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The Design of Sport Bicycle Speed Odometer

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Abstract: As bicycle sport equipment, a sport bike needs a speed and distance measuring device, due to the characteristic of road cycling, thereby mastering the state of motion. According to external conditions such as temperature, wind speed, the bike can make the appropriate adjustment to achieve the best movement effect. The bicycle speed odometer is a major accessibility tool that satisfies with needs of the people with fast development. This study elaborated a bike speed odometer design based on Hall element, taking AT89C52 single chip as the core, measuring speed with A44E Hall sensor, to finish the bike mileage/speed measurement and statistics by displaying bike mileage and speed in real time. By using the Hall elements, the hardware of speed odometer input the number of pulse of per circle into the single-chip computer system. Then the signal processed by the single-chip computer displays. The software is programmed with assembly language and modular design idea. The design of the hardware circuit is simple and the subroutine has universal property, which fully meet the design requirements and possess a wide range of application and dissemination value.

Keywords: Mileage/speed, single-chip computer, sport bicycle, the Hall element

INTRODUCTION

Biking is a popular and easily developed sports project which is the integration of the speed, strength and endurance quality (Zhang, 2009). With the development of the economy and society, not only people's material and spiritual life has a great promotion, but also the awareness of health and environmental protection improved significantly. More and more people consider that the bicycle is not only a transportation tool, but also has the fitness and recreational sport value (Lv, 2005), which lead to mass cycling boom. As the bicycle sport equipment, due to the characteristics of the road cycling project, the sport bike needs a speed measuring device in order to master the movement situation. According to the external conditions such as temperature, wind speed, the appropriate adjustment, it can achieve the best movement effect. As one of the auxiliary tools of the bike, the bike odometer is rapidly developing and its function develops from a single mileage display to speed and time display and even taking riders' heartbeat measurement and calorie consumption display and so forth. Recently, there are various of designs of the bike odometer, most of those take the measurement by mechanical or analog-digital circuit, existing some disadvantages, such as large volume, low precision, indirect-view, power consumption and so on (Dong *et al*., 2009). This design adopts a MCS-51 series of single-chip computer to design a small, portable and simple-operation bicycle speed odometer. It can automatically display the current walking distance and running speed of the bicycle.

TASK ANALYSIS AND IMPLEMENTATION

The task of this design: By using the general MCS-51 single-chip computer as the processing core, the sensor converts wheel rotation numbers into electric pulses, after processing and send it into a single chip. The MCS-51 timer/counter measures the total number of pulses and the time of each circle, then put the data into the single-chip computer, after calculating and displays the result through the LED to get the number of mileage and speed.

Overall thinking as follows: Assuming the circumference of a wheel as L, install m permanent magnets on the wheel and the maximum error of the mileage value is L/m.

By comprehensive analysis, m =1 during this design. When the wheel rotates one circle, the Hall element sensor could collect a pulse signal and pins from P3. 2 interrupt 0 inputs, once the sensor gets a signal; it will provides a count interrupt. Each interrupt represents the wheel rotation one circle and the rim circumference of interrupt number n is value of L product of mileage. The counter T1 calculates the time t of each circle and we can calculate the instantaneous speed v. At the same time, it could deal with the numeric and display on the digital tube in real-time, eight digital tubes, the first four show the total mileage, the last four show the current speed. If the bicycle speeds, the system will give an alarm signal, then the digital tube will stop.

The required targets and implementation methods are as follows:

- Utilize the mileage pulse signal produced from the Hall sensor
- Count the pulse signals

Implementation: Utilize the external interrupt T0 of the single chip computer to count the pulse signal from the Hall sensor.

- Process the data and the total mileage and the immediate speed display on the LED

Implementation: Utilize software programming to process the data in order to get the desired value.

The ultimate goals: the bicycle speed odometer mileage has the following functions, mileage, speed test and display function. By using single chip computer as control, the mileage and speed can be shown on the display circuit.

THE HARDWARE DESIGN OF BICYCLE SPEED ODOMETER

The signal is got from the Hall sensor. We can get the pulse signal from the Hall sensor, of which the mechanical structure is simple. Attach a magnet to the gear wheel of the rotation shaft, fix Hall element on the front fork and when the wheels turns, the Hall element would be close to the magnet and a signal will output. When the shaft rotates, it will to produce pulse signals continually. If the multiple magnets were attached to the gear wheel, the wheel can rotate one cycle and it can get multiple pulses output.

