

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
11 June 2009 (11.06.2009)

PCT

(10) International Publication Number
WO 2009/073532 A1

(51) International Patent Classification:
G06F 9/318 (2006.01) **G06F 9/35** (2006.01)

(74) Agent: **SLAYDEN, Bruce, W., II**; Baker Botts L.L.P.,
1500 San Jacinto Center, 98 San Jacinto Blvd., Austin, TX
78701 (US).

(21) International Application Number:
PCT/US2008/084921

(22) International Filing Date:
26 November 2008 (26.11.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/991,570 30 November 2007 (30.11.2007) US
12/147,647 27 June 2008 (27.06.2008) US

(71) Applicant (for all designated States except US): **MI-CROCHIP TECHNOLOGY INCORPORATED**
[US/US]; 2355 West Chandler Blvd., Chandler, AZ
85224-6199 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **JULICHER, Joseph** [US/US]; 43534 W. Elizabeth Ave., Maricopa, AZ
85238 (US). **SMIT, Zacharias, Marthinus** [ZA/US]; 319
W. Balsam Dr., Chandler, AZ 85248 (US). **STEEDMAN, Sean** [CA/US]; 2622 E. Rockledge Dr., Phoenix, AZ
85048 (US). **DELPORT, Vivien** [ZA/US]; 4290 S. Kerby
Way, Chandler, AZ 85249 (US). **ZDENEK, Jerrold, S.**
[US/US]; 19467 North Leland Rd., Maricopa, AZ 85238
(US). **ELLISON, Ryan, Scott** [US/US]; 1640 E. Carla
Vista Dr., Chandler, AZ 85225 (US). **SCHROEDER, Eric** [US/US]; 8705 Birch Brook Loop, Pickerington, OH
43147 (US).

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA,
CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE,
EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID,
IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK,
LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW,
MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT,
RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ,
TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM,
ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,
FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL,
NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG,
CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a
patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the
earlier application (Rule 4.17(iii))

Published:

- with international search report

(54) Title: ENHANCED MICROPROCESSOR OR MICROCONTROLLER

(57) Abstract: An n-bit microprocessor device has an n-bit central processing unit (CPU); a plurality of special function registers and general purpose registers which are memory-mapped to a plurality of banks, with at least two 16-bit indirect memory address registers which are accessible by the CPU across all banks; a bank access unit for coupling the CPU with one of the plurality of banks; a data memory coupled with the CPU; and a program memory coupled with the CPU, wherein the indirect address registers are operable to access the data memory or program memory and wherein a bit in each of the indirect memory address registers indicates an access to the data memory or to the program memory.



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ENHANCED MICROPROCESSOR OR MICROCONTROLLER

TECHNICAL FIELD

The technical field of the present application relates to microprocessors or microcontrollers.

BACKGROUND

Microcontrollers generally constitute a system on a chip and comprise a microprocessor and a plurality of peripheral components. A wide variety of such microcontrollers exist having 8-bit, 16-bit and 32-bit architecture. Existing microcontrollers such as 8-bit microcontrollers manufactured by Microchip Technology Inc. provide for a flexible architecture. Such microcontrollers comprise a Harvard architecture in which program and data memories are separated. Microcontrollers of this type further comprise a specific banking system that allows access to the data memory. Generally, the data memory is divided in a plurality of banks and a bank select register defines which of the banks is currently selected and accessible. To access other banks, the bank select register has to be re-programmed. Even though, a banking scheme, thus, only allows access to a defined memory bank, these controllers include instructions that force a switch to a predefined bank. This provides for improved and powerful performance despite the general access limitations.

However, there exists still bottlenecks in accessing the memory. Hence, there exists a need for an improved microcontroller architecture.

SUMMARY

According to an embodiment an n-bit microprocessor device may comprise an n-bit central processing unit (CPU); a plurality of special function registers and general purpose registers which are memory-mapped to a plurality of banks, with at least two 16-bit indirect memory address registers which are accessible by said CPU across all banks; a bank access unit for coupling said CPU with one of said plurality of banks; a data memory coupled with the CPU; and a program memory coupled with the CPU, wherein said indirect address registers are operable to access said data memory or program memory and wherein a bit in each of said indirect memory address registers indicates an access to said data memory or to said program memory.

According to a further embodiment, $n=8$. According to a further embodiment, the n -bit microprocessor may further comprise at least one virtual register, wherein writing data to said virtual register causes an indirect access using one of said indirect memory address registers to said data memory or to said program memory. According to a further embodiment, the at least one virtual register is mapped to each memory bank. According to a further embodiment, the n -bit microprocessor may further comprise a virtual register, wherein reading data from said virtual register causes an indirect access using one of said indirect memory address registers to said data memory or to said program memory. According to a further embodiment, the at least one virtual register can be mapped to each memory bank. According to a further embodiment, the virtual register may not be physically implemented in said microprocessor device. According to a further embodiment, the data memory may be 8-bit wide and said program memory may be 14-bit wide. According to a further embodiment, one additional bit of a data memory address may define an expanded memory address range used in a debug mode. According to a further embodiment, the bit in said indirect address register may be the most significant bit.

According to another embodiment, a method for operating an n -bit microprocessor device may comprise the steps of: providing an n -bit central processing unit (CPU); providing a plurality of special function registers and general purpose registers which are memory-mapped to a plurality of banks; providing at least two 16-bit indirect memory address registers which are accessible by said CPU across all banks; providing a bank access unit for coupling said CPU with one of said plurality of banks; providing a data memory coupled with the CPU; providing a program memory coupled with the CPU; and performing an indirect addressing using an indirect address register to access said data memory or program memory, wherein a bit in each of said indirect memory address registers indicates an access to said data memory or to said program memory, respectively.

According to a further embodiment, $n=8$. According to a further embodiment, the method may further comprise the step of generating an indirect memory write access by writing data to at least one virtual register, wherein the indirect memory access uses one of said indirect memory address registers. According to a further embodiment, the virtual register may be memory mapped to all memory banks. According to a further embodiment, the method may further comprise the step of generating an indirect memory read access by reading data from at least one virtual register, wherein the indirect memory read access uses

one of said indirect memory address registers. According to a further embodiment, the virtual register may be memory mapped to all memory banks. According to a further embodiment, the virtual register may not be physically implemented in said microprocessor device.

5 According to a further embodiment, the data memory may be 8-bit wide and said program memory may be 14-bit wide. According to a further embodiment, one additional bit of a data memory address may define an expanded memory address range used in a debug mode. According to a further embodiment, the bit in said indirect address register may be the most significant bit.

10 Other technical advantages of the present disclosure will be readily apparent to one skilled in the art from the following figures, descriptions, and claims. Various embodiments of the present application may obtain only a subset of the advantages set forth. No one advantage is critical to the embodiments.

15 **BRIEF DESCRIPTION OF THE DRAWINGS**

A more complete understanding of the present disclosure and advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings, in which like reference numbers indicate like features, and wherein:

20 Figure 1 shows a block diagram of microcontroller architecture according to an embodiment.

Figure 2 shows an embodiment of a program counter and its coupling to an internal bus.

Figures 3-6 show different operations on the program counter depending on the instruction being executed.

25 Figure 7 shows an embodiment of a stack and control logic.

Figure 8 shows an embodiment of a program memory map and stack.

Figure 9 shows an embodiment of a bank select register.

Figure 10 shows an embodiment of the structure of a memory bank in the data memory.

30 Figure 11 shows an access scheme for indirect memory access.

Figure 12 is a table showing the special function register summary according to an embodiment.

Figure 13A and B are a table showing the instruction set of a microprocessor or microcontroller according to an embodiment.

While embodiments of this disclosure have been depicted, described, and are defined by reference to example embodiments of the disclosure, such references do not imply a limitation on the disclosure, and no such limitation is to be inferred. The subject matter disclosed is capable of considerable modification, alteration, and equivalents in form and function, as will occur to those ordinarily skilled in the pertinent art and having the benefit of this disclosure. The depicted and described embodiments of this disclosure are examples only, and are not exhaustive of the scope of the disclosure.

DETAILED DESCRIPTION

Fig. 1 shows amongst others different functional units of a central processing unit of a microprocessor or microcontroller relevant for accessing program and data memory in a Harvard-type architecture according to an embodiment. An instruction register 110 may store a fetched instruction which may be decoded by a control logic 130. A plurality of indirect addressing registers 150 may be provided each storing an address. Even though shown separately in Figure 1, these and other special function registers are part of a special function register block 185. To perform an indirect addressing access, a read or write to a dedicated special function register in special function register block 185 is performed. In case such an indirect addressing access is executed, control logic 130 controls a multiplexer 140 which receives on the input side an address from indirect address register 150. According to an embodiment, the indirect address registers have a predefined bit, such as the most significant bit, which is decoded by control logic 130 to determine whether an indirect access to program memory 120 or to data memory 160 will be performed.

In an 8-bit architecture, the data memory is 8-bit wide. According to the Harvard architecture, the program memory is separated from the data memory and may have a different size. For example, in one embodiment, the program memory may be 14, 15 or 16 bits wide. Thus, instructions can be decoded that include for example, an 8 bit direct address. Some instruction may contain even more address bits that may be combined with another register to perform, for example, relative addressing.

The data memory 160 may be divided into a plurality of banks that can be decoded by 7 or 8 bits. Each bank can be considered as a register file. According to one embodiment,

data memory contains a total of 16 banks each having 256 addressable memory locations resulting in a total memory of 4096 bytes. According to another embodiment, 16 banks with 128 addressable memory locations may be provided. Other configurations are possible according to various embodiments. The central processing unit may further include an arithmetic logic unit 170 (ALU) coupled with a working register 180. Working register 180 is one of a plurality of special function registers of block 185. As stated above, data memory 160 may be divided into a plurality of banks 1...n. With the exception of certain addressing modes, instructions generally have only access to the selected memory bank. Thus, certain important special function registers from special function register block 185 are memory mapped to all memory banks 1..n as indicated by the arrow between data memory 160 and special function register block 185. According to various embodiments, special function registers not mapped to all memory banks may be mapped to a single memory bank at respective different memory locations. According to various embodiments, some special function registers may not be mapped to memory at all.

Even though the mapping of certain special function registers to all memory banks limits the accessible free RAM in each memory bank, many otherwise necessary bank switch sequences can be avoided to access important special function register. For example, a microcontroller may have 12 special function registers such as the working register 180 mapped to all memory banks. Thus, according to an embodiment, each memory bank may have 244 or 116 free memory locations depending on the size of each memory bank. Other configurations are possible according to various embodiments..

