

## **Multifunctional Controllable and Detachable Bicycle Power Generation / Charging Device**

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*Abstract: Based on the principle of mechanical control, circuit rectification and voltage stabilization, a multifunctional controllable removable bicycle power generation / charging device is designed and manufactured. The device includes the detachable module, the transmission module, the switch control module, the charging / generating control module and the energy storage module. The overall design idea is to introduce a control system control device to generate electricity or not, convert the mechanical energy into electric energy storage, and install the USB interface on the power generation device to make it suitable for the family circuit. Through the theoretical analysis of the gear transmission ratio, the gear transmission ratio and the switch device, and the circuit design and simulation, a micro power generation / charging device which is convenient to install and disassemble is made. The experimental results show that the maximum charging efficiency of the system reaches 71%, which solves the problem that the installation and disassembly of the current charging device are inconvenient, the price is expensive, the speed change can not be changed and the bicycle riding resistance is big, and the purpose of green environmental protection and energy saving is achieved.*

*Keywords: Bicycle power generation / charging, controllable disassembly, speed change system, switch control.*

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### **1. INTRODUCTION**

Over the past few years, the overexploitation and utilization of fossil fuels and the resulting series of consequences have made the problems of environmental pollution and sustainable development gradually into the public view. The topic of energy regeneration and utilization has also attracted the attention of the society. With the continuous improvement of people's awareness of environmental protection, bicycles, as a green and convenient means of transportation, are also favored by more and more people. The emergence of shared bicycles has changed the way people travel, and people do not have to have a fixed bike to solve the problem of short trip, which has changed the situation of the bicycle power plant industry. In the past, bicycle power plants are difficult to load and unload, special vehicles are special, and

the power generation power can not be adjusted according to speed. This makes the audience of bicycle generation products limited to the small crowd riding enthusiasts. The cost of some related manufacturers is still high, so that the public cannot afford it. Therefore, there is an urgent need for a power generation product for the public and for different types of vehicles, making people travel more green and convenient.

In this paper, a multifunctional controllable and detachable bicycle power generation / charging device is designed. The design idea is to add a gear control system to control power generation in a micro power generation / charging device. In the external structure, double clip design is adopted to facilitate the installation and disassembly of users. During the riding process, the friction wheel connected to the power generation device is contacted with the outside side of the wheel, and the kinetic energy of human riding is converted into electric energy storage by using the energy transformation principle. On this basis, the USB interface is added to make it suitable for household circuits, so as to realize two working modes of bicycle charging and household charging. The whole device is compact and convenient, easy to carry and load and unload. In contrast, most of the power generation devices used in bicycles need to be fixed on the frame for a long time, and it is very inconvenient to install and disassemble them. The friction generation between the chain and gear is more efficient, but the resistance is larger, and the long-time riding will wear the chain. When the bicycle is not needed for generating electricity, the friction between the bicycle body and the generator will cause obstruction to the ride. The power generation device researched in this paper overcomes the defects of traditional power generation products, has better economic and universal applicability, and has good application prospects.

## **2. SCHEME DESIGN**

The multifunction and dismantling bicycle power generation / charging device consists of a detachable module, a transmission module, a switch control module, a power generation / charge control module and an energy storage module. The detachable module is connected with the bicycle through two head clamps to realize the integral loading and unloading of the device. The transmission module is connected with the switch control module and is controlled by a telescopic switch to generate electricity. The power generation / charging control module and the energy storage module, through rectification filtering and DC-DC voltage stabilizing, convert the mechanical energy into electrical energy and store it. The power generation device has a USB interface to connect the electric circuit with the external circuit. The overall design of the device is shown in Figure 1, and the principle of each module is shown in Figure 2. The details are described below:

Detachable module: this part is connected with a bicycle through a double head clamp and adjusts the diameter of the ring and the direction of the fixture by the screw connecting unit with the fixture, so that the device can be connected with different types of car, and the applicability of the device can be increased.

(2) Transmission module: through the experiment to determine the transmission ratio, through the transmission, so that the generator at different riding speed, can reach its rated speed, so as to ensure the output of the required voltage, and can maintain high efficiency.

(3) Switch control module: this part controls the gear meshing through a telescopic switch, thereby changing the generator speed, simply controlling the power generation of the system, and reducing the riding hinder.

(4) power generation / charging control module: after using AC engine, the three-phase alternating current that sends out voltage and frequency pulsation, design circuit, after rectifying, filtering, DC-DC stable voltage, can be converted into stable DC, and stored in battery.