Hall sensors are sensitive to magnetic, which are commonly used in signal acquisition such as A44E.The sensor is a 3-terminal device, of which shape is similar to the triode. As long as the power is connected, it can work, with large voltage range and convenient usage (Wang, 2010).

The single-chip microcomputer has the general characteristics that others don't possess due to its integrated with the CPU, memory and the necessary interface and it can make a certain structure optimization of controlling function. Characteristics are as follows:

- Small volume, light weight
- Single power, low power consumption
- Strong function, low price
- All integrated on a chip, short wiring; reasonable
- Most of the data transmit in single chip microcomputer with fast running speed, strong anti-interference ability and high reliability

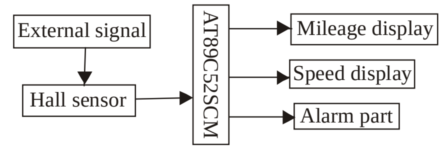

Fig. 1: The principle diagram of the system

At present, single-chip computer is widely used in measurement and control systems, industrial automation, intelligent instrument, integrated intelligent sensor, the integration of mechanical and electrical products, household electrical appliances, office automation, automotive electronics and aerospace electronic system ,single chip multi-machine systems areas and so on (Liu, 2009). My choice is AT89C52 single-chip computer. As shown in Fig. 1.
System schematics as shown in Fig. 2.

Integrated switch type hall sensor: A44E integrated Hall switch consists of five basic components: the voltage regulator A, Hall potential generator (namely silicon Hall tablet) B, differential amplifier C, Schmitt trigger D and OC gate output E. In the end of power, supply voltage Vcc, after voltage-stabilizing and add it at both ends of the hall potential generator. According to the Hall Effect principle, when the Hall tablet is in a magnetic field, drive a current in the direction perpendicular to the magnetic field and it will produce Hall potential difference VH output in the vertical direction. The VH signal will become the square wave and it will be sent to OC gate output after amplifying and shaping by the Schmidt trigger. When the applied magnetic field reach the operating point, the flip-flop output high voltage (relative to ground potential) to bread over the transistor and it will make the OC gate output low voltage. Usually this state is called open. When the applied field reaches the point of release, the trigger output low voltage and triode cutoff, which make OC gate output high voltage. This state is called close. The two voltage conversion could finish a switching action.

The principle and application of the single chip computer: AT89C52 is of low voltage, high performance CMOS 8 bit SCM made by ATMEL Company in the United States of America. It contains the 8 K Bytes repeatedly erasable read-only memory program (EPROM) and 256 bytes of RAM (RAM), which adopts ATMEL's high density, non-volatile storage technology and it is compatible with the standard MCS-51 command system and 8052 pin. There are general built-in 8 Central Processor (CPU) and Flash storage unit and they have powerful functions. AT89C52 chip is suitable for many of the more complex control applications.

