EMULATOR FOR SINGLECHIP MICROCONTROLLERS PIC

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ABSTRACT

The emulator is a hardware part of the development environment for debugging applications for the microcontrollers Microchip PIC. This emulator uses in–circuit debugger capability of the PIC16F877. There is another microcontroller on the emulator board to communicate with personal computer and to generate variable clock signal. The emulator contains a LED display unit, a small keypad and a couple of LEDs also. There is an analog to digital converter in the PIC microcontroller. The emulator circuitry simplifies the design of A/D applications.

1 INTRODUCTION

Development environment is a general expression in electronics, electrotechnics and in microelectronics, it means device or software tools for an easier development of an application or product. Singlechip Microcontrollers have recently been commonly applied very much in electronic systems. Word “singlechip” highlights the fact that relevant parts of the all microcontroller are integrated on one silicon chip inside the package. It is suitable to say at this point that there are two main architectures of microprocessor systems. Von Neumann’s solution is being used for systems like Personal Computer. This keeps the device opened for future expansion of memory capacities, computation rate or changeability of configuration. Von Neumann’s systems have common address space. The other systems are based on Harvard architecture that gives two separated areas of the memory. One is used for executable code, the other is for data. Harvard architecture can be found in singlechip microcontrollers. The capabilities and properties of these microcontrollers are specified relatively exactly. The designer has to know about these restrictions that affect the choice of the required microcontroller type. The scale of the available types is really wide. Among the many different types of microcontrollers are devices PIC produced by Microchip company. The design of the emulator is focused on the PIC 16F87x specification. The development environment consists of hardware and software part. Following text will refer to the hardware.

2 ANALYSIS

The design of any new electronic system or device equipped with a microcontroller needs premeditation at the beginning and the subsequent design of the electric circuit, printed copper board and the development of the microcontroller's software of course. It is the recommended procedure when these activities meet the others and compare their specific requirements. Discussion is necessary in a designer team. Even if everything seems to have been done perfectly the design may not be successful. Different prototypes, experiments and another laboratory investigation helps to eliminate possible development errors. When hardware is constructed or activated it is often used. Problems occur really frequently in the software development phase. There is very low probability that the first version of the software is definitive. It is recommended to use different tools, aids and methods to increase the probability and shorten the development time.

2.1 SIMULATORS

It is not always necessary to develop the software directly on required hardware in every case. The simulator can execute some of the development steps. The simulator is a software tool. Microcontroller's software is usually simulated on another microprocessor platform with an operating system. Normally it is a Personal Computer with appropriate simulating program. The gain for the designer is quality, standard and comfortable user–friendly environment that runs on the machine with many times higher computation rate. The simulator executes exactly most operations the microcontroller does. Especially arithmetic and logic operations are in detail simulated and the designer has direct control above the registers, memory or the state of some integrated peripherals as output port latches, UART transmitter, timers etc. Software breakpoints can be used very well, time consumption can be measured precisely and tracing or stepping is also usable. The states and values of function blocks as registers or memories are available in different forms. They can be watched as numbers in various number systems, character representation, back translated executable code etc. Anything can be changed without limitation during simulation, of course. The simulator has no connection to real application and it is the source of the restrictions for simulation at real time processes. So this is the reason for deploing the emulator.