(5) Energy storage module: select the appropriate mobile power supply design to provide temperature protection, short circuit protection, reset protection, input and output overvoltage protection, input anti reverse protection, input over current protection, battery overcharge over protection, PTC protection, and fully improve charge and discharge efficiency.

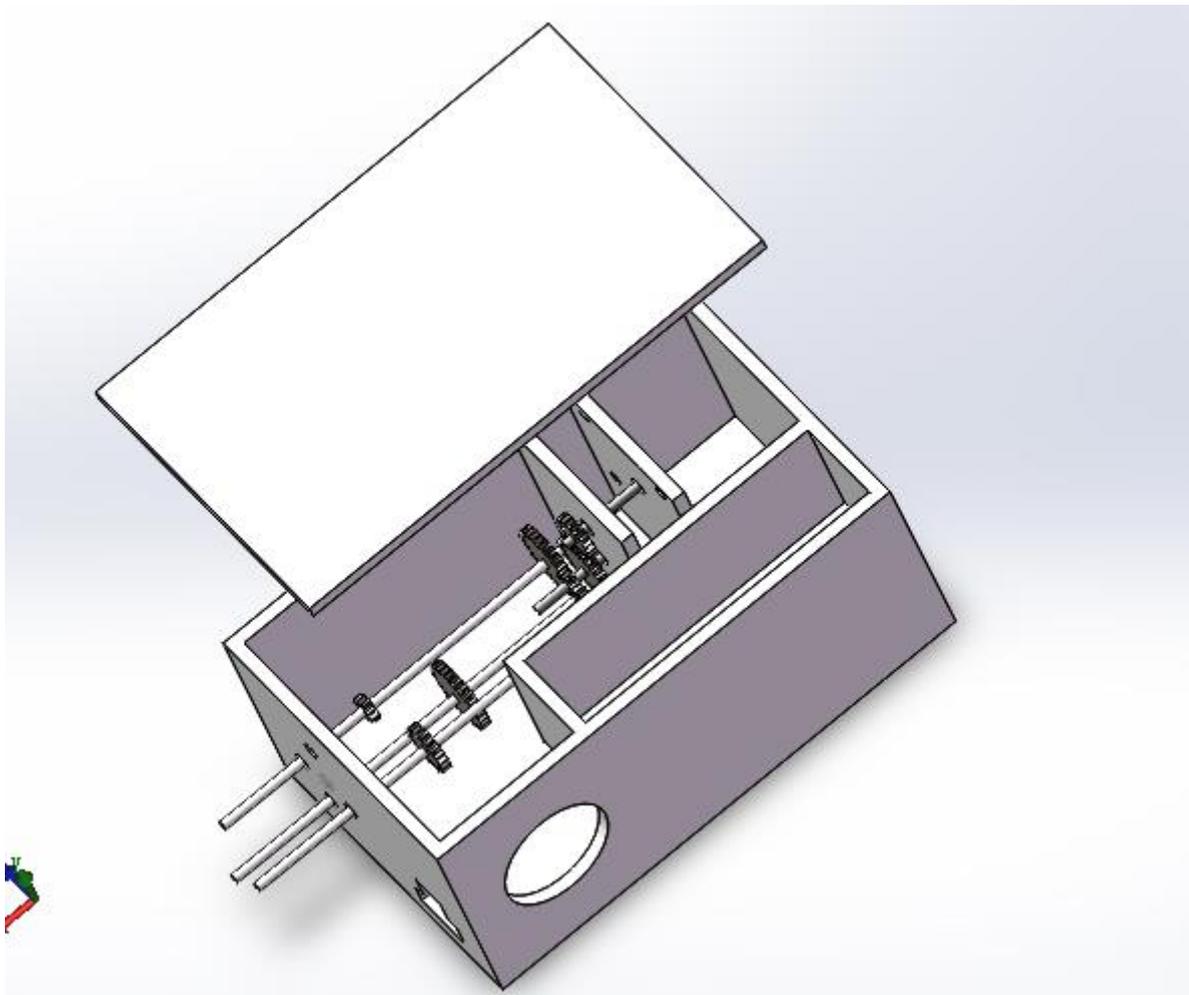


Fig 1. Overall design diagram of the device

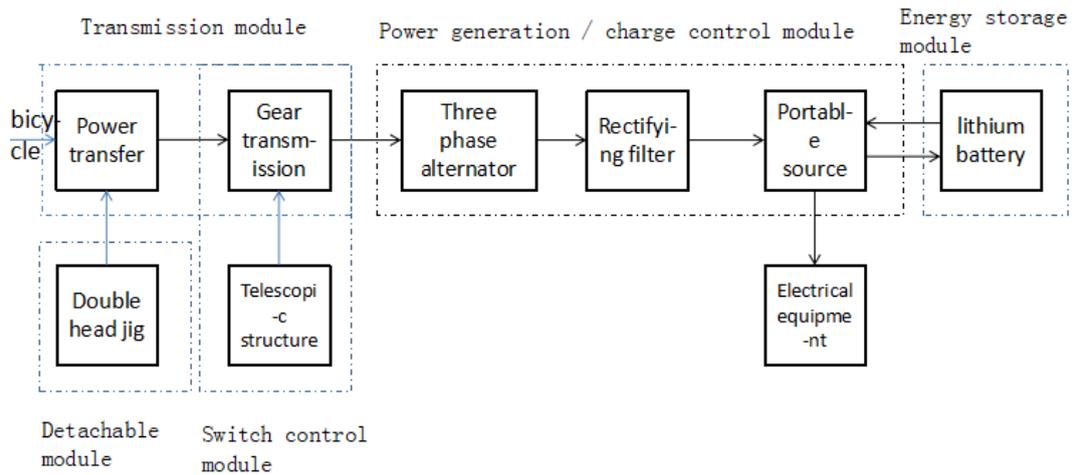


Fig 2. Device schematic diagram

### 3. THEORETICAL CALCULATION AND SIMULATION

#### 3.1 Design and software simulation of power generation / charge control circuit

According to the knowledge, this paper designs the circuit diagram shown in Figure 3, which contains the following parts:

rectifier and filter regulator module

The input terminal of the generator is connected with a three-phase bridge rectifier circuit to output DC voltage varying with the speed of the bicycle. The C1 capacitor acts as a filter, and the C2 capacitor is self-excited. After the LM7805 chip is used, the stable DC 5V voltage is output. Using Multisim software simulation, the result is shown in Figure 4, which proves that after the rectification voltage regulator circuit, a stable 5V DC voltage can be output.

charging and discharging module

Taking into account the need to achieve high lift efficiency, with trickle current / constant current / constant voltage three stage charging, boost current limiting output and other functions, FM6316GE power is used to manage IC. FM6316GE is a portable power management IC, which is used for mobile power supply, integrates lithium battery charging management, DC-DC boost current limiting, and load detection function. At the same time, it integrates the charging mode including trickle charge, constant current charging and constant voltage charging. FM6316GE has multiple protection design, including overload protection, charge protection, short circuit protection, soft start protection, over temperature and undervoltage protection. The comprehensive performance meets the requirements of this design.

Then the Multisim software is used to simulate the circuit diagram. The voltage source uses the ideal 10V three-phase AC voltage. The simulation experiment shows that the system can output stable 5V DC voltage and the charging efficiency can reach 71%. At the same time, the charging efficiency is greatly influenced by the generator frequency, the higher the frequency and the lower the charging efficiency.