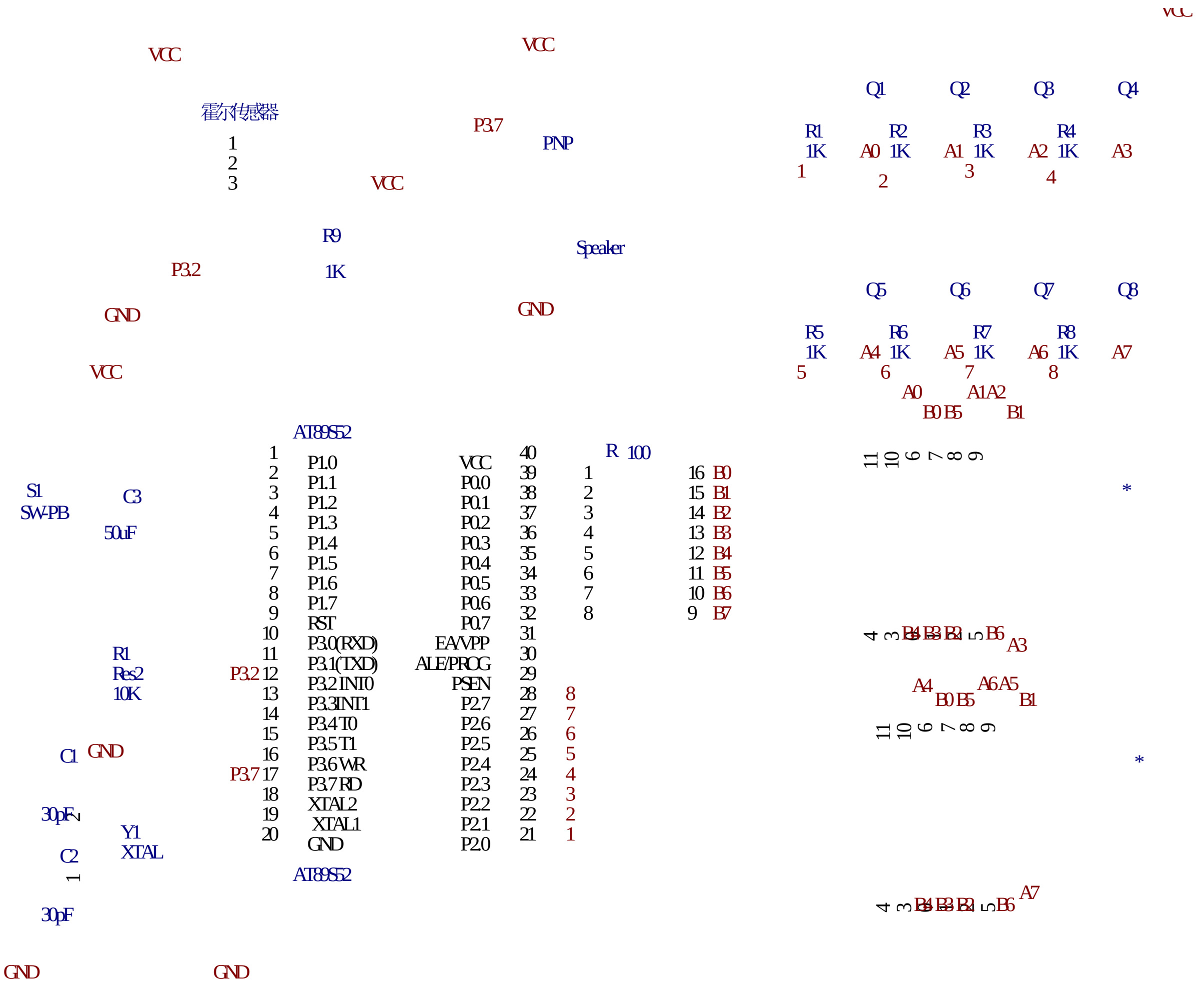

Fig. 2: The schematics of the system

The introduction of the single chip microcomputer interrupt system: Interrupt refers to that when the computer performs the normal procedures, there are some urgent events appearing in the system. At the same time, CPU temporarily suspends the current program to perform the service procedures in order to deal with the urgent events. Then, CPU automatically returns to the original program after the treatment.

- **Interrupt enables control:** The interrupt enable register IE controls all interrupts and the opening and shielding of an interrupt source. IE state is set up by software, a set of 1, the corresponding interrupt source interrupt enable; a set of 0, the corresponding interrupt source interrupt shielding. During CPU reset, IE is 0, prohibit all interrupts
- **Interrupt priority control:** AT89C52 MCU has two interrupt priorities, which can realize second-level interrupt nested service. Each interrupt priority is provided by the corresponding state of the interrupt priority register IP. IP state is set up by software. If a bit is set to 1, the corresponding interrupt source is high priority interrupt; if a set is 0, the corresponding interrupt source is low priority interrupts. If the chip resets, IP is 0, each interrupt source is low priority interrupt.

The functional introduction of the single chip timing/countering: The working of AT89C52 SCM timer/counter is controlled by two special functional register. TMOD is used to set the working mode; TCON is used to control the start and the interrupt request.

- **Working mode register TMOD:** Working mode register TMOD is used to set the timer/counter mode.
  When GATE = 0, as long as the TCON TR0 or TR1 is 1, you can start the timer/counter; when GATE = 1, the TR0 or TR1 is 1, while the external interrupt pin $\overline{\text{INTO}}$ or $\overline{\text{INTI}}$ is at a high level, the timer/counter can start to work.
  $C/\overline{T}$: Timing/counting mode selecting bit. $C/\overline{T} = 0$ refers to timing mode; $C/T = 1$ refers to counting mode.

M1M2: working set. Timer/counter has 4 working modes, set up by M1M2.
The design of TMOD is 90H, namely the strobe timer/counter 1, timing functions, working mode1.Working mode 16 bit timer/counter.