According to an embodiment, the enhanced microcontroller may contain an 8-bit ALU 170 and working register 180 (WREG). The ALU 170 may be a general purpose arithmetic unit. It performs arithmetic and Boolean functions between data in the working register 180 and any register file. The ALU 170 can be 8-bits wide and may be capable of addition, subtraction, shift, and logical operations. Unless otherwise mentioned, arithmetic operations may be two's complement in nature. WREG 180 may be an 8-bit working register used for ALU operations. The WREG register 180 is addressable and can be directly written or read. According to an embodiment, WREG 180 is one of the 12 common SFR's that are mapped to all 16 banks - its address may be for example 09h. The Arithmetic and Logic Unit 170 may be capable of carrying out arithmetic or logical operations on two operands or a single operand. All single operand instructions operate either on the WREG register 180 or

the given file register. For two operand instructions, one of the operands is the WREG register 180 and the other one is either a file register or an 8-bit immediate constant. Depending on the instruction executed, the ALU 170 may affect the values of the Carry (C), Digit Carry (DC) or Zero (Z) bits in the STATUS register 190. The C and DC bits operate as a borrow and digit borrow out bit, respectively, in subtraction. Examples affecting these status bits are such instructions as SUBLW and SUBWF as will be explained in more detail below.

The STATUS register 190, as shown in Figure 1 may contain: Arithmetic status of the ALU such as carry/borrow, digit carry/borrow, and zero flag; RP<1:0>, representing the lower two bank select; bits for direct addressing; IRP, representing the bank select register bit for indirect addressing; time out bit, and power down bit.

According to an embodiment, the enhanced microcontroller comprises a Bank Select Register (BSR), in order to maintain backwards compatibility, also bits RP<1:0> may be maintained. There may be full, bi-directional mirroring between RP<1:0> and BSR<1:0>: changing the one register, therefore, automatically changes the other. Hence, RP<1:0> and BSR<1:0> point to the same physical memory.

Even though the enhanced microcontroller contains multiple full indirect address registers 150 (file select registers (FSR's)), bit IRP may be also maintained for backwards compatibility - it is a direct, bi-directional mirror of FSR0H<0>. Changing FSR0H<0>, thus, automatically changes IRP, and visa versa. IRP and FSRH0h<0> point to the same physical memory.

According to an embodiment, the STATUS register 190 is common across all banks, and can be located at 03h. Fast context saving on interrupts, as will be explained in more detail below, is implemented for all the STATUS bits, except TO and PD. The STATUS register can be the destination for any instruction, like any other register. If the STATUS register is the destination for an instruction that affects the Z, DC or C bits, then these bits are set or cleared according to the device logic. Furthermore, the TO and PD bits are not writable. Therefore, the result of an instruction with the Status register 190 as destination may be different than intended. For example, the instruction CLRF STATUS will clear all the bits except TO and PD, and then the Z bit will automatically be set by device logic. This leaves the STATUS register 190 as '000u u100' (where u = unchanged). The C and DC bits operate as a Borrow and Digit Borrow out bit, respectively, in subtraction.

The status register 190 thus may contain the following bits:

IRP: Indirect Register Bank Select bit (For backwards compatability. Mirrors FSR0H<0>) 1 = Bank 2, 3 (100h-1FFh); 0 = Bank 0, 1 (00h-FFh)

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RP<1:0>: Register Bank Select bits (For backwards compatability. Mirrors BSR<1:0>) 00 = Bank 0 (00h-7Fh); 01 = Bank 1 (80h-FFh); 10 = Bank 2 (100h-17Fh); 11 = Bank 3 (180h-1FFh)

10 TO: Time-out bit (Not automatically saved on interrupts) 1 = After power-up, CLRWDT instruction or SLEEP instruction; 0 = A watch dog timer time-out occurred;

PD: Power-down bit (Not automatically saved on interrupts) 1 = After power-up or by the CLRWDT instruction; 0 = By execution of the SLEEP instruction

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Z: Zero bit: 1 = The result of an arithmetic or logic operation is zero; 0 = The result of an arithmetic or logic operation is not zero.

20 DC: Digit Carry/Borrow bit (ADDWF, ADDLW, SUBLW, SUBWF instructions): 1 = A carry-out from the 4th low-order bit of the result occurred; 0 = No carry-out from the 4th low-order bit of the result.

C: Carry/Borrow bit (ADDWF, ADDLW, SUBLW, SUBWF instructions): 1 = A carry-out from the Most Significant bit of the result occurred; 0 = No carry-out from the Most Significant bit of the result occurred.

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For Borrow, the polarity can be reversed. A subtraction is executed by adding the two's complement of the second operand. For rotate (RRF, RLF) instructions, this bit is loaded with either the high or low-order bit of the source register.

30 The enhanced microcontroller core can directly or indirectly address its register files (banks) or data memory. According to an embodiment, all special function registers, including the Program Counter (PC) and Working Register (WREG), are mapped in the data

memory. The enhanced microcontroller core has an orthogonal (symmetrical) instruction set that makes it possible to carry out any operation on any register using any addressing mode. This symmetrical nature and lack of 'special optimal situations' make programming with the enhanced microcontroller core simple yet efficient. In addition, the learning curve for a user is reduced significantly.

According to an embodiment, the following blocks may be realized in the core: Program counter; Instruction decode; ALU; read only memory (ROM) Latch/IR Latch; FSRs and address generation logic; Working Register; WREG; Status bits in STATUS; Interrupt vectoring control; with fast context saving; The bank select register BSR.

The following blocks may not be considered part of the CPU: The stack; Reset generation circuitry (watch dog timer (WDT), power on reset (POR), brown out reset (BOR), etc.); Program Memory; Peripherals; RAM; RAM Address Control; Q-clock generator and control; Interrupt Enable and Flagging; interrupt control registers; Configuration bits; Device ID word; ID locations; Clock drivers.

As stated above, according to an embodiment, the following registers may be common across all 16 banks: INDF0 (Used for indirect addressing and may not be a physical register); INDF1 (Used for indirect addressing and may not be a physical register); PCL (PC LSB); STATUS; FSR0L (Indirect memory address 0, LSB); FSR0H (Indirect memory address 0, MSB); FSR1L (Indirect memory address 1, LSB); FSR1H (Indirect memory address 1, MSB); WREG, the working register; BSR (Bank select register); PCLATH (Write buffer for program counter PC<14:8>); interrupt control register INTCON.

According to an embodiment, the microprocessor or microcontroller may further comprise an interrupt control unit 105 which may be coupled with certain special function registers 115. Upon occurrence of an interrupt or any other induced context switch, such as software traps, the contents of the following registers selected from the special function registers mapped to all memory banks are automatically saved. STATUS (except for TO and PD); BSR, PCLATH, WREG, FSR0 (Both FSR0H and FSR0L), and FSR1 (Both FSR1H and FSR1L). The registers are automatically restored to their pre-interrupt values upon a return from interrupt.

To this end, as shown in Figure 1, the microprocessor or microcontroller core may have at least one additional set of registers 115 which will store the content of the above

mentioned registers. However, according to other embodiments, a stack, additional data memory, etc. may be provided to store the content of these registers upon a context switch.

As shown in Figure 2, the program counter PC consists of two concatenated 8 bit registers PCL 230 and PCH 240. It addresses words in program memory, and according to an embodiment, is e.g. 15 bits wide. Thus, it can be used to address up to 32 kW. PCL 230, the low byte of the PC, is mapped in the data memory 160. Thus, it is common across all banks, and located for example at address 02h. PCL 240 is readable and writable just as any other register. Any time that PCL 230 is modified by an instruction, whether a write to PCL 230 or a read-modify-write, the CPU may need to execute a forced NOP in order to retrieve the instruction at the new address. PCH 240 is the high byte of the PC and is not directly addressable. Since PCH may not be mapped in data or program memory, register PCLATH 220 (PC high latch) is used as holding latches for the high bits of the PC (PCH<6:0>). According to an embodiment, PCLATH 220 is mapped into data memory. Thus, it is common across all banks, and can be located at address 0Ah. PCLATH 220 is only updated by explicit loading of the register. therefore, according to an embodiment no other instructions update it. The enhanced microcontroller may be designed that updating PCLATH 220 does not automatically update PCH 240. PCH 240 is only updated with the content of PCLATH 220 on GOTO, CALL and CALLW instructions. The PC is incremented by 1 after each instruction fetch on the rising edge of Q1 unless: Modified by a GOTO, CALL, RETURN, RETLW, RETFIE, or Branch instruction; Modified by an interrupt response; Due to destination write to PCL by an instruction.

“Skips” are equivalent to a forced NOP cycle at the skipped address. As shown in Figure 2, the operations of the PC 230, 240 and PCLATH 220, for different instructions are as follows:

Read instructions on PCL 230: PCL 230 → data bus 200 → ALU 170 or destination.

Write instructions on PCL 230: 8-bit data → data bus 200 → PCL 230.

Read-Modify-Write instructions on PCL 230: Any instruction that does a read-write-modify operation on PCL 230. Read: PCL 230 → data bus 200 → ALU 170; Write: 8-bit result → data bus → PCL 230.

RETURN instruction: TOS → PC <14:0> 230, 240.

Figure 3 shows in addition a fetched instruction 210 and its effect on the program counter 230, 240. Figure 3 applies to the following instructions:

GOTO instruction: A destination address is provided in the 2-word instruction (opcode) 210. Opcode<7:0> $\rightarrow$ PCL<7:0> 230; Opcode<10:8> $\rightarrow$ PCH<2:0> 240; PCLATH<6:3> 220 $\rightarrow$ PCH<6:3> 240.

CALL instruction: An 11-bit destination address is provided in the instruction 210. Push the current address (PC +1) to the stack. Opcode <7:0> $\rightarrow$ PCL <7:0> 230; Opcode <10:8> $\rightarrow$ PCH <2:0> 240; PCLATH <6:3> 220 $\rightarrow$ PCH <6:3> 240.

Figure 4 shows the configuration for the following instructions:

BRA instruction: A 9-bit, signed, offset is provided in the instruction 210. Opcode <8:0> + PC (+1) $\rightarrow$ PC.

Figure 5 shows the configuration for the following instructions:

BRW instruction: An 8-bit unsigned, offset provided in WREG 180. PC (+1) + WREG $\rightarrow$ PC.

Figure 6 shows the configuration for the following instructions:

CALLW instruction: An 8-bit destination address is provided in WREG 180. Push the current address (PC +1) to the stack. WREG <7:0> $\rightarrow$ PCL <7:0>; PCLATH <6:0> $\rightarrow$ PCH <6:0>.