2.2 EMULATORS

The emulator is an electronic circuit with microcotroller of the same type as is used in the developed application. Minimum tolerance between required and used type is allowed. The emulator can be constructed as a stand alone device with its own user interface (display and small keypad) or it is expanded by software for Personal Computer. The best solution is a complete integrated development environment with a simulator and a higher programming interface for example a C+ compiler or a macro assembler. The other case is a simple "suit box" emulator of the Intel 8048 singlechip microcontrollers independent of any Personal Computer. Every command has been input through a small keypad and everything should be watched on a seven segments LED display. The emulator runs on an other circuit of the same type, as is the emulated one. The essence and efficiency are based on the fact that the developed software runs in the target microcontroller in "real" time and environment without the limits the simulator has. Quotation mark signs reality there is no ideal emulator, because of the uninterrupted clock execution, detailed electrical parameters, dimensions etc. On the other hand if there is justified requirement for better properties or performance of the emulator, a better emulator can certainly be found or developed. The best emulators are on chip support circuits or special programmable logic arrays. Evaluation of the emulated circuit state is done by another chip situated very close to the emulated one. It is difficult and expensive to produce these kinds of emulators. The achieved electrical (input/output capacitance and resistance, highest frequency) and thermal parameters (lead off lose thermal power, working temperature range) of the emulator should be equal to convention microcontroller. Precise emulators are used strongly with high–powered projects as space research, military, aeronautic or medical programs. Simpler and cheaper emulators can be a little circumscribed and the designer should be considered by the designer bound. Some of simpler emulators are not fully hardware supported, but allow debugging of the user application. It is called In–Circuit Debugger (ICD). Some difference can be between emulator and debugger, but it is quite correct to use emulator generally. Next part of the text is about ICD emulator design.

3 PIC MICROCONTROLLER ICD EMULATOR DESIGN

This chapter deals with the design of an emulator for debugging programs written in assembler language. The emulator should set break points, work in step mode, change values of File Registers and be able to show the contents of available memory areas. It will be possible to set the clock frequency from 32,768 Hz to 16 MHz. For debugging purpose the application board is equipped with LED and LCD display, buttons, couple of light emitting diodes for watching of the port state. Only three pins of the microcontroller are reserved for emulator RB7, RB6 and /MCLR. Software limitations are: instruction at address 000h must be a NOP; six general-purpose registers at address space 1EBh-1F0h are reserved; 152 bytes of the program memory are allocated by debugger code and one level of the hardware stack is not available. The emulator uses an ICD function implemented in some PIC microcontrollers. Many PICs have a ICSP function without ICD function. Intended for these is a simplified debugging tool with one possible breakpoint and no main line return. Microcontrollers PIC produced by Microchip company are often used in driving, automation and regulation. Portfolio PIC microcontrollers is built up by simple devices with a small number of the input/output pins, a low memory capacities and complicated great devices with tens pins and kilobytes of memory. The best known product classes are PIC 12, 14 and 16. Devices that have neither ICD nor ICSP function can be emulated by professional (In–Circuit) debuggers. Their price is several tens of thousands Czech crowns.

3.1 IN-CIRCUIT DEBUGGER

The function ICD implemented in PIC16F87x is described in the following text. The Configuration word at address 2004h contents an executable code of the unconditional jump instruction. The parameter of this jump is debugger code address. The debugger code ussualy lies at the top of the program memory. The debugger is the part of emulator, Its code can be changed and adapted on debugging request. Its purpose is to communicate with higher systems at a time when information about microcontroller’s state should be read or get changed. Debugger code executing session is closed by RETURN instruction. Control gets back to the user’s program immediately. The debugger code should be written as an interrupt subroutine. It means that nothing can be changed if it is used by a user’s program. The debugger code should be short, quick, without errors etc. Debugger subroutine calling is performed when at least one of the specific conditions is completed. The first is the current value of the program counter equals the value stored in BIGBUG file register (break point address). The second is SSTEP flag is set and one instruction of user's program is executed. The third one is the detection of the falling edge on RB6 pin. Timers/counters, UART and PSP timing are stopped when FREEZ flag is set and the debugger code is actually performed. Watchdog timer cannot be stopped. The hardware ICD support, the debugger code and environment software being run on the Personal Computer determine behaviour of the emulator system. Together it gives a basic useful tool for an easier software development.

3.2 SHORTFORM DESCRIPTION OF THE PIC16F877 DEVICE

The core of the emulator realises singlechip RISC (Reduced Instruction Set Computer) microcontroller PIC16F877. The PIC16F877 is the highest representative of the 16F87x class that all have built in ICD function. The most important data and values will be introduced. These parameters determine emulator capability.

