US006338109B1

(12) **United States Patent**
Snyder et al.

(10) **Patent No.: US 6,338,109 B1**
(45) **Date of Patent: *Jan. 8, 2002**

(54) **MICROCONTROLLER DEVELOPMENT SYSTEM AND APPLICATIONS THEREOF FOR DEVELOPMENT OF A UNIVERSAL SERIAL BUS MICROCONTROLLER**

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(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **08/711,419**

(22) Filed: **Aug. 30, 1996**

(51) **Int. Cl.**[7] **G06F 13/00**
(52) **U.S. Cl.** **710/129**; 710/100; 710/126; 710/127; 711/103; 714/29; 395/500
(58) **Field of Search** 395/183.05, 200.53, 395/500, 306, 309, 307, 280; 703/23, 28; 711/103; 714/29; 709/223; 710/129, 127, 100, 126

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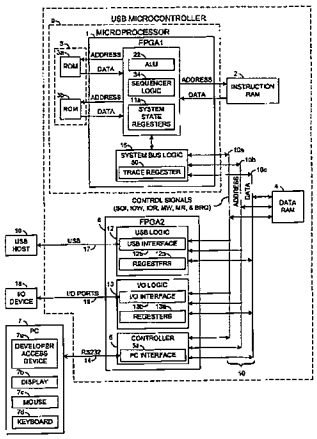
(57) **ABSTRACT**

A microcontroller including a system bus; a microprocessor coupled to the system bus and configured to transfer data and control signals over the system bus; a memory device coupled to the microprocessor and mapped to the system bus and configured to store microprogram instructions for execution by the microprocessor; a controller coupled to the system bus and configured to transfer data and control signals to the microprocessor over the system bus; a host interface coupled to the system bus and configured to interface to a host computer and receive the data and the control signals over the system bus from the microprocessor; and an I/O interface coupled to the system bus and configured to interface to at least one I/O device and receive the data and the control signals over the system bus from the microprocessor.

23 Claims, 2 Drawing Sheets



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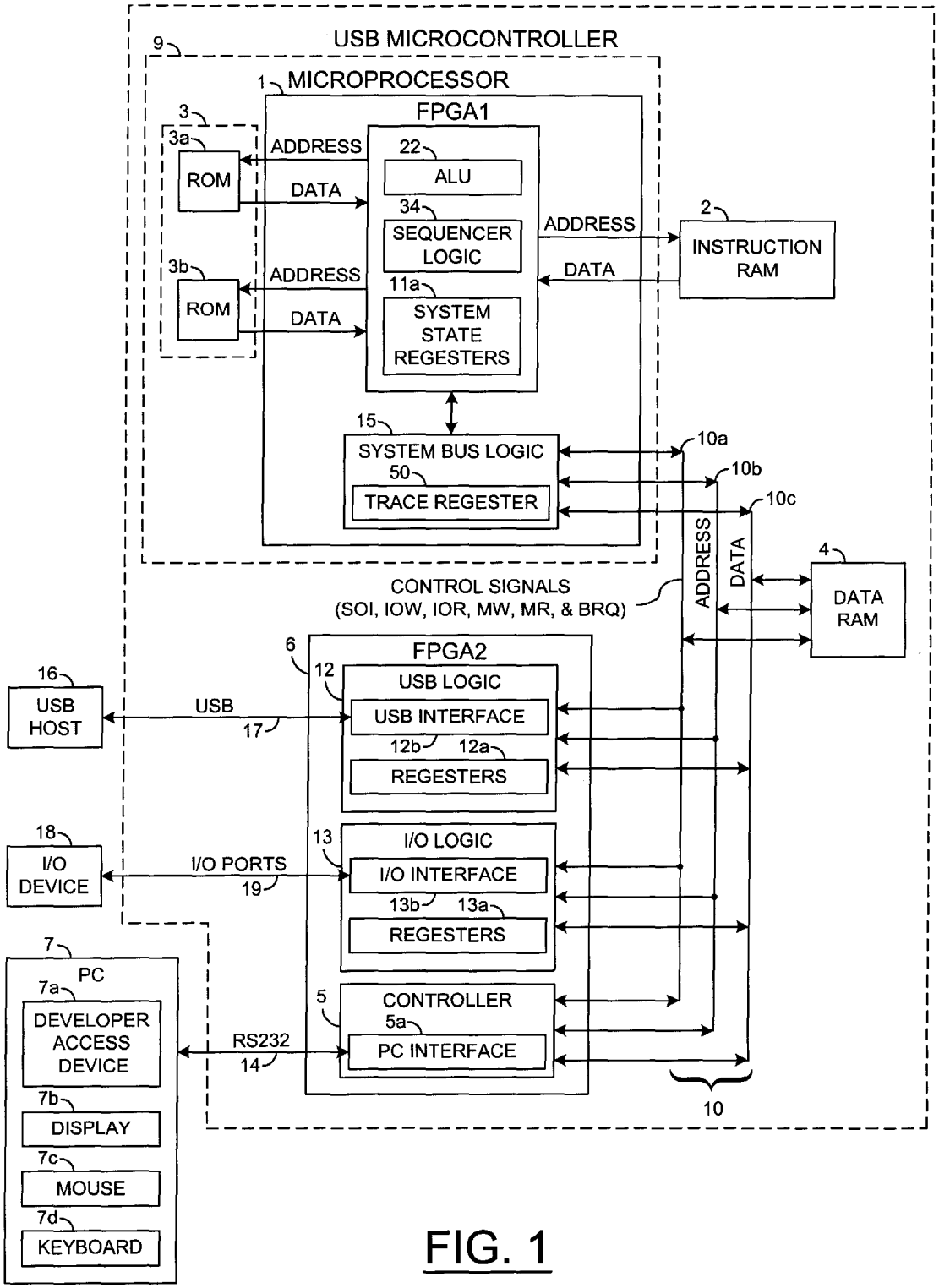