- **Control register TCON:** TF1 (TCON.7) timer/counter T1 overflow interrupt request flag. TF1 is set as 1 automatically by the hardware when timer/counter T1 count overflow. TF1 automatically reset by the hardware after the CPU response interruption. When T1 works, CPU can query the status of the TF. Therefore, TF1 can be used as query test sign. Also, TF1 can use the software to provide 1 or 0, which has the same zero clearing effect like the hardware.
  TR1 (TCON.6) timer / counter T1 operation control bit. When TR1 is set to 1, timer/counter T1 starts to work; when TR1 is set to 0, timer/counter T1 stops working. TR1 is set to 1 or 0 by the software.
  TF0 (TCON.5): timer/counter T0 overflow interrupt request flag.
  TR0 (TCON.4): timer/counter T0 operation control bit.

Peripheral circuit design of single chip microcomputer:

- **Clock circuit design:** Clock is the heart of the simple chip microcontroller and each function parts operate based on the clock frequency, which directly affect the speed of the simple chip microcomputer and also the quality of the clock circuit has a direct influence on the stability of single chip microcomputer system. AT89C52 chip has a high gain inverting amplifier which is used to form oscillator. The high gain inverting amplifier input is the chip pin XTAL1 and the output is a pin XTAL2. The two pins are connected a quartz crystal oscillator and the capacitor to form a stable self-excited oscillator.

Electric capacity C1 and C2 in circuit is always around 30P. There is no straight demand about the external capacitor, but the amount of capacity will affect the height of oscillator and the stability of it. It will also affect the speed of oscillation starting and the stability of the temperature. However, the amount of the external crystal filters depends on the working scope of the single chip computer. Every single chip computer has its own working frequency. And the oscillating frequency of the external crystal filters should not be above that of single chip. Moreover, if single chip computer has serial communication, we should choose the divided filters which are divided by the serial communication frequency. This design uses 12MHz and then the period counting is:

$$T = \frac{1}{(12 \times 10^{6}\ Hz \times 1/12)} = 1\mu S$$

- **The design of the reset circuit:** The design of reset circuit reset circuit adopts pull-button reset circuit, which is one of the commonly used reset circuit. Simple Chip computer, which is called the manual reset, could produce a high level by pressing the button. If the power is on, just switch on the power, the capacitance C is equivalent to the instantaneous short circuit. Plus 5 v immediately to RET/VPD end and the high level make 89C52 reset automatically, which is power on reset; If the operation process needs to program from the execution, just press button. Press the button and plus 5 v directly added to RET/VPD end, which is called manual reset. After reset, they are parallel from P0 to P3 and I/O port is the high level. Other registers will reset and only SBUF register state uncertainty.

Working principle: The moment the power is on, RC circuit begins charging and RST pin appears high level. As long as RST end maintains 10 ms above high level, it can make SCM effectively reset.

- **The design of display circuit:** In the SCM system, using the LED digital display to displays various numbers or symbols because of its clear display, high brightness, low working voltage, long life characteristics, so it has the extensive use. This design adopts the dynamic scanning displaying interface circuit. The dynamic display interface circuit matches the entire display 8 stroke segment A-H with homonymous ends and each public COM of the display is controlled independently by I/O line. When the CPU output font code to field, all display receives the same font code, but which display lights depends on the COM terminal. During the process of lighting scanning in rotation, the time for each lighting is extremely short (approximately 1ms). Owing to the persistence of vision and the afterglow effect of the diode, despite the fact that each monitor is not lighted at the same time, if the lighting speed is fast enough, a stable set of display data should be shown to us, no sense of flicker
- **The design of alarm circuit:** The alarm circuit adopts a buzzer alarm. When the instant speed exceeds a predetermined value, the buzzer sounds and the indicator light flashes, which alarms that the speed should reduce.

THE SOFTWARE PROGRAM DESIGN OF THE BICYCLE SPEED ODOMETER

Modular structure design is a programming process. It divides the whole function of the system into many small function modules, based on the requirements and the structure of hardware design and then writes a program according to these small modules (Hu, 2003). Based on the Hall sensor, the software design of bicycle speed odometer includes a the power-up initialization procedure, interrupt subroutine, speed, mileage, speed calling a subroutine, mileage call subroutine, LED display subroutine, delay subroutine and so on. Owing to achieving a lot of functions, the modular design should be adopted. The respective analysis to the main parts as follow:

The overall program design of the bicycle odometer: In the main program module, it needs to complete each interface chip initialization, bicycle mileage and speed initialization, the design of the interrupt vector, the waiting for the open interrupting and the circular waiting and so on. In addition, in the main program module, the start/clear flag register, mileage register, speed register should be set and initialized. Then according to each mark the contents of a register, the main program will complete the start, clear, log and meter speed and other different operations respectively.

