compare
  - FCHS – change sign
  - FABS – absolute value
  - FSIN, FCOS- sine, cosine
  - FPTAN, FPATAN- tangent, arcs tangent
- **Additional special internal interrupt dedicated for DFPAU or DFPMU**

UNITS SUMMARY

Control Unit – Performs the core synchronization and data flow control. This module manages execution of all instructions. The Control Unit also manages execution of STOP instruction and waking the processor up from the STOP mode.
Opcode Decoder – Performs an instruction opcode decoding and the control functions for all other blocks**.**
ALU – Arithmetic Logic Unit performs the arithmetic and logic operations, during execution of an instruction. It contains accumulator (A, B), Condition Code Register (CCREG), Index registers X, Y and related logic, like arithmetic unit, logic unit, multiplier and divider.
Bus Controller – Program Memory, Data Memory & SFR's (Special Function Register) interface – controls access into the program and data memories and special registers. It contains Program Counter (PC), Stack Pointer (SP) register, and related logic.
Interrupt Controller – D68HC11E extended IC has implemented 17-level interrupt priority control. The interrupt requests may come from external pins (IRQ and XIRQ), as well as from particular peripherals. The D68HC11E peripheral systems generate maskable interrupts, which are recognized only, if the global interrupt mask bit (I) in the CCR, is cleared. Maskable interrupts are prioritized according to default arrangement, established during reset. However, any source may be elevated to the highest maskable priority position, by using HPRIO register. When interrupt condition occurs, an interrupt status flag is set to indicate the condition.
Timer, Compare Capture & COP Watchdog – This timer system is based on a free-running, 16-bit counter, with a 4-stage programmable prescaler. A timer overflow function allows software to extend the timing capability of the system, beyond the 16-bit range of the counter. Three independent input-capture functions are used, to automatically record the time, when a selected transition is detected at a respective timer input pin. Five output-compare functions are included for generating output signals or for timing software delays. Since the input-capture and output-compare functions may not be familiar to all users, these concepts are explained in greater detail. A programmable periodic interrupt circuit called RTI is tapped off of the main 16-bit timer counter. Software can select one of four rates for the RTI, which is most commonly used to pace the execution of software routines. The COP watchdog function is loosely related to the main timer in that the clock input to the COP system (clk*2^{17}) is tapped off the free-running counter chain. The timer subsystem involves more registers and control bits, than any other subsystem on the MCU. Each of the three input-capture functions has its own 16-bit time capture latch (input-capture

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register) and each of the five output-compare functions has its own 16-bit compare register. All timer functions, including the timer overflow and RTI, have their own interrupt controls and separate interrupt vectors. Additional control bits permit software, to control the edge(s) that trigger each input-capture function and the automatic actions that result from output-compare functions. Although hardwired logic is included to automate many timer activities, this timer architecture is mainly a software-oriented system. This structure is easily adaptable to a very wide range of applications, although it is not as efficient, as a dedicated hardware for some specific timing applications.

SCI – The SCI is a full-duplex UART type asynchronous system, using standard non return to zero (NRZ) format: 1 start bit, 8 or 9 data bits and a 1 stop bit. The D68HC11E resynchronizes the receiver bit clock on all one to zero transitions in the bit stream. The differences in baud rate between the sending device and the SCI are not as likely to cause reception errors. Three logic samples are taken near the middle of data bit time and majority logic decides the sense for the bit. The receiver also has the ability to enter a temporary standby mode (called receiver wakeup), to ignore messages intended for a different receiver. Logic automatically wakes the receiver up, in time to see the first character of the next message. This wakeup feature greatly reduces CPU overhead in multi-drop SCI networks. The SCI transmitter can produce queued characters of idle (whole characters of all logic 1) and break (whole characters of all logic 0). In addition to the usual Transmit Data Register Empty (TDRE) status flag, this SCI also provides a Transmit Complete (TC) indication that can be used in applications with a modem.