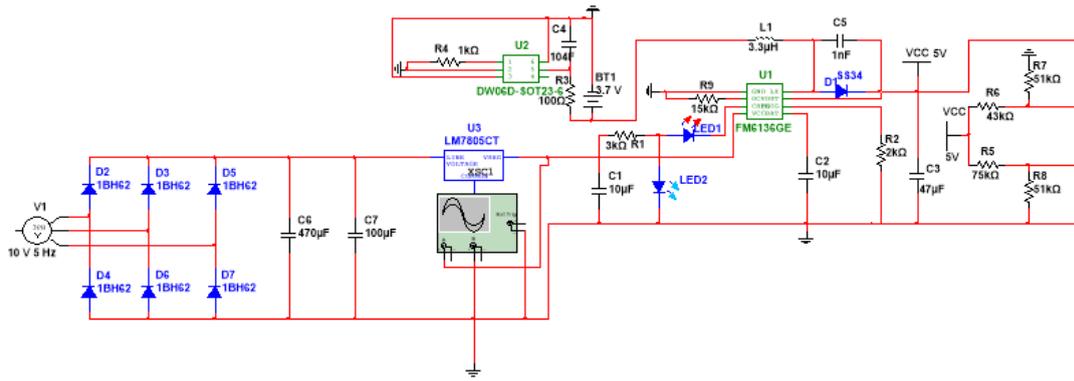


Fig 3. Circuit diagram

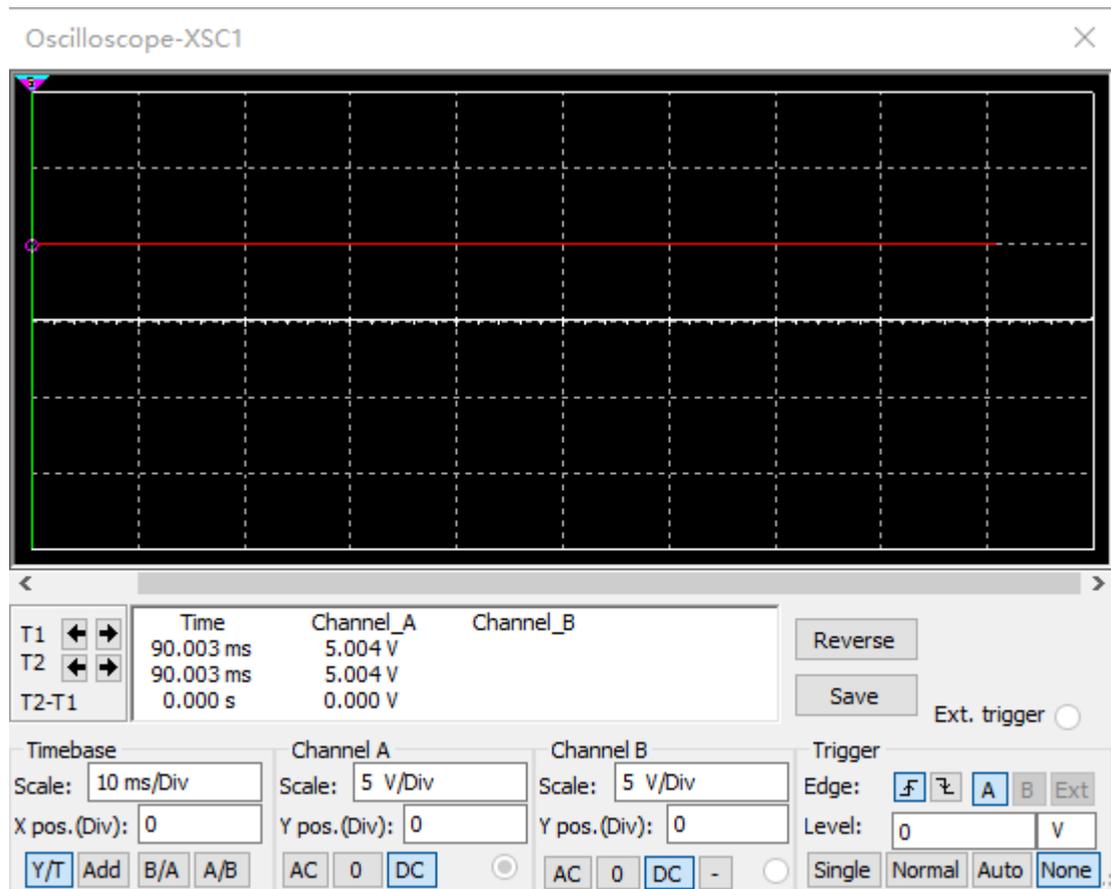


Fig 4. simulation result

### 3.2 Design and software simulation of drive and switch control module

The power generation device is fixed on the bicycle wheel support through a double head clamp, and the generator gear is rotated by the contact of the friction roller and the outside of the wheel to drive the generator. In order to drive the power from the roller to the generator and reduce the riding resistance when the bicycle is running, in this paper, the mechanical transmission of figure 5 and the control device of figure 6 switch are designed. The whole design idea is that the gear drive uses the active gear and the acceleration gear design. In the slow speed of the bicycle, the generator can also rotate the electricity at high speed by accelerating the function of the gear. In addition, a telescopic mechanism similar to ballpoint

pen is designed outside the device as a switching unit. In Figure 5, axis 1 and axis 3 are connected to a telescopic structure respectively. By controlling the position of axis 1 and axis 3, the gear 1, gear 4, gear 3 and gear 6 are meshed with the main gear, and then the working state of the power generation device is controlled. The specific principle of the work is as follows:

(1) The working principle of the telescopic structure

When the button is pressed, push the bracket to move down, so that the shaft moves down. At this time, the protrusion on the bracket is stuck into the hole in the shell, and the position of the fixing bracket is fixed. The closed ring on the shaft presses the spring to store energy and the shaft extends. When the protrusion on the bracket is pressed, the spring drives the shaft and the bracket to move up, and the original position is restored.

(2) The first speed work mode

At low speed, the first gear mode can be used to make the generator gear get higher speed. At this time, the axis 2 moves to the working position under the control of the telescopic structure, the gear 1 on the shaft is engaged with the gear 2, the gear 4 is engaged with the gear 5, and the axis 3 and the upper gear are idling. The gear 2 axis, that is, axis 2, is the transmission axis, which is connected with the external friction wheel, and drives the axis 1 and the upper gear to rotate. Under the action of the gear 4, the gear 5 and its axis start to rotate, and then drive the gear 7 to rotate. The gear 8 is the generator gear and enters the first gear mode under the drive of the gear 7. Because the gear number 1, the ratio of 2 teeth to 1:3, and the subsequent gear amplifying the speed, the generator can get a larger speed.

