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| **北 京 邮 电 大 学**  **实 验 报 告**  **课程名称\_\_\_\_计算机组成原理实验\_\_\_\_**  **实验名称\_\_\_\_\_\_\_实验4-6\_\_\_\_\_\_\_\_\_\_**  **\_计算机\_学院\_305\_班 姓名\_\_张晨阳\_\_**  **教师\_\_李晶\_\_ 成绩\_\_\_\_\_\_**  **\_2024\_年\_5\_月\_29\_日** |

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| **实验四、微程序控制器实验**   1. **实验任务及目的**   **实验目的：**   1. 掌握微程序控制器的原理； 2. 掌握TEC-8模型计算机中微程序控制器的实现方法，尤其是微地址转移逻辑的实现方法； 3. 理解条件转移对计算机的重要性；   **实验任务：**   1. 熟悉微程序流程图和微程序指令系统    1. 跟踪控制台操作写寄存器、写存储器、读存储器、读寄存器、的执行过程；    2. 跟踪指令的执行过程：执行ADD、LD、ST指令 2. **实验电路分析**   **实验四微程序控制电路如下图：**    图中上边部分的CM4、CM3、CM2、CM1、CM0组成控制存储器，对应着40位的微指令，其中控制字段29位，顺序字段11位。其中，CM0用于存储微指令最低的8位代码，CM4用于存储微指令最高的8位代码。  中间部分的REG6组成微地址寄存器。在一条微指令结束时，用T3的下降沿将微地址转移逻辑产生的下一条微指令地址NμA5，NμA4-T ~ NμA0-T写入微地址寄存器。  下面的若干与、或门电路组成微地址转移逻辑，负责决定下一条微指令的地址。其输入信号包括当前微指令的下址和控制信号等；T3的下降沿触发微地址寄存器的更新。新的微地址用于选择控制存储器中的下一条微指令，从而实现微指令的顺序执行。举例说明，假设现在P1为1，其余判别位为0，则下一条微指令的地址为：  NμA5-T = NμA5  NμA4-T = NμA4  NμA3-T = NμA3 或 (P1 与 IR7)  NμA2-T = NμA2 或 (P1 与 IR6)  NμA1-T = NμA1 或 (P1 与 IR5)  NμA0-T = NμA3 或 (P1 与 IR4)  这新的微地址将会在T3的下降沿更新至微地址寄存器。  **微指令格式如下图：**    实验中涉及的后继地址、判别字段、微命令的含义如下表：   |  |  | | --- | --- | | 字段 | 解释 | | NµA5~NµA0 | 下址，在微指令顺序执行的情况下，它是下一条微指令的地址 | | P0 | =1时，根据后继微地址NµA5~NµA0和模式开关SWC、SWB、SWA确定下一条微指令的地址。 | | P1 | =1时，根据后继微地址NµA5~NµA0和指令操作码IR7~IR4确定下一条微指令的地址。 | | P2 | =1时，根据后继微地址NµA5~NµA0和进位C确定下一条微指令的地址 | | P3 | =1时，根据后继微地址NµA5~NµA0和结果为0标志Z确定下一条微指令的地址 | | P4 | =1时，根据后继微地址NµA5~NµA0和中断信号INT确定下一条微指令的地址。模型计算机中，中断信号INT由时序发生器在接到中断请求信号后产生。 | | STOP | =1时，在T3结束后时序发生器停止输出节拍脉冲T1、T2、T3。 | | IABUS | =1时，将中断地址寄存器中的地址送数据总线DBUS。 | | LIAR | =1时，在T3的上升沿，将PC7~PC0写入中断地址寄存器IAR | | INTDI | =1时，置允许中断标志(在时序发生器中)为0，禁止TEC-8模型计算机响应中断请求。 | | INTEN | =1时，置允许中断标志(在时序发生器中)为1，允许TEC-8模型计算机响应中断请求。 | | PCADD | =1时，将当前的PC值加上相对转移量，生成新的PC。 |  1. **微程序流程图分析**   **实验的微程序流程如下图：**    每次复位后，会从流程图的最上部开始，先对P0进行条件判断，然后根据SWC, SWB, SWA的不同取值，跳转不同的操作模式。接着按照箭头的指向，顺序执行各条微指令。  如果操作模式为000，即取指模式，还会涉及指令的编码。该编码由IR7~IR4给出。执行完相应的指令后，对P4进行条件判断，继续执行相应的指令。   1. **实验过程及结果**            1. **实验收获及体会**   微指令控制器主要用于控制计算机中指令的执行过程。微指令是一组微操作的序列，它们直接控制计算机的硬件执行特定的指令。通过微指令控制器，可以有效地管理和协调各个硬件模块的动作，确保指令以正确的顺序和时序执行。  