- DIL40 package backward compatible to PIC16C64, 65, 662, 67, 74, 76, 765,77 and PIC16F74, 77.
- Instruction set has 35 instructions 14 bits wide. Every instruction is executed during one instruction cycle. One instruction cycle is divided into four clock cycles. The only exception are branch instructions that need two instruction cycles to complete.
- The highest clock frequency is 20 MHz (5 MIPS performance)
- Memory capacity is 8192 words × 14 bits for instructions, 368 bytes RAM and 256 bytes EEPROM for data.
- Another feature is Power−on Reset (POR), It spares one pin for initiation if needed. Power−up Timer (PWRT) holds RESET signal in active state 72 ms for supply voltage stabilization after power on. The oscillator Start−up Timer (OST) extends RESET time for good crystal oscillator stability on power up. Brown−out Reset (BOR) watches supply voltage level. When voltage goes bellow 4 V then RESET is performed. For better reliability of the system Watchdog Timer (WDT) with independent RC oscillator can be used.
- The interrupt system has 14 sources of the interrupt signal. The returnable addresses are stored in hardware eight level deep stack. Data memory and file registers are accessible directly, indirectly or relatively. Program memory can be reading protected, but application running inside the microcontroller is able to read or modify memory without restrictions. Programming is low voltage In−Circuit only two I/O pins and one /MCLR pin are used. Supply voltage range is since 2.0 till 5.5 V. Low voltage supplement (4.5 V and lower) disables some capabilities of the circuit (BOR, Bulk−Erase). There is previously mentioned ICD function for easier software development.
- Output pins can sink or source currents up to 25 mA. Typical current consumption at 3 V at 4 MHz frequency is 0,6 mA, at 32 kHz it is 20 μA. In standby mode consumption is less than 1 μA. Fully static logic keeps internal information even no clock present.
- There is selectable clock generator mode: LP (Low Power Crystal), XT (High speed Crystal/Resonator), HS (High speed Crystal/Resonator), RC (Resistor/Capacitor) or internal RC oscillator running at 4 MHz.

- Microcontroller peripherals are 8 and 16 bits timers/counters, 10 bits PWM, 10 bits A/D converter with 8 multiplexed analog inputs, communication interfaces SPI, I2C, USART/SCI, PSP etc.

3.3 THE EMULATOR CIRCUITRY DESCRIPTION

The emulator circuitry has four parts (driver B1, clock generator B2, clock multiplier B3 and emulation socket EC). The application board BA can be used optionally to develop basic level software or to start programming on PICs at first.

The driver connects parts together and sources supply voltage 5 V. Communication interface between emulator and Personal Computer is serial RS232. Clock generator can be set by three digital signals grouped into CLG_BUS. Program download and emulation procedure is provided by these signals: PGD (data), PGC (clock) and /MCLR (initiation). Higher voltage 10 V is used to activate ICSP and ICD function.

The clock generator is a programmable frequency oscillator. It uses four base frequencies: 9.216; 10; 11.0592; 12 MHz and a 16 bits frequency divider to generate a required clock. Estimated output frequency is from 32,768 Hz to 1.2 MHz.

The clock multiplier increases output frequency by a coefficient 2, 4, 8, 16, 32 or 64. Multiplying is based on phase locked loop with frequency divider in loop back.

The emulation socket with a PIC microcontroller should be applied in user's application. The six−wired cable connects the driver board and the emulation socket. There are three jumpers at the emulation socket to select a source supply voltage, clock and /MCLR signal.

There are two RISC Atmel AVR microcontrollers used to manage driver and clock generator board. They are In−Circuit programmable, so capability of the circuit is easily changeable.

4 CONCLUSION

The text refers to the development environment for singlechip microcontrollers. There is theory about simulators and emulators written at begin and their advantages and disadvantages are described. There is a short description of the PIC16F877 microcontroller. A simple emulator is designed it uses an In−Circuit Debugger function that is implemented in PIC16F87x microcontrollers. The block diagram shows interconnection of the all circuit parts.

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