Interrupt 0 is used to input the amount of the wheel circle. Once the wheel rotates one circle, the Hall sensor outputs a low level pulse. According to the contents of the mileage register, it can calculate and judge the number of the mileage. Interrupt 1 is used to control the start / stop of the timer T1. When the input is 0, it will close the timer. The control signal is formed after the count of the wheel circles is processed through the frequency-halving circuit. Thus, each time the timer T1 opens is just the time for one turn. According to the wheel circumference, it can calculate the speed of the bicycle. The program flow as shown in Fig. 3.

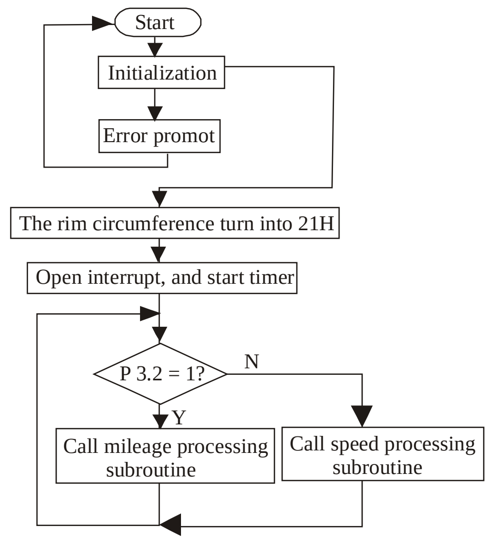

Fig. 3: The main program flow char

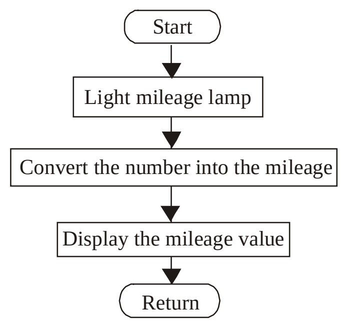

Fig. 4: The flow diagram of the mileage processing subprogram

Interrupt subroutine design: Timer interrupt is set to meet the need of the timing or counting. There are two internal timer/counters in the single chip microcomputer. According to the count structure, using the counting method realize the timing and counting function. When the structure counts overflow, it indicates that timing or counting is full and then the count overflow signal as an interrupt request to set an overflow flag. The interrupt request is in the chip interior; therefore, the leading-in end should not be set in the chip.

Timer/counter control register TCON is an 8 bit address register, its address is 88H, bit addressing. The high 4 bits is used to control the timer/counter interrupt and low 4 bits is lent to external interrupt to be used for interrupt flag and trigger mode select bit. This design adopts the timer interrupt to count the bicycle mileage and speed.

The design of the data processing subroutine:

- **The design of the mileage calculation subroutine:** External interrupt 0 service programs are used to count input ring pulse from the SCM P3.2 port, as sixteen hexadecimal counters. 60 H is low level, 62H is high level. After every counting, it will store the mileage data. When the wheel rotates one circle, it will input pulse data into the simple chip computer through the Hall element and get the pulse numbers. Then, by using the multiplication subroutine, it can calculate mileage. The flow diagram of the mileage processing subprogram as shown in Fig. 4.
- **Speed calculation subroutine:** External interrupt 1 service program is used to process the timing data after the wheel rotates one circle. When the sign bit (00 H) is 1, counting overflow, the maximum time (#0FFH); when the sign bit is 0, the counting unit (TL1, TH1, 6C H, 6D H) value is put in 68 H ˜ 6 BH units. The timer calculate the time for one circle and get the bicycle speed by the result that wheel circumference divided by the time. As shown in Fig. 5.