(3) The second speed working mode

In order to achieve greater efficiency, the second gear mode can be used when the bicycle speed is fast. The axis 1 is pulled out by using the telescopic device, and the axis 3 is moved to the working position. Work under the principle of a similar working mode. Because the gear number 3 and the 2-gear ratio 2:3, the generator works at relatively small speed.

(4) The mode of empty rotation does not work

Using the telescopic device, the axis 1 and the axis 3 are all out of operation. At this time, the axis 2 will be idling and the generator will stop generating electricity. This working mode is applied to reduce gear friction and electromagnetic damping when generating electricity.

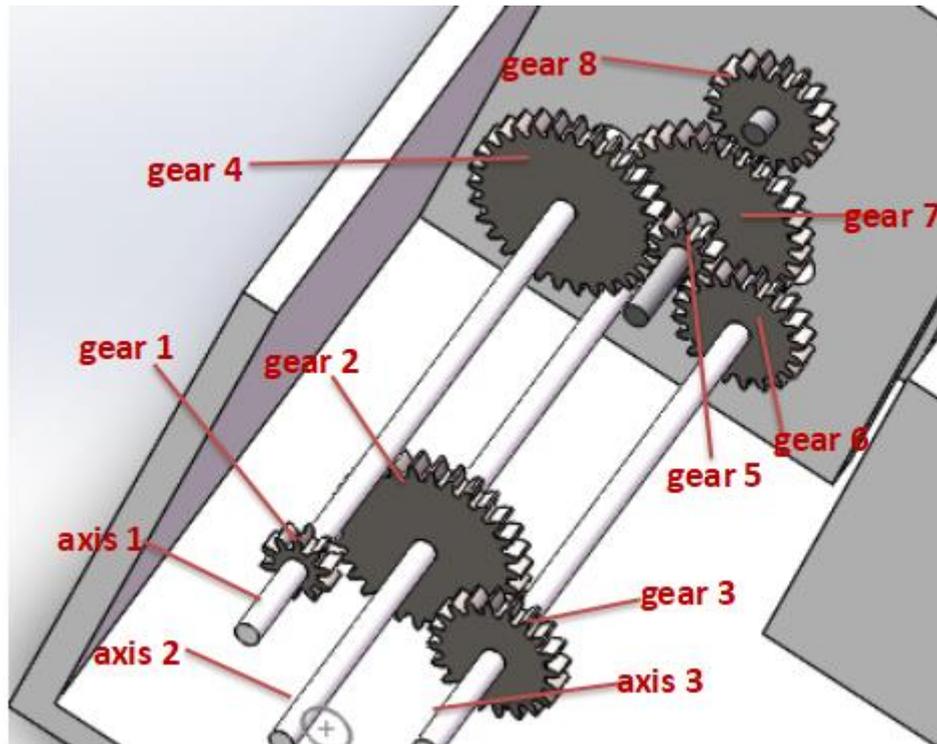


Fig 5. Mechanical drive

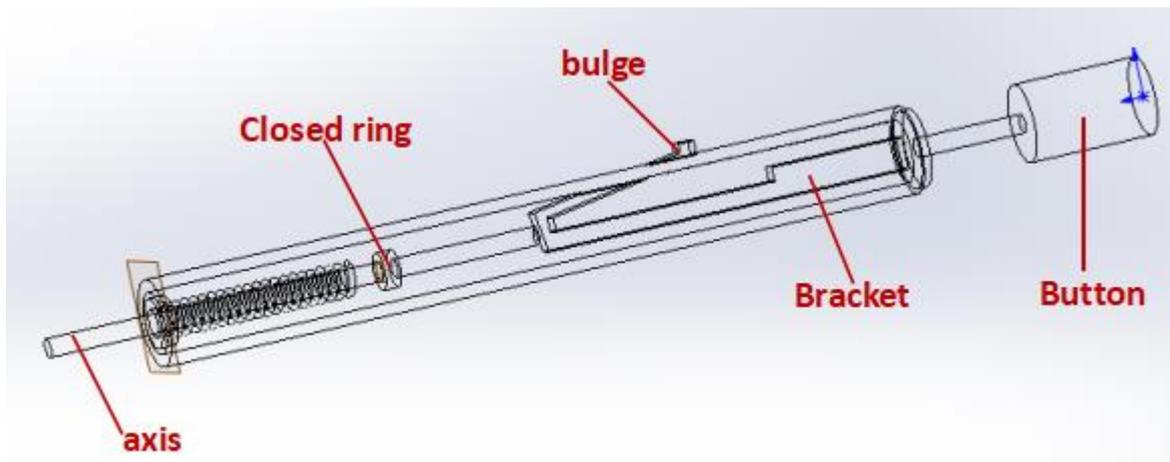


Fig 6. Switch control device

#### 4. HARDWARE FABRICATION AND EXPERIMENT

On the basis of the simulation experiment, the parameters of each component are designed, and the hardware assembly and experiment are carried out. As shown in the following figure, figure 7 is made of the circuit board and battery, and figure 8 is the physical figure of the shell.

The whole device is made of 115\*70\*55mm acrylic board, and the inverter, filter, voltage regulator and charge and discharge regulator are integrated on the PCB circuit board. The generator uses a three-phase AC permanent magnet motor. When riding at a normal speed (60r/min), the generator accelerates the gear by accelerating the gear, and after the power generation control module is processed, the circuit can output the 5V DC voltage steadily. The