To enable a test memory area, the program counter 230, 240 may have a hidden 16th bit, PC<15>. When PC<15> is set the instructions will be fetched from a test area. In user mode, PC<15> is always 0, and cannot be modified in software. In test mode, PC<15> defaults to 0, but can be set by a "load configuration" command. It can be cleared by a "Reset PC" command. The test memory access may behave with an in circuit debugger (ICD) as follows:

ICD_v1: PC<15> is forced high to fetch the ICD vector, but returns to 0 after the first instruction (GOTO ICD_ROUTINE) is executed. From then until exiting the debug exec, PC<14:11> is forced to '1111b', but PCLATH is not affected. ICD_v2: If the ICD debug exec

is in user memory, then it follows ICD_V1. If the debug exec is in test memory, then PC<15> is forced high to fetch the ICD vector, and returns to zero on icd_return.

The enhanced microcontroller devices according to various embodiments may support a stack memory 15 bits wide and 16 bits deep as shown in Fig 7. During normal operation, the stack 310 is assumed to be 16 words deep. In normal mode, no direct user access is provided to the stack 310. The stack is not part of either the program or data memory space. The full PC (Program Counter) is pushed onto the stack when a CALL or CALLW instruction is executed, or an interrupt request is acknowledged. The PC value is pulled off the stack on a RETURN, RETLW, or RETFIE, instruction. PCLATH is not affected by any of the CALL or RETURN type instructions.

The stack 310 operates as a 16 word by 15-bit RAM and a 4-bit stack pointer. Incrementing/decrementing the pointer past 1111b/0000b will cause it to wrap around to 0000b/1111b. During a CALL type instruction, the stack pointer is incremented and the contents of the PC are loaded to the stack 310. During a RETURN type instruction the contents pointed to are transferred to the PC and then the stack pointer is decremented. The stack pointer is initialized to '1111b' after all Resets. The first call will cause the pointer to wrap to 0000b.

A stack overflow/underflow event occurs when the stack pointer is incremented/decremented past 1111b/0000b AND a data transfer to/from the stack is conducted at the new address. An overflow event must not occur on the first CALL. On the 16th consecutive call, the stack pointer will have a value of 1111b. The 17th consecutive CALL will cause the stack pointer to wrap around to 0000b, and the PC to be loaded at this position. This constitutes an overflow event. When the stack has been popped enough times to reach 0000b, further popping will cause the contents at 0000b to be transferred to the PC, and the stack pointer to be decremented. The stack pointer will wrap to 1111b, this DOES NOT constitute an underflow event. Only on the next consecutive pop, when data transfer from 1111b is attempted, will an underflow event occur. In user mode, a stack overflow or underflow will set the appropriate bit (STOF or STUF) in the PCON register, and cause a software reset.

When in ICD mode, the stack may have two segments. The normal user mode stack is still 16 words deep, but a separate ICD stack may also be provided. In ICD mode it will be possible to access the top of the stack and the stack pointer. In ICD mode, the top of the

stack (TOS) is readable and writable. Two register locations, TOSH and TOSL, will address the stack RAM location pointed to by the stack pointer (STKPTR). After a CALL type instruction, the software can read the pushed value by reading the TOSH and TOSL registers. These values can be placed on a user defined software stack. Writing to the TOS registers will cause the PC to be updated with the new value on the next RETURN type instruction.

The STKPTR register contains the stack pointer value. As previously noted, STKPTR is accessible in ICD mode only. In ICD mode, the stack pointer can be accessed through the STKPTR register. The user may read and write the stack pointer values. The stack pointer is initialized to '1111b' after all Resets. In ICD mode, an automatic software reset will not be applied on an overflow/underflow event. However, the stack overflow (STOF) or underflow (STUF) bit in the PCON register will still be set, allowing software verification of a stack condition. Because a reset will not be executed on an underflow/overflow, the stack pointer (STKPTR) will not be reset. On an overflow/underflow the stack pointer will wrap around and then resume normal operation. The user has to clear the overflow (STOF) or underflow (STUF) bits explicitly - and they will again be automatically set on subsequent overflows/underflows. Stack Overflow/Underflow events can only be caused by an instruction that modifies the stack pointer using the stack pointer hardware.

This includes: CALL, TRAP; RETURN, RETFIE, RETLW; Any interrupt and ICD traps. Instructions that modify the stack pointer through the ALU (ICD mode only) will not cause the stack underflow/overflow condition, and thus will not set the (STOF) or (STUF) bits. Examples are (ICD mode only): INCF STKPTR; DECF STKPTR; ADDWF STKPTR.

When a device is reset, the PC is loaded with the Reset vector (0h). The stack pointer is initialized to '1111b', and the Top of Stack register (TOS) is '0000h'. A second push increments the stack pointer and then loads the current PC into stack level. On the 16th consecutive call, the stack pointer will have a value of 1111b. The 17th consecutive CALL will cause the stack pointer to wrap around to 0000b, and the PC to be loaded at this position. This constitutes an overflow event. A RETURN pop will copy the stack contents pointed to the PC and then decrement the stack pointer. When the stack has been popped enough times to reach 0000b, further popping will cause the contents at 0000b to be transferred to the PC, and the stack pointer to be decremented. The stack pointer will wrap to 1111b, this DOES NOT constitute an underflow event. Only on the next consecutive pop, when data transfer from 1111b is attempted, will an underflow event occur. In debug (ICD) mode a special

instruction will cause the STKPTR to be incremented. The PC is not loaded to TOS. It is up to the user to make sure TOS is loaded with the appropriate data before executing the INCF STKPTR instruction (this instruction is thus equivalent to a PUSH instruction. The DECF STKPTR instruction will decrement the stack pointer, the PC is not loaded with the TOS value.

As shown in Fig. 8, the 15-bit program counter 400 is capable of addressing a 32k x 14 bit program memory space. The program memory space 430 primarily contains instructions for execution; however, data tables may be stored and accessed as well (using legacy program memory read/write infrastructure, as well as the new functionality associated with indirect addressing, see the FSR section for more detail). There is also a 16th PC bit hidden during normal operation, and when set, it is possible to address another 32k x 14 of memory reserved for configuration bits, the device ID, and test memory 440. This bit is only set in test mode or programming mode. As shown in figure 8, the Reset vector is at '0000h' and the interrupt vector is at '0004h'.

According to one embodiment, the enhanced microcontroller can address data memory 160 and general purpose RAM of up to 2048 bytes. The data memory address bus is 11 bits wide. Data memory is partitioned into 16 banks of 128 bytes each that contain the General Purpose Registers (GPRs) and Special Function Registers (SFRs). The bank is selected by the bank select register (BSR<3:0>) as shown in Figure 9. The BSR register can access more than 16 banks; however, this may be only allowed in ICD mode to allow for a larger data space for the ICD registers. (In ICD mode 32 banks can be accessed). The bits BSR0 and BSR1 are also mapped into the STATUS register as RP0 and RP1 respectively. This is to allow for backward compatibility with existing devices. A read or write to BSR0/1 will affect RP0/1 and vice versa. Figure 10 shows an example data memory map.

When the core is operating with an ICD module or in another embodiment, the total number of banks may be expanded to 32 for 4096 total addresses. This is to allow the ICD registers to be mapped into the data space and not use any of the user memory map. This will only be enabled when the ICD module is enabled. The user will have no access to any bank greater than Bank15. Other configurations are possible according to various embodiments.

Figure 11 shows an embodiment of indirect addressing scheme which is a mode of addressing data memory where the data memory address in the instruction is determined by another register. This can be useful for data tables or stacks in the data/program memory.

The value of the file select register (FSR) register 960 is used as the data memory address. The enhanced microcontroller has two 16-bit register pairs 960 for indirect addressing. These so called file select register pairs are: FSR0H and FSR0L; and FSR1H and FSR1L. The FSRs 960 are 16-bit registers and thus allow addressing of up to 65,536 locations. A single
 5 bit 965 in these file select registers 960 can be used to determine whether an access to data memory 160 or program memory 120 will be performed. To this end, logic unit 930 forwards the content of file select register 960 to either program memory address 910 or RAM address 920 for accessing the respective memories.

Non-indirect addressing uses the respective content "File" of a fetched instruction 950
 10 through multiplexer 940. Bank access are then performed through RAM address 920 wherein the bank address is provided by the respective bank access register to form a full address 920. As shown in Figure 11, file select registers 960 are provided for indirect addressing. For indirect addressing, the output of multiplexer 940 provides the "File" address through the content of the respective file select register 960. If indirect addressing is selected, bit 15
 15 indicated by numeral 965 of each file select register 960 is used to determine whether an access to program memory 120 through program memory address 910 or to data memory 160 through data address 920 will be performed. Indirect addressing is initiated through a respective select signal (not shown) controlling multiplexer 940.

When $FSR_n<15>$ equals 0, data memory 160 is addressed. When $FSR_n<15>$ is 1,
 20 program memory 120 is addressed. The data memory 160 is mapped into the first half of this address space (0000h to 7FFFh). If $FSR_n<15>$ is 0, $FSR_n<10:0>$ points to data memory locations 000h to 7FFh. In this case $FSR_n<11:14>$ is ignored. The program memory 120 is mapped into the upper half of this address space (8000h to FFFFh). If $FSR_n<15>$ is 1, then $FSR_n<14:0>$ points to program memory addresses 0000h to 7FFFh. In summary: Addresses
 25 8000h and higher point to program memory. Addresses below 8000h point to data memory, with only the lower 11 bits used for address decoding.

In addition, there are virtual registers INDF0 and INDF1 (See Figure 10), which are not physically implemented. Reading or writing to these registers activates indirect addressing, with the value in the corresponding FSR register being the address of the data. If
 30 file INDF0 (or INDF1) itself is read indirectly via an FSR, all '0's are read (Zero bit is set). Similarly, if INDF0 (or INDF1) is written to indirectly, the operation will be equivalent to a NOP, and the STATUS bits are not affected. Indirect writes to program memory space

(FSR_n<15> = 1) will have no effect, and will lead to the equivalent of a NOP being executed. Indirect reads from program memory space (FSR_n<15> = 1) will cause the first 8 bits of the program memory location to be transferred to the destination register, the EEDATH/PMDATH will be updated with the upper 6 bits. According to various
 5 embodiments, other mechanism may be implemented to induce indirect addressing.

Figure 12 shows a summary of all special function registers according to an embodiment as used in any bank n of the data memory.