在现代计算机体系结构中，为了提高指令执行速度，常常采用流水线技术。微指令控制器在流水线中的应用涉及到对各个流水段的控制。通过适当的微指令序列，可以实现流水线的正确插入、转发和阻塞处理，从而最大化流水线的效率。  通过计算机组成原理理论课的学习，我觉得实验的指令格式可以进行如下优化：用5位编码（最多可表示31种指令，全0表示不执行任何命令）来表示原控制字段的内容，其余部分不变，原40位指令可被压缩为16位。  **实验五、CPU组成与机器指令的执行**   1. **实验任务及目的**   **实验目的：**   * + - 1. 用微程序控制器控制数据通路，将相应的信号线连接，构成一台能够运行测试程序的CPU；       2. 执行一个简单的程序，掌握机器指令与微指令的关系；       3. 理解计算机如何取出指令、如何执行指令、如何在一条指令执行结束之后自动取出下一条指令并执行，从而牢固建立计算机整机概念。   **实验任务：**   * + - 1. 预习任务：完成对给定程序的手工汇编。       2. 通过简单的连线构成能够运行程序的TEC-8模型计算机。       3. 将程序写入存储器，给寄存器R2、R3赋初值。       4. 跟踪执行程序，用单拍方式运行一遍，用连续方式运行一遍，详细记录实验过程及结果。       5. 用实验台操作检查程序运行结果。  1. **程序的手工汇编结果**  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | **地址** | **指令** | **二进制机器代码** | **地址** | **指令** | **二进制机器代码** | | 00H | LD R0,[R3] | 01010011 | 0AH | INC R2 | 01001000 | | 01H | INC R3 | 01001100 | 0BH | ST R2,[R2] | 01101010 | | 02H | LD R1,[R3] | 01010111 | 0CH | AND R0,R1 | 00110001 | | 03H | SUB R0,R1 | 00100001 | 0DH | OUT R2 | 10100010 | | 04H | JZ 0BH | 10000110 | 0EH | STP | 11100000 | | 05H | ST R0,[R2] | 01101000 | 0FH | 85H | 10000101 | | 06H | INC R3 | 01001100 | 10H | 23H | 00100011 | | 07H | LD R0,[R3] | 01010011 | 11H | EFH | 11101111 | | 08H | ADD R0,R1 | 00010001 | 12H | 00H | 00000000 | | 09H | JC 0CH | 01110010 | 13H | 00H |  |  1. **实验过程及结果**   **单拍方式**   |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | **指令** | **μA** | **NμA** | **P** | **INS** | **PC** | **AR** | **IR** | **A** | **B** | **D** | |  | 000001 | 100000 | 00010 | 01010011 | 00H | 00H | 00000000 |  |  |  | | LD R0,[R3] | 100101 | 001110 | 00000 | 01010011 | 01H | 00H | 01010011 |  |  |  | |  | 001110 | 000001 | 10000 | 01001100 | 01H | 0fH | 01010011 |  | 0FH | 85H | |  | 000001 | 100000 | 00010 | 01001100 | 01H | 0fH | 01010011 | 85H | 0FH |  | | INC R3 | 100100 | 000001 | 10000 | 01010111 | 02H | 0FH | 01001100 | 0FH | 85H | 10H | |  | 000001 | 100000 | 00000 | 01010111 | 02H | 0FH | 01001100 | 10H | 85H |  | | LD R1,[R3] | 100101 | 001110 | 00000 | 00100001 | 03H | 0FH | 01010111 |  | 10H | 10H | |  | 001110 | 000001 | 10000 | 00100001 | 03H | 10H | 01010111 |  | 10H | 23H | |  | 000001 | 100000 | 00000 | 00100001 | 03H | 10H | 01010111 | 23H | 10H |  | | SUB R0,R1 | 100010 | 000001 | 10000 | 10000110 | 04H | 10H | 00100001 | 85H | 23H | 62H | |  | 000001 | 100000 | 00000 | 10000110 | 04H | 10H | 00100001 | 62H | 23H |  | | JZ 0BH | 101000 | 010010 | 00000 | 01101000 | 05H | 10H | 10000110 | 23H | 12H |  | |  | 010010 | 000001 | 10000 | 01101000 | 05H | 10H | 10000110 | 23H | 12H |  | |  | 000001 | 100000 | 00000 | 01101000 | 05H | 10H | 10000110 | 23H | 12H |  | | ST R0,[R2] | 100110 | 010000 | 00000 | 01001100 | 06H | 10H | 01101000 | 12H | 62H | 12H | |  | 010000 | 000001 | 10000 | 01001100 | 06H | 12H | 01101000 | 12H | 62H | 62H | |  | 000001 | 100000 | 00000 | 01001100 | 06H | 12H | 01101000 | 12H | 62H |  | | INC R3 | 100100 | 000001 | 10000 | 01010011 | 07H | 12H | 01001100 | 10H | 62H | 11H | |  | 000001 | 100000 | 00000 | 01010011 | 07H | 12H | 01001100 | 11H | 62H |  | | LD R0,[R3] | 100101 | 001110 | 00000 | 00010001 | 08H | 12H | 01010011 | 62H | 11H | 11H | |  | 001110 | 000001 | 10000 | 00010001 | 08H | 11H | 01010011 | 62H | 11H | EFH | |  | 000001 | 100000 | 00000 | 00010001 | 08H | 11H | 01010011 | EFH | 11H |  | | ADD R0,R1 | 100001 | 000001 | 10000 | 01110010 | 09H | 11H | 00010001 | EFH | 23H | 12H | |  | 000001 | 100000 | 00000 | 01110010 | 09H | 11H | 00010001 | 12H | 23H |  | | JC 0CH | 100111 | 010010 | 00000 | 01001000 | 0AH | 11H | 01110010 | 12H | 12H |  | |  | 010011 | 000001 | 10000 | 01001000 | 0AH | 11H | 01110010 | 12H | 12H |  | |  | 000001 | 100000 | 00000 | 00110001 | 0CH | 11H | 01110010 | 12H | 12H |  | | AND R0,R1 | 100001 | 000001 | 10000 | 10100010 | 0DH | 11H | 00110001 | 12H | 23H | 02H | |  | 000001 | 100000 | 00000 | 10100010 | 0DH | 11H | 00110001 | 02H | 23H |  | | OUT R2 | 101010 | 000001 | 10000 | 11100000 | 0EH | 11H | 10100010 | 02H | 12H | 12H | |  | 000001 | 100000 | 00000 | 11100000 | 0EH | 11H | 10100010 | 02H | 12H |  | | STP | 101110 | 000001 | 10000 | 10000101 | 0FH | 11H | 11100000 | 02H | 02H |  | |  | 000001 | 100000 | 00000 | 10000101 | 0FH | 11H | 11100000 | 02H | 02H |  |   **连续方式**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | **寄存器/地址** | **R0** | **R1** | **R2** | **R3** | **12H** | | **执行操作前的值** | 00H | 00H | 12H | 0FH | 00H | | **寄存器/地址** | **R0** | **R1** | **R2** | **R3** | **12H** | | **执行操作后的值** | 02H | 23H | 12H | 11H | 62H |  1. **实验收获及体会**   通过实验五，我更加理解了CPU的组成结构以及对于存储器和寄存器的读写操作也更加熟悉。