SPI Unit – it's a fully configurable master/slave Serial Peripheral Interface, which allows user to configure polarity and phase of Serial Clock Signal SCK. It allows the microcontroller, to communicate with serial peripheral devices. It is also capable of interprocessor communications, in a multi-master system. A serial clock line (SCK), synchronizes shifting and sampling of the information on the two independent serial data lines. SPI data are simultaneously transmitted and received. SPI system is flexible enough, to interface directly with numerous standard product peripherals, from several manufacturers. Data rates as high as CLK/8. Clock control logic allows a selection of clock polarity and a choice of two fundamentally different clocking protocols, to accommodate most available synchronous serial peripheral devices. When the SPI is configured as a master, software selects one of four different bit rates for the serial clock. SPI automatically drives slave select outputs SSO[7:0] and address SPI slave device, to exchange serially shifted data. Error-detection logic is included, to support interprocessor communications. A write-collision detector indicates, when an attempt is made to write data to the serial shift register, while a transfer is in progress. A multiple-master mode-fault detector automatically disables SPI output drivers if more than one SPI devices simultaneously attempts to become bus master.

Pulse Accumulator – This system is based on an 8-bit counter and can be configured to operate as a simple event counter or for gated time accumulation. Unlike the main timer, the 8-bit pulse accumulator counter can be read or written at any time (the 16-bit counter in the main timer cannot be written). Control bits allow the user to configure and control the pulse accumulator subsystem. Two maskable interrupts are associated with the system, each having its own controls and interrupt vector. The PAI pin, associated with the pulse accumulator, can be configured to act as a clock (event counting mode) or as a gate signal, to enable a free-running E divided by 64 clock to the 8-bit counter (gated time accumulation mode). The alternate functions of the pulse accumulator input (PAI) pin, present some interesting application possibilities.

I/O Ports – All ports are 8-bit general-purpose bi-directional I/O system. The PORTA, PORTB, PORTC, PORTD, PORTE data registers, have their corresponding data direction registers DDRA, DDRC, DDRD to control ports data flow. It assures, that all D68HC11's ports have full I/O selectable registers. Writes to any ports pins cause data to be stored in the data registers. If any port pins are configured as output, then data registers are driven out of those pins. Reads from port pins, configured as input, causes that input pin to be read. If port pins is configured as output, during read data register is read. Writes to any ports pins not configured as outputs, do not cause data to be driven out of those pins, but the data is stored in the output registers. Thus, if the pins later become outputs, the last data written to port will be driven out the port pins.

ADCCTRL – External ADC Controller is used as interface between D68HC11E internal registers and external serial/parallel ADC converter. This module has several different options, so its details are described in separate document.

EEPROMCTRL – External Serial EEPROM Controller. Manages data exchange between D68HC11E and external EEPROM. During initialization copies contents of the whole external EEPROM, to internal EEPRAM (EEPROM Mirror implemented in standard parallel RAM). This module has several different options, so its details are described in separate document.

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™** provides 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, external, program memories, 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 breakpoint is executed, if any write/read occurs at particular address, with certain data pattern or without pattern. The **DoCD™** system includes three-wire interface and complete set of tools, to communicate and work with core in real time debugging. It is built as 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. The separate CLKDOCD clock line allows the debugger to operate while the CPU is in STOP mode and the major clock line CLK is stopped.

PERFORMANCE

The following table gives a survey about the Core area and

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performance in **AMD FPGA** devices after Place & Route:

Device	Speed grade	Slices	F_{max}
SPARTAN2	-6	2 049	33 MHz
SPARTAN2E	-7	2 049	35 MHz
SPARTAN3	-5	2 047	47 MHz
SPARTAN3E	-5	2 047	47 MHz
SPARTAN6	-3	2 282	76 MHz
VIRTEX	-6	2 047	33 MHz
VIRTEX2	-6	2 047	67 MHz
VIRTEX4	-12	2 041	92 MHz

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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