Figures 13A and B show the instruction set wherein the enhanced instructions using the architecture as explained above are explained in detail below.

10

DDFSR Add Literal to FSR_n: Syntax: ADDFSR n, k

Operands: $-32 \leq k \leq 31$

$$n \in [0,1]$$

Operation: $\text{FSR}(n) + k \rightarrow \text{FSR}(n)$

Status Affected: None

15

Encoding: 11 0001 0nkk kkkk

Description: The signed 6-bit literal 'k' is added to the contents of the FSR specified by 'n'. FSR_n is limited to the range 0000h -FFFFh. Incrementing/decrementing it beyond these bounds will cause it to wrap around. Note that addresses 8000h and larger point to program memory. Addresses below 8000h point to data memory, with only the lower 11 bits
 20 used for address decoding.

Words: 1

Cycles: 1

Q Cycle Activity:

25

Q1	Q2	Q3	Q4
Decode	Read FSR _n	Process Data	Write to FSR _n

Example: ADDFSR 1, 23h

Before Instruction FSR1= 0FFh

After Instruction FSR1= 0122h

30

DDWFC ADD WREG and CARRY bit to f: Syntax: ADDWFC f {,d}

Operands: $0 \leq f \leq 127$

$$d \in [0,1]$$

Operation: $(WREG) + (f) + (C) \rightarrow \text{dest}$

Status Affected: C, DC, Z

5

Encoding: 11 1101 dfff ffff

Description: Add WREG, the CARRY flag and data memory location 'f'. If 'd' is '0', the result is placed in WREG. If 'd' is '1', the result is placed in data memory location 'f'.

Cycles: 1

10

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read reg 'f'	Process Data	Write to destination

Example: ADDWFC REG, 0

15

Before Instruction CARRY bit=1

REG = 02h

WREG = 4Dh

After Instruction CARRY bit=0

REG = 02h

WREG = 50h

20

SRF Arithmetic Right Shift: Syntax: ASRF f {,d}

Operands: $0 \leq f \leq 127$

$$d \in [0,1]$$

Operation: $(f<7>) \rightarrow \text{dest}<7>$

$(f<7:1>) \rightarrow \text{dest}<6:0>$,

$(f<0>) \rightarrow C$,

25

Status Affected: C, Z

Encoding: 11 0111 dfff ffff

Description: The contents of register 'f' are shifted one bit to the right through the CARRY flag. The MSb remains unchanged. If 'd' is '0', the result is placed in WREG. If 'd' is '1', the result is stored back in register 'f'.

Words: 1

Cycles: 1

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read reg 'f'	Process Data	Write to destination

Example: ASRF REG, 0

Before Instruction REG = 1110 0110

C = 1

After Instruction REG = 1110 0110

WREG = 1111 0011

C = 0

A Relative Branch: Syntax: BRA k

Operands: $-256 \leq k \leq 255$

Operation: $(PC) + k \rightarrow PC$

Status Affected: None

Encoding: 11 001k kkkk kkkk

Description: Add the 2's complement number 'k' to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be $PC + 1 + k$. This instruction is a two-cycle instruction.

Words: 1

Cycles: 2

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read literal 'k'	Process Data	Write to PC
No operation	No operation	No operation	No operation

Example: 0023h BRA 005h

Before Instruction PC = address(0023h)

After Instruction PC = address(0029h)

RW Relative Branch with WREG: Syntax: BRW

Operands: None

Operation: $(PC) + (WREG) \rightarrow PC$

Status Affected: None

Encoding: 00 0000 0000 1011

Description: Add the contents of WREG (unsigned) to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be $PC + 1 + (WREG)$. This instruction is a two-cycle instruction. The contents of WREG is treated as an unsigned number.

Words: 1

Cycles: 2

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read reg WREG	Process Data	Write to PC
No operation	No operation	No operation	No operation

Example: 0024h BRW

Before Instruction PC = address(0024h)

WREG = 85h

After Instruction PC = address(00AAh)

ALLW Subroutine Call With WREG: Syntax: CALLW

Operands: None

Operation: $(PC) + 1 \rightarrow TOS,$
 $(WREG) \rightarrow PC<7:0>,$
 $(PCLATH<6:0>) \rightarrow PC<14:8>$

Status Affected: None

Encoding: 00 0000 0000 1010

Description: Subroutine call with WREG. First, the return address $(PC + 1)$ is pushed onto the return stack. Then, the contents of WREG is loaded into

PC<7:0>, and the contents of PCLATH into PC<14:8>. CALLW is a two-cycle instruction.

Words: 1

Cycles: 2

5

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read register WREG	Process Data	Write to PC
No operation	No operation	No operation	No operation

Example: 0025h CALLW

10

Before Instruction PC = address (0025h)

WREG = 1Ah

PCLATH = 10h

After Instruction TOS = address (0026h)

PC = 101Ah

15

WREG = 1Ah

PCLATH = 10h

SLF Logical Left Shift: Syntax: LSLF f {,d}

Operands: $0 \leq f \leq 127$

$d \in [0,1]$

20

Operation: $(f<7>) \rightarrow C$
 $(f<6:0>) \rightarrow \text{dest}<7:1>$
 $0 \rightarrow \text{dest}<0>$

Status Affected: C, Z

25

Encoding: 11 0101 dfff ffff

Description: The contents of register 'f' are shifted one bit to the left through the CARRY flag. A '0' is shifted into the LSb. If 'd' is '0', the result is placed in WREG. If 'd' is '1', the result is stored back in register 'f'.

Words: 1

Cycles: 1

Q Cycle Activity:

	Q1	Q2	Q3	Q4
5	Decode	Read reg 'f'	Process Data	Write to destination

Example: LSLF REG, 0

Before Instruction REG = 1110 0110

C = 0

After Instruction REG = 1110 0110

WREG = 1100 1100

C = 1

SRF Logical Right Shift: Syntax: LSRF f {,d}

Operands: $0 \leq f \leq 127$

$d \in [0,1]$

Operation: $0 \rightarrow \text{dest} \langle 7 \rangle$

$(f \langle 7:1 \rangle) \rightarrow \text{dest} \langle 6:0 \rangle,$

$(f \langle 0 \rangle) \rightarrow C,$

Status Affected: C, Z

Encoding: 11 0110 dfff ffff

Description: The contents of register 'f' are shifted one bit to the right through the CARRY flag. A '0' is shifted into the MSb. If 'd' is '0', the result is placed in WREG. If 'd' is '1', the result is stored back in register 'f'.

Words: 1

Cycles: 1

Q Cycle Activity:

	Q1	Q2	Q3	Q4
25	Decode	Read register 'f'	Process Data	Write to destination

Example: LSRF REG, 0

Before Instruction REG = 1110 0110

C = 1

After Instruction REG = 1110 0110
 WREG = 0111 0011
 C = 0

5 OVIW Move INDFn to WREG, with pre/post increment/decrement

Syntax: MOVIW ++/--FSRn++/--

$n \in [0,1]$

Operands:

Operation: INDFn $\rightarrow$ WREG

Apply pre/post increment/decrement operation to FSRn.

10 Status Affected: Z (Only if destination is WREG)

Encoding: 00 0000 0001 0nmm

MM	Operation
00	++FSRn
01	--FSRn
10	FSRn++
11	FSRn--

15 Description: This instruction is used to move data between one of the indirect registers (INDFn) and WREG. Before/after this move, the pointer (FSRn) is updated by pre/post incrementing/decrementing it. FSRn is limited to the range 0000h - FFFFh. Incrementing/decrementing it beyond these bounds will cause it to wrap around. Note that addresses larger than 7FFFh point to program memory. Addresses below 8000h point to data memory, with only the lower 11 bits used for address decoding. The increment/decrement operation on FSRn WILL NOT affect any STATUS bits. This instruction can only affect the Z flag if a value of 00h is moved to WREG.

Words: 1

Cycles: 1

Q Cycle Activity:

Q1	Q2	Q3	Q4
30 Decode	Update pointer if	Process Data	Write to Destination

Read Source register.

register. Update
pointer if needed.

Example: MOVIW FSR0++

Before Instruction FSR0 = 22h
WREG = FFh
(22h) = 12h
(23h) = 33h

After Instruction FSR0 = 23h
WREG = 12h
(22h) = 12h
(23h) = 33h

Example: MOVIW ++FSR0

Before Instruction FSR0 = 22h
WREG = FFh
(22h) = 12h
(23h) = 33h

After Instruction FSR0 = 23h
WREG = 33h
(22h) = 12h
(23h) = 33h

OVIW Move INDFn to WREG, Indexed Indirect Addressing

Syntax: MOVIW [k]FSRn

Operands: $-32 \leq k \leq 31$ $n \in [0,1]$ Operation: $(FSRn + k) \rightarrow WREG$

Move data between location pointed to by FSRn + k and WREG.

Status Affected: Z (Only if destination is WREG)

Encoding: 11 1111 0nkk kkkk

Description: This instruction is used to move data between a location pointed to by FSRn + k and WREG. FSRn is NOT updated with k. The addressable

range is limited to 0000h - FFFFh. Indexing beyond these bounds will cause an address wrap-around. Note that addresses 8000h and higher point to program memory. Addresses below 8000h point to data memory, with only the lower 11 bits used for address decoding. Address calculation (addition of k to FSRn) WILL NOT affect any STATUS bits. This instruction can only affect the Z flag if a value of 00h is moved to WREG.

Words: 1

Cycles: 1

Q Cycle Activity:

10	Q1	Q2	Q3	Q4
	Decode	Address Calculation. Read Source register.	Process Data	Write to Destination register.

Example: MOVIW [5]FSR0

15	Before Instruction	FSR0 = 22h WREG = FFh (22h) = 12h (27h) = 39h
20	After Instruction	FSR0 = 22h WREG = 39h (22h) = 12h (27h) = 39h

Example: MOVIW [-5]FSR0

25	Before Instruction	FSR0 = 22h WREG = FFh (1Dh) = 17h (22h) = 12h
30	After Instruction	FSR0 = 22h WREG = 17h (1Dh) = 17h (22h) = 12h

OVLB Move literal to BSR: Syntax: MOVLB kOperands: $0 \leq k \leq 15$ Operation: $k \rightarrow \text{BSR}$

Status Affected: None

5 Encoding: 00 0000 0010 kkkk
 Description: The four-bit literal 'k' is loaded into the Bank Select Register (BSR).

Words: 1

Cycles: 1

10 Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read literal 'k'	Process Data	Write literal 'k' to BSR

15 OVL P Move literal to PCLATH: Syntax: MOVLP kOperands: $0 \leq k \leq 127$ Operation: $k \rightarrow \text{PCLATH}$

Status Affected: None

Encoding: 11 0001 1kkk kkkk

20 Description: The seven-bit literal 'k' is loaded into the PCLATH register.

Words: 1

Cycles: 1

Q Cycle Activity:

Q1	Q2	Q3	Q4
25 Decode	Read literal 'k'	Process Data	Write literal 'k' to PCLATH

OVWI Indexed Indirect Move: Syntax: MOVWI [k]FSRnOperands: $-32 \leq k \leq 31$

$$n \in [0,1]$$

30 Operation: $\text{WREG} \rightarrow (\text{FSRn}+k)$

Move data between WREG and location pointed to by FSRn + k.