FIG. 1

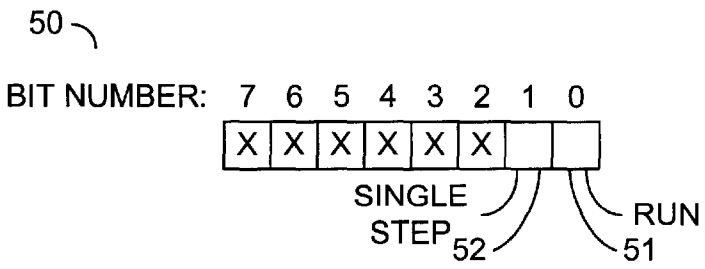

FIG. 2

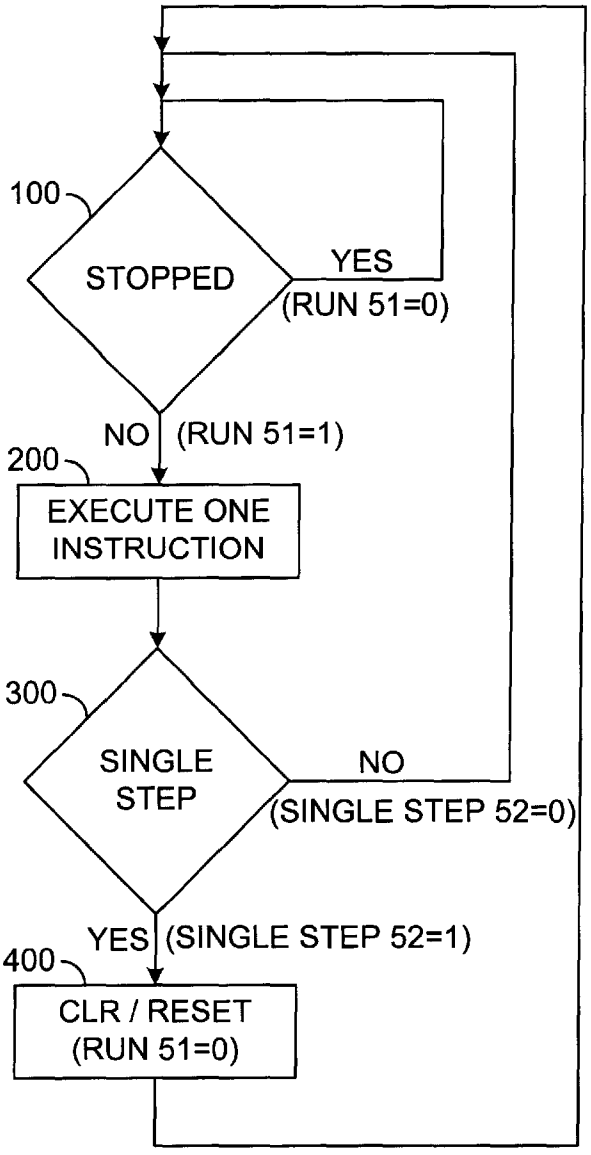

FIG. 3

MICROCONTROLLER DEVELOPMENT SYSTEM AND APPLICATIONS THEREOF FOR DEVELOPMENT OF A UNIVERSAL SERIAL BUS MICROCONTROLLER

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to microprocessor development systems, and more particularly to a Universal Serial Bus ("USB") microcontroller development system configured to aid in the design, debug, and testing of USB compliant devices and firmware.