circuit board interface adopts the common USB interface, which can generate electricity conveniently by using the home circuit. The internal gear system uses variable speed design to achieve controllable power generation. The device has a double head clip which can be conveniently assembled on the bicycle.

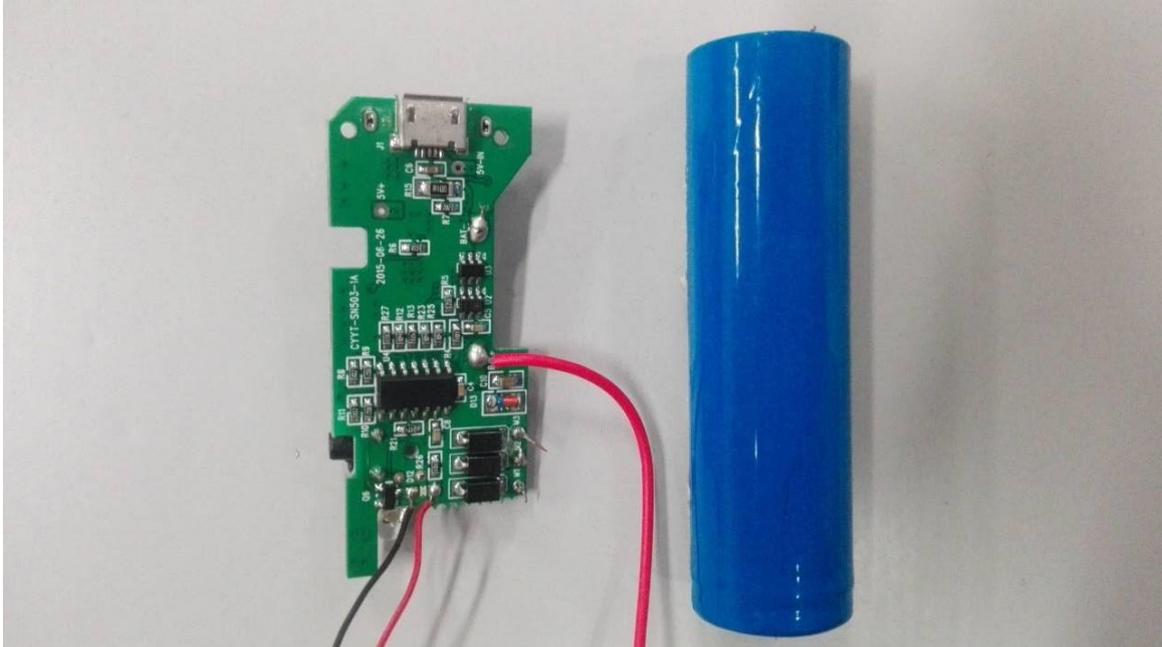


Fig 7. Circuit PCB board and battery



Fig 8. Shell diagram

#### 4.1 An experiment to determine the transmission ratio

In order to determine the transmission ratio of the transmission device, the experiment of determining the transmission ratio is carried out in the laboratory. The whole set of experimental devices includes a three-phase AC generator with a rated voltage of 10V, a transmission gear device with a transmission ratio of 1:3,1:4,1:4.5, a self-made handle and a multimeter.

The pulsating alternating current output of the three-phase alternator becomes a stable DC power through the rectifier voltage regulator and uses the multimeter to measure the effective value of the AC voltage issued by the three-phase generator at different transmission ratio and speed at different speed, and record and make the fold line diagram, as shown in figure 9. It is known that the input voltage of the LM7805 chip is more than 5V, so it can be obtained from figure 9 that when the rotor speed is at 270~450r/min, the voltage satisfies the input voltage requirement; and the bicycle pedal speed is about 60r/min under normal condition, then the transmission ratio of the bicycle power plant used in the experiment is about 1:4.5.