Status Affected: Z (Only if destination is WREG)

Encoding: 11 1111 1nkk kkkk

Description: This instruction is used to move data between WREG and the location pointed to by FSRn + k. FSRn is NOT updated with k. The addressable range is limited to 0000h - FFFFh. Indexing beyond these bounds will cause an address wrap-around. Note that addresses 8000h and higher point to program memory. Addresses below 8000h point to data memory, with only the lower 11 bits used for address decoding. Address calculation (addition of k to FSRn) WILL NOT affect any STATUS bits.

Words: 1

Cycles: 1

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Address Calculation.	Process Data	Write to Destination
	Read Source register.		register.

Example: MOVWI [3]FSR0

Before Instruction FSR0 = 22h

WREG = FFh

(22h) = 12h

(25h) = 56h

After Instruction FSR0 = 22h

WREG = FFh

(22h) = 12h

(25h) = FFh

Example: MOVWI [-1]FSR0

Before Instruction FSR0 = 22h

WREG = FFh

26

(21h) = 56h

(22h) = 12h

After Instruction FSR0 = 22h

WREG = FFh

5

(21h) = FFh

(22h) = 12h

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read register 'f'	Process Data	Write to destination

10

OVWI Move WREG to INDFn, with pre/post increment/decrement

Syntax: MOVWI ++/--FSRn++/--

Operands:

 $n \in [0,1]$ Operation: WREG $\rightarrow$ INDFn

15

Apply pre/post increment/decrement operation to FSR used.

Status Affected: Z (Only if destination is WREG)

Encoding: 00 0000 0001 1nmm

MM	Operations
----	------------

00 ++FSRn

20

01 --FSRn

10 FSRn++

11 FSRn--

25

Description: This instruction is used to move data between WREG and one of the indirect registers (INDFn). Before/after this move, the pointer (FSRn) is updated by pre/post incrementing/decrementing it. FSRn is limited to the range 0000h - FFFFh. Incrementing/decrementing it beyond these bounds will cause it to wrap around. Note that addresses 8000h and higher point to program memory. Addresses below 8000h point to data memory, with only

the lower 11 bits used for address decoding. The increment/decrement operation on FSRn WILL NOT affect any STATUS bits.

Words: 1

Cycles: 1

5

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Update pointer if needed.	Process Data	Write to INDFn. Update pointer if needed.

10

Example: MOVWI FSR0--

Before Instruction FSR0 = 22h
 WREG = FFh
 (21h) = 56h
 (22h) = 12h

15

After Instruction FSR0 = 21h
 WREG = FFh
 (21h) = 56h
 (22h) = FFh

Example: MOVWI --FSR0

20

Before Instruction FSR0 = 22h
 WREG = FFh
 (21h) = 56h
 (22h) = 12h

After Instruction FSR0 = 21h
 WREG = FFh
 (21h) = FFh
 (22h) = 12h

25

ESET Software Reset: Syntax: RESET

30

Operands: None

Operation: Execute nMCLR. Reset all registers and flags that are affected by a MCLR Reset. Set PCON.nSWRST flag.

Status Affected: All

Encoding: 00 0000 0000 0001

Description: This instruction provides a way to execute a MCLR Reset by software.

5 Words: 1

Cycles: 1

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Start Reset	No operation	No operation

10 Example: RESET

After Instruction	Registers=Reset Value
	Flags* = Reset Value

UBWFB Subtract WREG from f with Borrow: Syntax: SUBWFB f {,d}

15 Operands: $0 \leq f \leq 127$

$d \in [0,1]$

Operation: $(f) - (WREG) - (B) \rightarrow \text{dest}$

Status Affected: C, DC, Z

Encoding: 11 1011 dfff ffff

20 Description: Subtract WREG and the BORROW flag (CARRY) from register 'f' (2's complement method). If 'd' is '0', the result is stored in WREG. If 'd' is '1', the result is stored back in register 'f'.

Words: 1

Cycles: 1

25 Example 1: SUBWFB REG, 1

Before Instruction	REG = 19h (0001 1001)
	WREG = 0Dh (0000 1101)
	C = 1 (So B = 0)
After Instruction	REG = 0Ch (0000 1100)
	WREG = 0Dh (0000 1101)
	C = 1 (No Borrow)

30

DC = 0 (Indicates a digit borrow)

Example 2: SUBWFB REG, 0

Before Instruction REG = 1Bh (0001 1011)

WREG = 1Ah (0001 1010)

C = 0 (So B = 1)

After Instruction REG = 1Bh (0001 1011)

WREG = 00h

C = 1 (No Borrow)

DC = 1 (No digit borrow)

Z = 1 Result is zero

CLAIMS

What is claimed is:

1. An n-bit microprocessor device comprising:
 - an n-bit central processing unit (CPU);
 - 5 a plurality of special function registers and general purpose registers which are memory-mapped to a plurality of banks, comprising at least two 16-bit indirect memory address registers which are accessible by said CPU across all banks;
 - a bank access unit for coupling said CPU with one of said plurality of banks;
 - a data memory coupled with the CPU; and
 - 10 a program memory coupled with the CPU,wherein said indirect address registers are operable to access said data memory or program memory and wherein a bit in each of said indirect memory address registers indicates an access to said data memory or to said program memory.
- 15 2. The n-bit microprocessor according to Claim 1, wherein $n=8$.
3. The n-bit microprocessor according to Claim 1, further comprising at least one virtual register, wherein writing data to said virtual register causes an indirect access using one of said indirect memory address registers to said data memory or to said
20 program memory.
4. The n-bit microprocessor according to Claim 3, wherein the at least one virtual register is mapped to each memory bank.
- 25 5. The n-bit microprocessor according to Claim 1, further comprising a virtual register, wherein reading data from said virtual register causes an indirect access using one of said indirect memory address registers to said data memory or to said program memory.
- 30 6. The n-bit microprocessor according to Claim 5, wherein the at least one virtual register is mapped to each memory bank.

7. The n-bit microprocessor according to Claim 5, wherein said virtual register is not physically implemented in said microprocessor device.

8. The n-bit microprocessor according to Claim 1, wherein said data memory is 8-bit
5 wide and said program memory is 14-bit wide.

9. The n-bit microprocessor according to Claim 8, wherein one additional bit of a data memory address defines an expanded memory address range used in a debug mode.

10

10. The n-bit microprocessor according to Claim 8, wherein said bit in said indirect address register is the most significant bit.

11. A method for operating an n-bit microprocessor device comprising the steps of:

15

providing an n-bit central processing unit (CPU);

providing a plurality of special function registers and general purpose registers which are memory-mapped to a plurality of banks,

providing at least two 16-bit indirect memory address registers which are accessible by said CPU across all banks;

20

providing a bank access unit for coupling said CPU with one of said plurality of banks;

providing a data memory coupled with the CPU;

providing a program memory coupled with the CPU; and

performing an indirect addressing using an indirect address register to access
25 said data memory or program memory, wherein a bit in each of said indirect memory address registers indicates an access to said data memory or to said program memory, respectively.

12. The method according to Claim 11, wherein $n=8$.

30

13. The method according to Claim 11, further comprising the step of generating an indirect memory write access by writing data to at least one virtual register, wherein the indirect memory access uses one of said indirect memory address registers.

5 14. The method according to Claim 13, wherein said virtual register is memory mapped to all memory banks.

15. The method according to Claim 11, further comprising the step of generating an indirect memory read access by reading data from at least one virtual register, wherein
10 the indirect memory read access uses one of said indirect memory address registers.

16. The method according to Claim 13, wherein said virtual register is memory mapped to all memory banks.

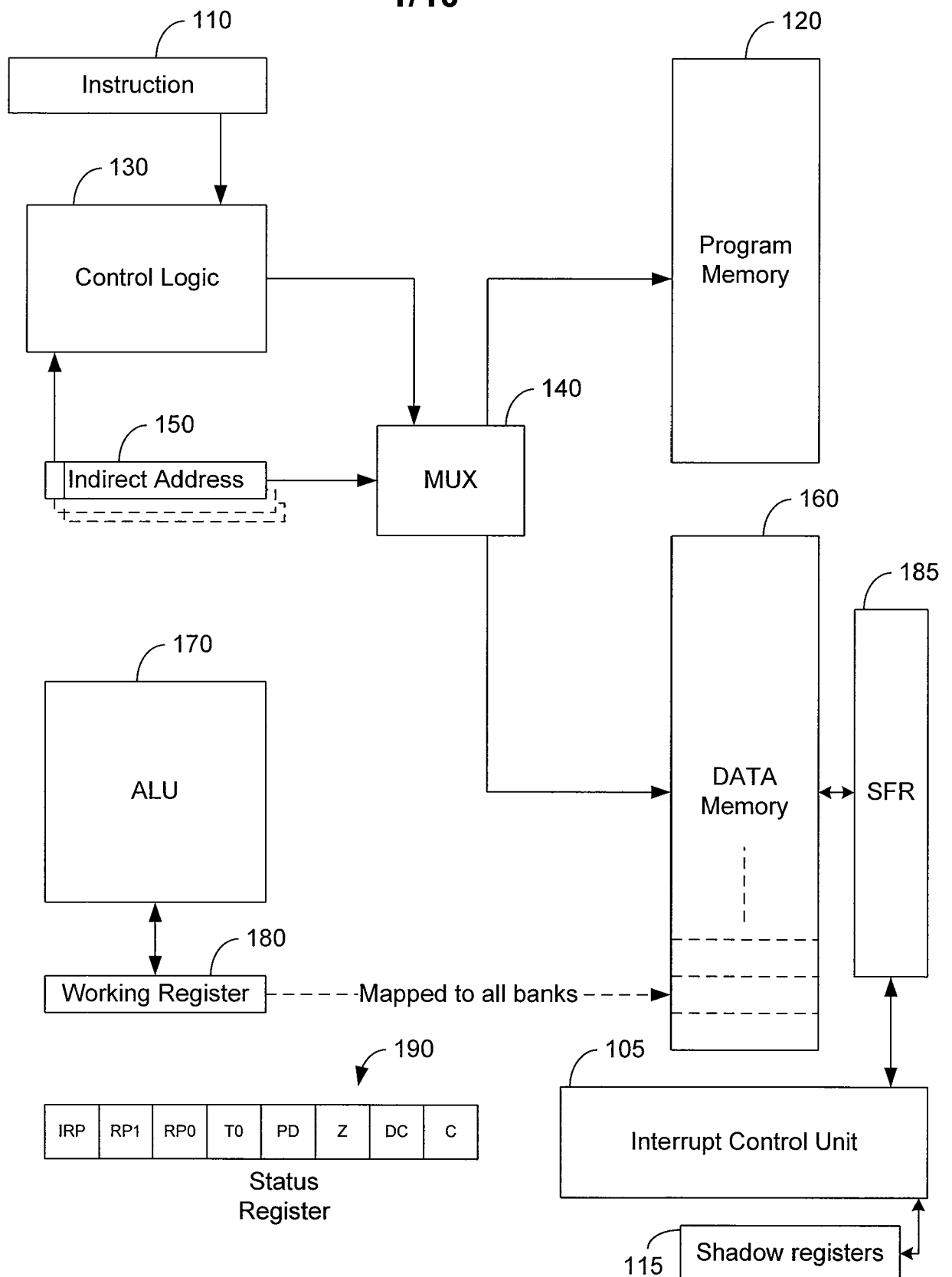
15 17. The method according to Claim 15, wherein said virtual register is not physically implemented in said microprocessor device.