2. Discussion of Background

USB is a peripheral bus standard that allows computer peripherals to be attached to a personal computer without the need for specialized cards or other vendor specific hardware attachments. The USB standard specifies a common configuration for the connection of well known peripherals such as CD-ROM, tape and floppy disk drives, scanners, printers, keyboards, joysticks, mice, telephones, modems, etc. In addition to well known peripheral devices, the USB standard has flexibility to accommodate less known and newly developed technologies. Information about the USB standard, including the specification for building USB compliant devices, is currently available free of charge over the Internet.

Developers wishing to implement USB devices must build that device to the USB standard. Prior to fabricating IC's for USB standard devices, a developer will spend a significant amount of resources in testing and refinement of prototypes. An efficient method for testing USB compliant devices is needed to reduce the costs associated with prototype development and testing of those devices.

The design and manufacture of electronic devices such as counters, state machines, specialized registers, and microprocessors is currently aided by technologies that allow engineers to specify design characteristics of a circuit, such as storage device size, register types, connections and associated logic, in a Hardware Description Language ("HDL"). This source code or HDL is then compiled, allowing the electronic device to be simulated and debugged while implementing the specified circuit characteristics. Once the operation of device is verified, the compiled source code can be mapped to a specific architecture such as Application Specific Integrated Circuits ("ASICs") or Field Programmable Gate Arrays ("FPGAs"). This allows the system designer to produce a device with design flexibility and portability into various architecture families.

As an example, a 3-bit shift register can be implemented in a HDL such as Register Transfer Language ("RTL") with the following RTL statements:

```
ENTITY shifter3 IS port (
    clk  :    IN BIT;
    x    :    IN BIT;
    q0   :    OUT BIT;
    q1   :    OUT BIT;
    q2   :    OUT BIT;
END shifter3;
ARCHITECTURE struct OF shifter3 IS
    SIGNAL q0_temp, q1_temp, q2_temp : BIT;
    BEGIN
        d1   : DFF PORT MAP (x,clk,q0_temp);
        d2   : DFF PORT MAP (q0_temp,clk,q1_temp);
        d3   : DFF PORT MAP (q1_temp,clk,q2_temp);
```


-continued

```
        q0   <= q0_temp;
        q1   <= q1_temp;
        q2   <= q2_temp;
END struct;
```

which defines the inputs and outputs of the shifter and then maps those bits to a series of D Flip-Flops. After compiling the source code and debugging the circuit, a netlist can be generated for a specific family of FPGA or ASIC devices to produce the circuit with the desired functionality.

SUMMARY OF THE INVENTION

Accordingly, one object of the present invention is to provide a flexible USB microcontroller development system that allows for testing of USB compliant devices. The microcontroller includes a microprocessor with instruction RAM, a controller with a computer interface (e.g., RS-232) to a personal computer or other external computing device, data RAM, USB logic and registers for interfacing to a USB host computer, and I/O logic and registers for interfacing to an I/O device. The USB microcontroller development system includes the microcontroller, an external computer, a USB host computer, and an I/O device. The USB microcontroller development system allows both the microprocessor or an attached external computer to control the microcontroller. This is accomplished by mapping the USB microcontroller system state which includes the contents of the data RAM, the microprocessors system state registers including system state registers corresponding to the contents of the instruction RAM, the USB logic registers, and the I/O logic registers to a system bus. The controller or microprocessor places address, data, and control signals on the system bus which are decoded by various logic to allow reading or writing of the system state. The controller reads or writes the instruction RAM by reading or writing a program counter and an instruction register, included as part of the microprocessor's system state registers, via the system bus. Accordingly, the external computer connected to the controller via the RS-232 bus can read or write the USB microcontroller system state to aid in the design, debug, and testing of USB compliant devices and firmware.

It is also an object of the present invention to provide a development access device on the external computer for providing a user a graphical interface for controlling the USB microcontroller. The development access device displaying menus, buttons, text boxes etc. corresponding to the microprocessor's system state registers, the contents of the instruction RAM, the USB logic registers, and the I/O logic registers. The user, after selecting the appropriate menu, button, or filling in the appropriate text box, can read or write the corresponding microprocessor's system state registers, the contents of the instruction RAM, the USB logic registers, and the I/O logic registers via the external computer and computer interface to control the USB microcontroller.

It is yet another object of the present invention to provide a method for implementing the above USB microcontroller development system utilizing a Hardware Description Language. By utilizing a Hardware Description Language, the design engineers are free to concentrate on the design of important features of the system and it's functionality rather than a gate level implementation of the system. After determining top level characteristics and functional blocks of the system, an HDL program describing those characteristics

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