At the same time, in order to ensure the normal operation of the device at different speeds, the speed change device is set up, that is to set 2 transmission gears to increase the transmission ratio, so that the output voltage of the generator can reach the minimum required voltage when the bicycle is running at low speed, and the efficiency of the power generation can be improved when driving at high speed.

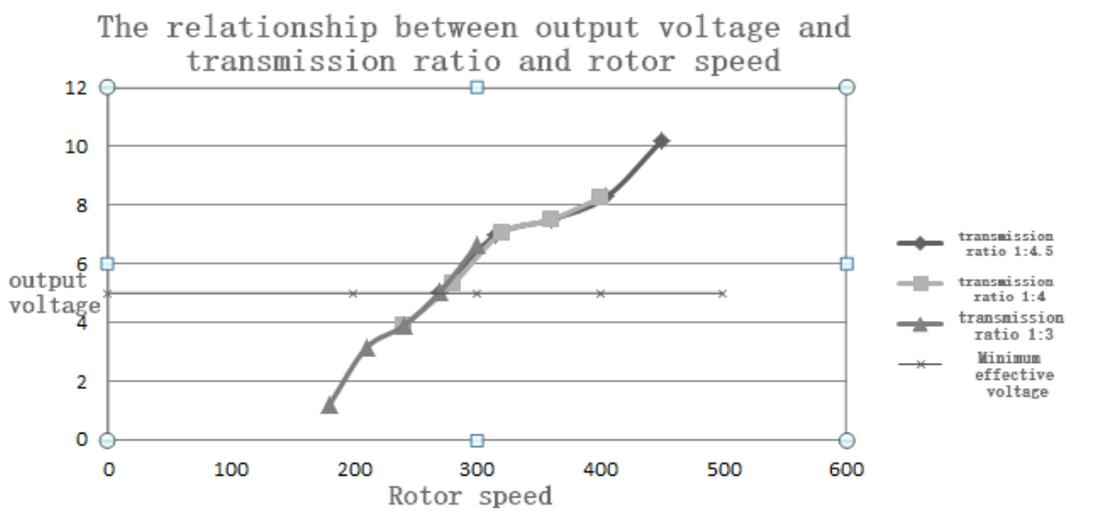


Fig 9. The relationship between output voltage and transmission ratio and rotor speed

#### 4.2 An experiment for testing the effect of a component

In order to test the desired effect of the components, the components effect test is carried out. The whole set of experimental devices includes PCB circuit board, battery, power use device, multimeter, oscillograph. The output voltage of the circuit board is shown in Figure 10, and the circuit board can output a stable voltage. The charging effect of the circuit board is also shown in Figure 10, which is indicated by a small light on the circuit board. The above experiments show that the customized PCB is in line with the expected results.



Fig 10. Charging effect of circuit board

### 4.3 Measurement of charge efficiency

The experiment is known by the transmission ratio, when the rotor speed is between 270r/min~450r/min, the voltage meets the input voltage requirements, so the charging efficiency at these speeds is tested. The whole set of experimental devices includes the PCB circuit board, the battery, the power use device, the multimeter, the oscilloscope.

The test circuit is shown in figure 11. The test results are shown in figure 12, and the test results are shown in table 1. The test results show that the higher the rotor speed is, the higher the rotor speed is, the higher the charging efficiency is, and the maximum charging efficiency is about 71%.

In order to better test the performance of the power generation device, this article uses a power generation device to charge a mobile phone with a 3000 Mah of 50% residual electricity. The charging experiment is shown in Figure 12, the white data line connection device and the power use device. The experimental results show that the device is full of 5% electricity, which takes about 10 minutes, and it takes about 3 hours to estimate the lithium battery when it is filled with 10000 mah.