18. The method according to Claim 11, wherein said data memory is 8-bit wide and said program memory is 14-bit wide.
20

19. The method according to Claim 18, wherein one additional bit of a data memory address defines an expanded memory address range used in a debug mode.

20. The n-bit microprocessor according to Claim 18, wherein said bit in said indirect
25 address register is the most significant bit.

1/10

**Figure 1**

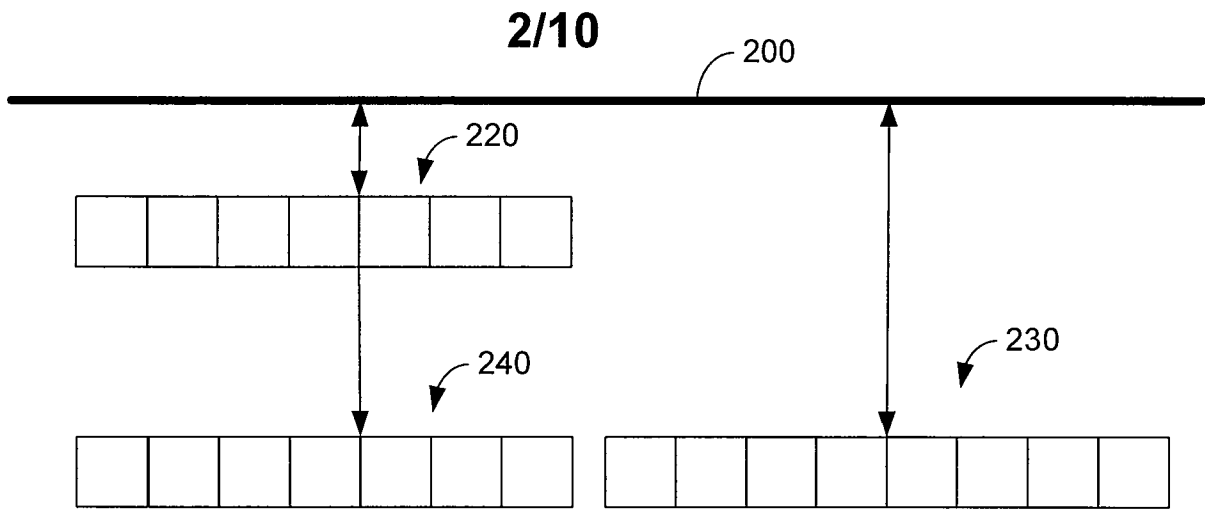


Figure 2

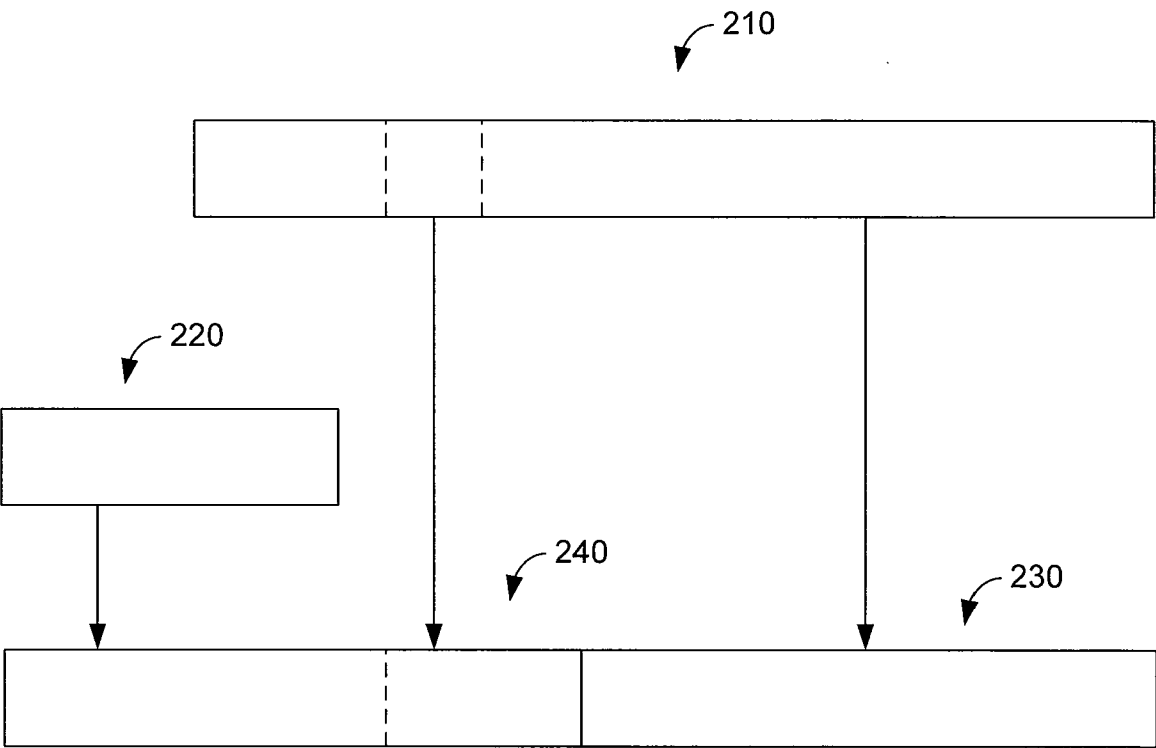


Figure 3

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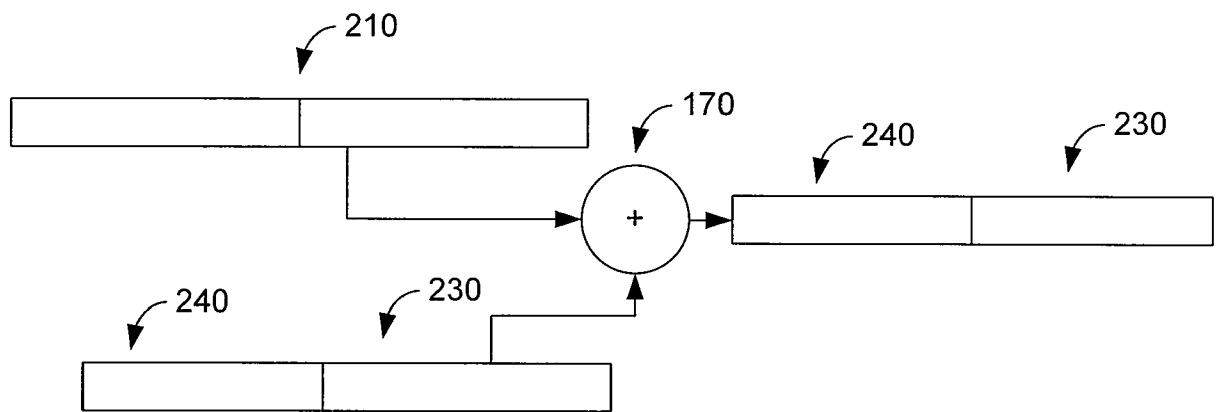