也掌握了计算机如何取指令、执行指令、以及执行完当前指令取下一条指令，对计算机组成原理理论的学习也很有帮助。  具体实验时，因为还未完全明白原理，以至于担心数据记不全，在单拍方式时，执行到STP后，依然QD了很多次，一直到了15H，记录了很多没用的数据。后来也是经过同学的提醒，才意识到已经做完单拍方式的实验。这也让我意识到，做实验之前，应该先学习理论，掌握原理，实践是用来巩固学习的，而不是通过实验学习陌生的知识。  **实验六、中断原理实验**   1. **实验任务及目的**   **实验目的：**   * + - 1. 从硬件、软件结合的角度，模拟中断的过程；       2. 通过简单的中断系统掌握中断的相关概念；       3. 了解微程序控制器与中断控制器协调的基本原理；       4. 掌握中断子程序和一般子程序的本质区别,掌握中断的突发性和随机性。   **实验任务：**   * + - 1. 理解中断相关指令，以及每个信号的意义和变化条件       2. 将主程序和中断服务程序手工汇编成二进制机器代码       3. 通过简单的连线构成能够运行程序的TEC-8模型计算机。       4. 将主程序和中断服务程序装入存储器，给寄存器R1赋初值01H，R0赋初值0。       5. 执行三遍主程序和中断服务程序，详细记录中断有关信号变化情况，特别记录好断点和R0的值。       6. 将主程序中地址为00H的EI指令改为DI，重新运行程序，记录现象。  1. **程序的手工汇编结果（包括主程序和中断服务程序）**  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | **主程序机器代码** | | | **中断服务程序机器代码** | | | | **地址** | **指令** | **二进制机器代码** | **地址** | **指令** | **二进制机器代码** | | 00H | EI\DI | 11010000 | 45H | ADD R0,R0 | 00010000 | | 01H | INC R0 | 01000000 | 46H | EI | 11010000 | | 02H | INC R0 | 01000000 | 47H | IRET | 10110000 | | 03H | INC R0 | 01000000 |  |  |  | | 04H | INC R0 | 01000000 |  |  |  | | 05H | INC R0 | 01000000 |  |  |  | | 06H | INC R0 | 01000000 |  |  |  | | 07H | INC R0 | 01000000 |  |  |  | | 08H | INC R0 | 01000000 |  |  |  | | 09H | JMP [R1] | 10010100 |  |  |  |  1. **实验过程及结果**  |  |  |  | | --- | --- | --- | | **执行程序顺序** | **PC断点值** | **中断时的R0** | | **第1遍** | 05H | 15H | | **第2遍** | 06H | 84H | | **第3遍** | 09H | C0H |   第一遍执行到断点后，再一步步执行中断服务程序，PC的变化如下：  45H 🡪 46H 🡪 47H 🡪 05H 🡪 06H …  第二遍执行到断点后，再一步步执行中断服务程序，PC的变化如下：  45H 🡪 46H 🡪 47H 🡪 06H 🡪 07H …  第三遍执行到断点后，再一步步执行中断服务程序，PC的变化如下：  45H 🡪 46H 🡪 47H 🡪 09H 🡪 10H …   1. **实验收获及体会**   通过实验六，我熟悉了中断控制器和微程序控制器在中断过程中的作用，掌握了中断机制，加深了对中断的理解。同时，还巩固了实验四和实验五的硬件操作。  在实验过程中，我发现编写结束后正常执行一遍很容易回到断点，继续执行原程序，但继续设置断点，执行时会在47H和48H两个地址间跳跃而不回到断点处。除此之外，在关中断的情况下，不会跳转到中断程序，而是继续执行原程序。 |

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