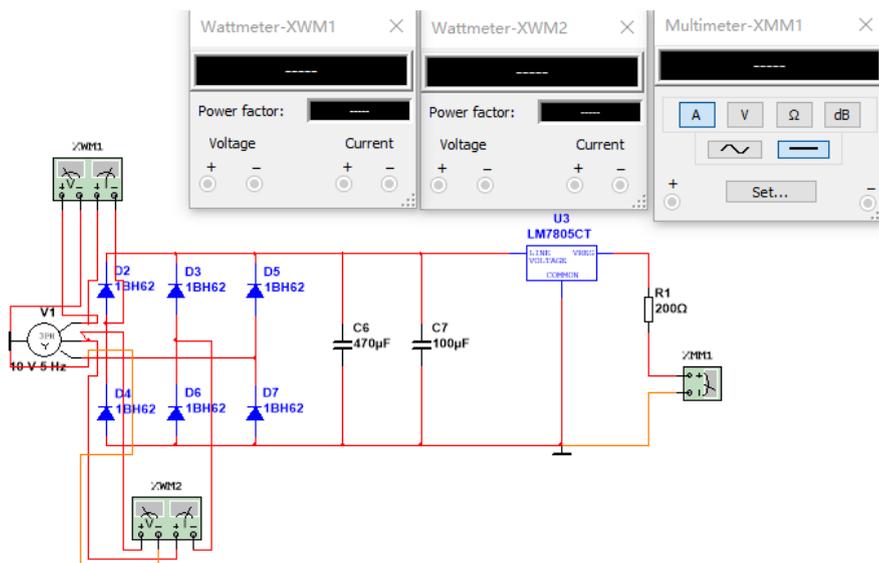


Fig 11. Charging efficiency calculation circuit

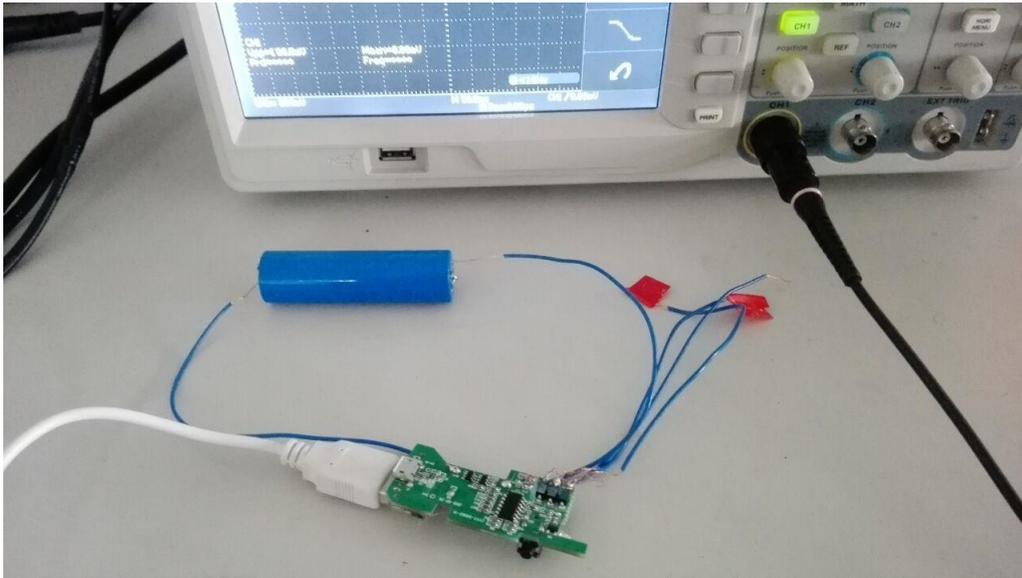


Fig 12. Experiment of measuring charge efficiency

Table 1. The relationship between the charging efficiency and the rotor speed

Rotor speed (r/min)	270	280	300	315	320
Charging efficiency	71.39%	70.92%	68.99%	68.67%	67.20%
Rotor speed (r/min)	360	400	405	450	
Charging efficiency	60.54%	56.29%	54.14%	42.99%	

#### 4.4 Loading test

After completing the installation of the whole device, it is installed on the common shared bicycle and tested on the road. The result shows that the generator is normal, the transmission system runs normally, and the whole device runs well. The design goal has been successfully completed.



Fig 13. Power plant loading diagram

## 5. CONCLUSION

In this paper, a multi-function controllable removable bicycle charging / generating device is designed and demonstrated, which has the following characteristics compared with the traditional charging device on the market:

- (1) Easy installation and dismantling: the device is connected with bicycles through double clip structure and is easy to assemble and disassemble with shared bicycles and other public bicycles. The flexible direction is also easy to adjust the contact between the power shaft and the wheel of the generating set, so as to avoid the special purpose of the special vehicle. The scope of use of bicycle power generation / charging devices has been greatly expanded.
- (2) The gear transmission structure is adopted: unlike the traditional fixed transmission mode, the power generation / charging device has a flexible transmission mode, which can adjust the power generation and even close the power plant directly according to the riding requirements. Charging more efficiently and reducing riding resistance.
- (3) Lower cost: the power generation / charging device uses mature, standardized materials on the market, and the generator is a widely visible small alternator. It is very convenient for the large batch production of the manufacturer.

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