Figure 4

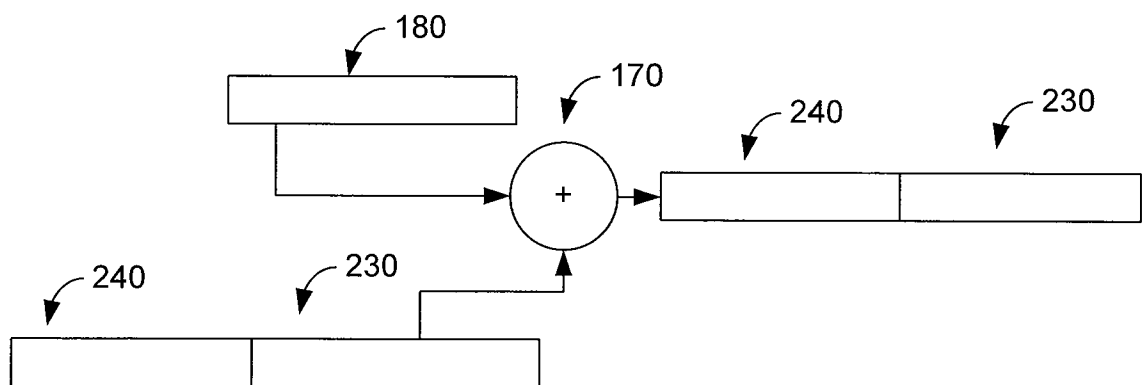


Figure 5

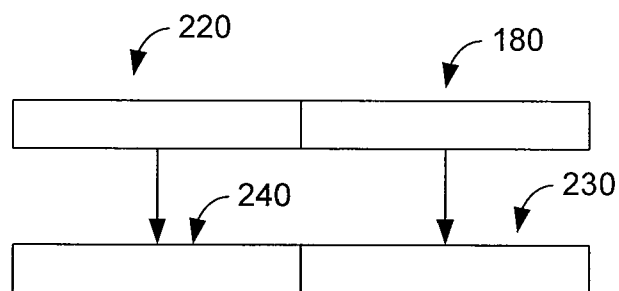
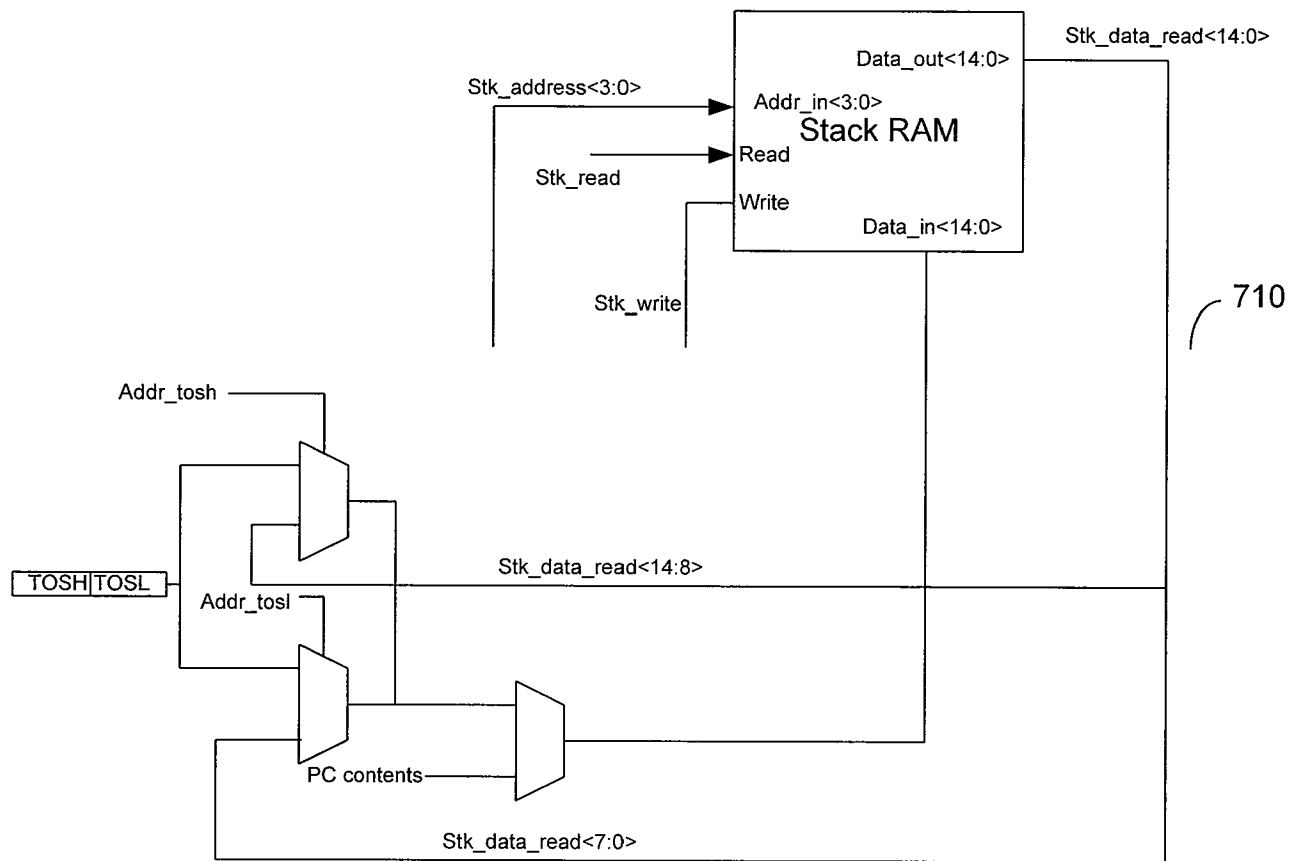


Figure 6

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**Figure 7**

5/10

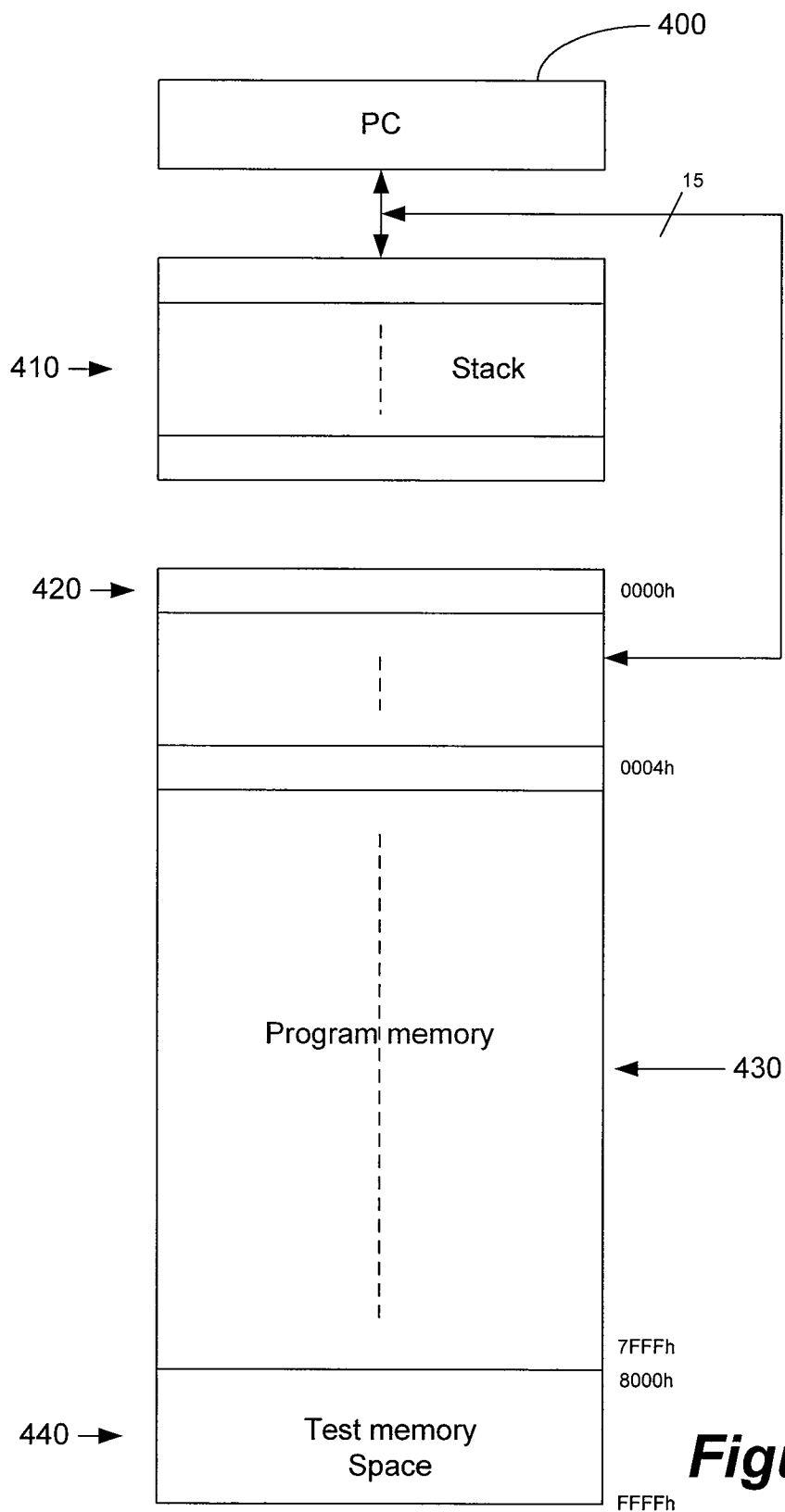


Figure 8

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-	-	-	BSR4	BSR3	BSR2	BSR1	BSR0
---	---	---	------	------	------	------	------