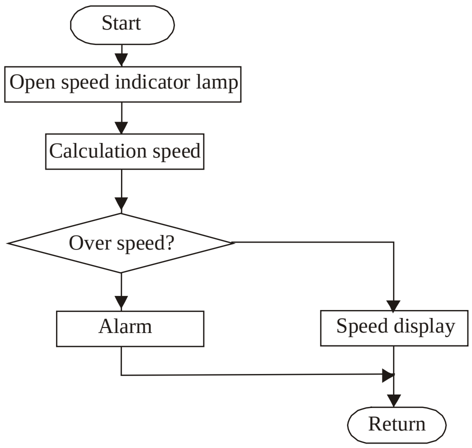

Fig. 5: The flow diagram of the speed processing subprogram

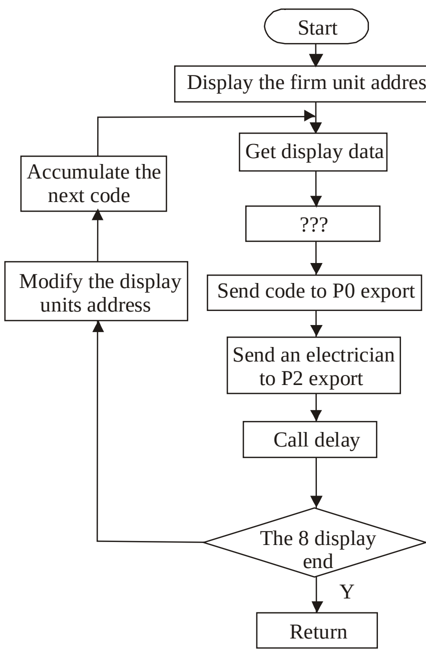

Fig. 6: The flow diagram of the speed processing subprogram

- **The design of display subroutine:** The design adopts the dynamic scanning display circuit which could connect the entire display 8 stroke segment A-H homonymous ends together and the public COM of each display is controlled by I/O line independently. When the CPU output font code into the field delivery outlet, all display receive the same font code, but exactly which display lights depends on the COM terminal which can adapt the time-sharing method to control each display COM end alternately and all display are lit (display subroutine flow chart 6). During the alternate lighting scanning process, the time of each display lighting is extremely short (approximately 1ms) due to the persistence of vision and the afterglow effect of the light emitting diode, despite the fact that you monitor is not lighted at the same time, but as long as the speed of the scanning is fast enough, a stable set of display data should be shown to us, no sense of flicker (Fig. 6).

THE SYSTEM DEBUGGING AND ANALYSIS

System simulation debugging: PROTEUS system simulation platform and the development platform are developed by British Lab center Company, which currently is one of the most complete system design and simulation platforms all over the world. PROTEUS can achieve digital circuit, analog circuit and simulation circuit of the micro control system and the peripheral mix circuit system, system collaborative simulation and PCB design and other functions. PROTEUS software is capable of real time simulation, debugging and testing of EDA tools and it truly can finish debugging and verification without the target prototype.

After completing wiring schematics, check it by using the electrical rule check command provided by PROTEUS ISIS editing environment and modify the principle diagram according to the error checking report till it pass the electrical rule checking.

Simulation of MCU system is big characteristic of PROTEUS VSM. At the same time, the simulation system could integrate the source code editing and compiling into the same design environment, so that the user can edit the code directly in the design and easily find the influence on the simulation results after modifying source code. Through the compiling without any error, the source code can be simulated. During the process of simulation, it continuous improves function of the circuit and program, to reach the design target finally.

Debug faults and analysis: There are some problems in the simulation process. The specific breakdowns and solution methods are as follows:

- **The digital tube display:** The design of the circuit digital tube adopts the method of the anode connection. When we misuse the cathode digital tube in the simulation, the LED digital tube will doesn’t work
- **P0 shows high resistance state:** Under the normal conditions, the output port P0 should interchange between high (red) and low (blue), but actually, the P0 port appears the high impedance state (gray). If P0 as I/O export, it should be connected with the pull-up resistor. When connected with a pull-up resistor, the output of port P0 is normal.

CONCLUSION

The main task of this design is to develop a bicycle odometer with the MCS-51 microcontroller. This design mainly includes hardware and software. The simplicity of the hardware has been emphasized and it should simplify the hardware circuit as much as possible to save board space, thereby achieving its optimization design. The software is programmed in assembly language, the idea of modular design and has strong readability. The simulation and the experiment can testify that the system is feasible and it can meet the design requirements, achieve the design target to realize the bicycle mileage / speed calculation function and then display it by LED. But there are some deficiencies existing. When it displays speed, if the bicycle moves too quickly, the speed of the display will be too fast, so the speed should be shown on timing display, so that people can clearly see the speed. The hardware parts are applied widely and the price is low, such as AT89C52 SCM, D trigger 74LS74 and so on. This means that all functions of the devices are more powerful and stable. Especially the design of the core component of AT89C52 SCM, of which software technology is mature and it has a full kinds that can support the chip. The microprocessor can be used to process the data and it cost very low. The software system adopts modular design and it has strong readability, which is convenient for the second development.

The design has the advantages of simple circuit, low cost and it can meet the basic requirements of the high performance, speed, distance. Also it can take the mileage/speed measurement under many situations, with wide application prospect.

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