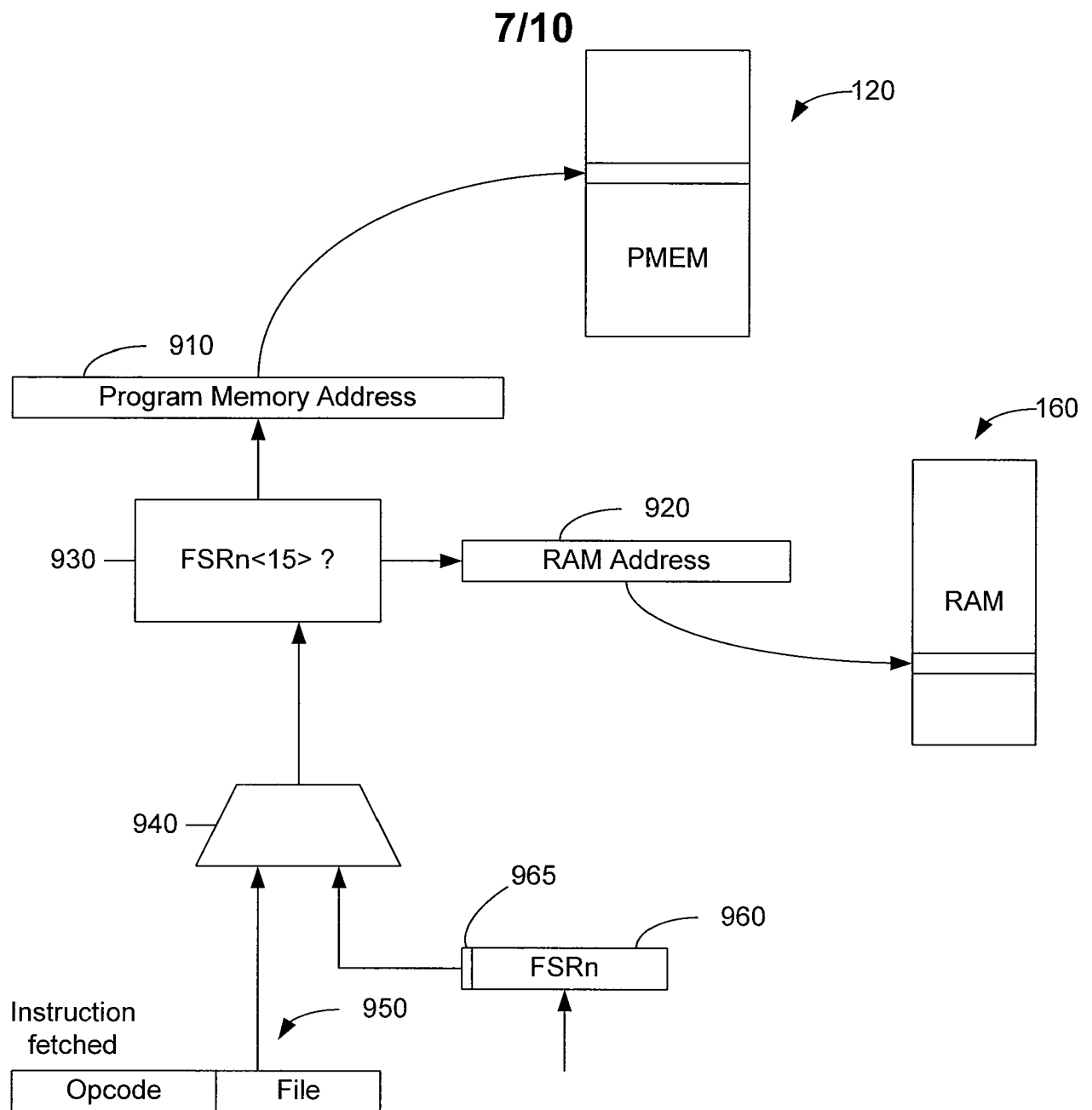
Bank Select register

Figure 9

INDF0
INDF1
PCL
STATUS
FSR0L
FSR0H
FSR1L
FSR1H
BSR
WREG
PCLATH
INTCON

Bank n

Figure 10

**Figure 11**

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Value on all other resets
Bank n											
000h	INDF0	Addressing this location uses contents of FSR0H/FSR0L to address data memory (not a physical register)								xxxx xxxx	xxxx xxxx
001h	INDF1	Addressing this location uses contents of FSR1H/FSR1L to address data memory (not a physical register)								xxxx xxxx	xxxx xxxx
002h	PCL	Program Counter (PC) Least Significant byte								0000 0000	0000 0000
003h	STATUS	IRP	RP1	RP0	$\overline{TO}$	$\overline{PD}$	Z	DC	C	0001 1xxx	0001 1xxx
004h	FSR0L	Indirect Data Memory Address 0, LSB								xxxx xxxx	xxxx xxxx
005h	FSR0H	Indirect Data Memory Address 0, MSB								xxxx xxxx	xxxx xxxx
006h	FSR1L	Indirect Data Memory Address 1, LSB								xxxx xxxx	xxxx xxxx
007h	FSR1H	Indirect Data Memory Address 1, MSB								xxxx xxxx	xxxx xxxx
008h	BSR	—	—	—	BSR4	BSR3	BSR2	BSR1	BSR0	---0 0000	---0 0000
009h	WREG	WREG7	WREG6	WREG5	WREG4	WREG3	WREG2	WREG1	WREG0	xxxx xxxx	xxxx xxxx
00Ah	PCLATH	—	Write Buffer for the upper 7 bits of the Program Counter							-000 0000	-000 0000
00Bh	INTCON	GIE	PEIE	TOIE	INTE	RABIE	TOIF	INTF	RABIF	0000 0000	0000 0000
Legend: x = unknown, u = unchanged, q = value depends on condition, - = unimplemented, read as '0', r = reserved. Shaded locations are unimplemented, read as '0'.											

Figure 12

Mnemonic, Operands		Description	Cycles	14-Bit Opcode				Status Affected	Notes
				MSb		LSb			
BYTE-ORIENTED FILE REGISTER OPERATIONS									
ADDWF	f, d	Add WREG and f	1	00	0111	dfff	ffff	C, DC, Z	1, 2
ADDWFC	f, d	Add with Carry WREG and f	1	11	1101	dfff	ffff	C, DC, Z	1, 2
ANDWF	f, d	AND WREG with f	1	00	0101	dfff	ffff	Z	1, 2
ASRF	f, d	Arithmetic Right Shift	1	11	0111	dfff	ffff	C, Z	1, 2
LSLF	f, d	Logical Left Shift	1	11	0101	dfff	ffff	C, Z	1, 2
LSRF	f, d	Logical Right Shift	1	11	0110	dfff	ffff	C, Z	1, 2
CLRF	f	Clear f	1	00	0001	1fff	ffff	Z	2
CLRW	—	Clear WREG	1	00	0001	0000	00xx	Z	
COMF	f, d	Complement f	1	00	1001	dfff	ffff	Z	1, 2
DECf	f, d	Decrement f	1	00	0011	dfff	ffff	Z	1, 2
INCF	f, d	Increment f	1	00	1010	dfff	ffff	Z	1, 2
IORWF	f, d	Inclusive OR WREG with f	1	00	0100	dfff	ffff	Z	1, 2
MOVF	f, d	Move f	1	00	1000	dfff	ffff	Z	1, 2
MOVWF	f	Move WREG to f	1	00	0000	1fff	ffff		
RLF	f, d	Rotate Left f through Carry	1	00	1101	dfff	ffff	C	1, 2
RRF	f, d	Rotate Right f through Carry	1	00	1100	dfff	ffff	C	1, 2
SUBWF	f, d	Subtract WREG from f	1	00	0010	dfff	ffff	C, DC, Z	1, 2
SUBWFB	f, d	Subtract with Borrow WREG from f	1	11	1011	dfff	ffff	C, DC, Z	1, 2
SWAPF	f, d	Swap nibbles in f	1	00	1110	dfff	ffff		1, 2
XORWF	f, d	Exclusive OR WREG with f	1	00	0110	dfff	ffff	Z	1, 2
BYTE ORIENTED SKIP OPERATIONS									
DECFSZ	f, d	Decrement f, Skip if 0	1(2)	00	1011	dfff	ffff		1, 2, 3
INCFSZ	f, d	Increment f, Skip if 0	1(2)	00	1111	dfff	ffff		1, 2, 3
BIT-ORIENTED FILE REGISTER OPERATIONS									
BCF	f, b	Bit Clear f	1	01	10bb	bfff	ffff		1, 2
BSF	f, b	Bit Set f	1	01	11bb	bfff	ffff		1, 2
BIT-ORIENTED SKIP OPERATIONS									
BTFSC	f, b	Bit Test f, Skip if Clear	1 (2)	01	10bb	bfff	ffff		3
BTFSS	f, b	Bit Test f, Skip if Set	1 (2)	01	11bb	bfff	ffff		3
LITERAL OPERATIONS									
ADDLW	k	Add literal and WREG	1	11	1110	kkkk	kkkk	C, DC, Z	
ANDLW	k	AND literal with WREG	1	11	1001	kkkk	kkkk	Z	
IORLW	k	Inclusive OR literal with WREG	1	11	1000	kkkk	kkkk	Z	
MOVLB	k	Move literal to BSR	1	00	0000	001k	kkkk		
MOVLW	k	Move literal to PCLATH	1	11	0001	1kkk	kkkk		
MOVLW	k	Move literal to WREG	1	11	0000	kkkk	kkkk		
SUBLW	k	Subtract WREG from literal	1	11	1100	kkkk	kkkk	C, DC, Z	
XORLW	k	Exclusive OR literal with WREG	1	11	1010	kkkk	kkkk	Z	

Note 1: When an I/O register is modified as a function of itself (e.g., `MOVF GPIO, 1`), the value used will be that value present on the pins themselves. For example, if the data latch is '1' for a pin configured as input and is driven low by an external device, the data will be written back with a '0'.

2: If this instruction is executed on the TMR0 register (and where applicable, d = 1), the prescaler will be cleared if assigned to the Timer0 module.

3: If the Program Counter (PC) is modified, or a conditional test is true, the instruction requires two cycles. The second cycle is executed as a NOP.

Figure 13A

Mnemonic, Operands	Description	Cycles	14-Bit Opcode				Status Affected	Notes
			MSb		LSb			
CONTROL OPERATIONS								
BRA k	Relative Branch	2	11	001k	kkkk	kkkk		
BRW -	Relative Branch with WREG	2	00	0000	0110	0000		
CALL k	Call Subroutine	2	10	0kkk	kkkk	kkkk		
CALLW -	Call Subrouting with WREG	2	00	0000	0000	1010		
GOTO k	Go to address	2	10	1kkk	kkkk	kkkk		
RETFIE k	Return from interrupt	2	00	0000	0000	1001		
RETLW k	Return with literal in WREG	2	11	0100	kkkk	kkkk		
RETURN -	Return from Subroutine	2	00	0000	0000	1000		
INHERENT OPERATIONS								
CLRWDT -	Clear Watchdog Timer	1	00	0000	0110	0100	$\overline{TO}$, $\overline{PD}$	
NOP -	No Operation	1	00	0000	0000	0000		
RESET -	Software device Reset	1	00	0000	0110	0001		
SLEEP -	Go into Standby mode	1	00	0000	0110	0011	$\overline{TO}$, $\overline{PD}$	
C-COMPILER OPTIMIZED								
ADDFSR n, k	Add Literal to FSRn	1	11	0001	0nkk	kkkk		
MOVIW	Move INDFn to WREG, with pre/post inc/dec	1	00	0000	0001	0rmm	Z	
	Move INDFn to WREG, Indexed Indirect.	1	11	1111	0nkk	kkkk	Z	
MOVWI	Move WREG to INDFn, with pre/post inc/dec	1	00	0000	0001	1rmm		
	Move WREG to INDFn, Indexed Indirect.	1	11	1111	1nkk	kkkk		

- Note 1: When an I/O register is modified as a function of itself (e.g., MOVF GPIO, 1), the value used will be that value present on the pins themselves. For example, if the data latch is '1' for a pin configured as input and is driven low by an external device, the data will be written back with a '0'.
- 2: If this instruction is executed on the TMR0 register (and where applicable, d = 1), the prescaler will be cleared if assigned to the Timer0 module.
- 3: If the Program Counter (PC) is modified, or a conditional test is true, the instruction requires two cycles. The second cycle is executed as a NOP.

Figure 13B

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2008/084921

A. CLASSIFICATION OF SUBJECT MATTER
 INV. G06F9/318 G06F9/35

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 5 034 887 A (YASUI IKUO [JP] ET AL) 23 July 1991 (1991-07-23) the whole document	1, 11
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A	US 2002/184465 A1 (GROSBACH JAMES H [US] ET AL) 5 December 2002 (2002-12-05) paragraph [0019] paragraph [0022] paragraph [0042] - paragraph [0043]; figure 4	1, 11
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

G document member of the same patent family

Date of the actual completion of the international search

18 March 2009

Date of mailing of the international search report

26/03/2009

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040,
 Fax: (+31-70) 340-3016

Authorized officer

Moraiti, Marina

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2008/084921

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International application No

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