# Smart Gym Lock Pin

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**Abstract**
Now days, technology has changed our daily life in various aspects. To help people have a better sports experience, lots of products are designed to help users record the data. We will show a smart lock pin used on the strength training machines. This lock pin can record the data of users automatically and give proper advice in real time to correct the movement. We have our special design in the structure and the circuit to improve the accuracy of the data and mathematical model to help us get more useful information from the data which will be discussed in this paper.

**Keywords**: smart fitness sensor, data anylisis, smart lock pin.

## 1 Introduction

The smart lock pin is designed for the strength training machines to record the users data and give some advice on movements after analysing the data. We found that most sport sensors on the market record data such as exercise time, running distance, heart rate and calories. There is a gap in strength training machines field. There is not an automatic data record sensor for such equipment. After researching the machines, we find we can make a smart lock pin for these machines because each facility needs a lock pin to lock the weight block and there is a linkage between the data we want to record and the position of the lock pin. We use this relationship to make this smart fitness lock pin to help users to record their data on the strength training machines.

## 2 Background

### 2.1 Strength finess equipment lock pin

In the Gym, there are many machines for people to do sports. Weight blocks are used in the strength training machines to provide the load. People can adjust the load by change the position of the lock pin. The lock pin has a 10 centimeters stainless steel rod and a 5 centimeters steel or rubber handle.

### 2.2 Infrared distance sensor

The infrared distance sensor can detect the distance between one point and a plane. The sensor has two windows: infrared emitter and CMOS infrared sensor. The sensor's working principle is that the sensor emits infrared to the plane and the plane will reflect the infrared into the sensor's infrared detect part. The position between the reflected infrared projected point on the image plane and the central point of the plane has a relationship with the distance between the sensor and the plane. We can get the distance after reading out the position. The range of this distance sensor is proper to our project. We choose the SHARP GP2Y0A60SZ0F which has a 10cm to 150cm range and a high resolution.

### 2.3 CC2541 with BLE

Bluetooth low energy is a wireless communication technology. Compared to the previous version, BLE consumes less energy. It is used in many fields such as health care, sports and fitness sensor and some alart sensors. It is merged into the Bluetooth Standard in 2010. Most devices and systems adopt BLE.

We choose to use the cc2541 from Texas Instruments. It's a system-on-chip solution for 2.4GHZ Bluetooth low energy applications. The CC2541 combines a leading RF transceiver with an industry-standard enhanced 8051 MCU which has powerful peripherals. So we can use this single chip to communicate and analyse data.

We choose the CC2541 module DX-BT05 from the Daxialongque technology company which embedded the RF antenna, cc2541 and the voltage conversion module.

## 3 System Construction

The system consists of three part: main shell structure, circuit design and battery system.

### 3.1 Main Shell Structure

The outlook of the smart lock pin is the same like the classic lock pin. But inside the lock pin, we have our own design to coordinate the function we added to the lock pin(Figure1.A).

The infrared sensor should be vertical all along because we want the exact distance between the sensor and the ground. To achieve this, we use two bearings to let the handle rotate freely and stable at first. And then we put some small weight blocks into the shell of the lock pin to make it lose balance so that no matter what the initial state is, the sensor in the lock pin will always face the ground to ensure the distance is correct.

In the lock pin shell we need to put two PCBs(printed circuit board), we design a parallel groove for the PCBs(Figure1.D). We can easily push the PCBs into the shell and hold it stably. We design two small connectors(SH1.0) to locate the position and at the same time we use the two small interfaces to transmit the signal and the power between the two PCBs.

We use lithium battery(16340, height 3.4 centimeters, diameter 1.6 centimeters, 600maH) to supply the power. We also design a chamber for the battery and a charging cradle (Figure1.B.C). We use the two electrodes and add a foolproof design.

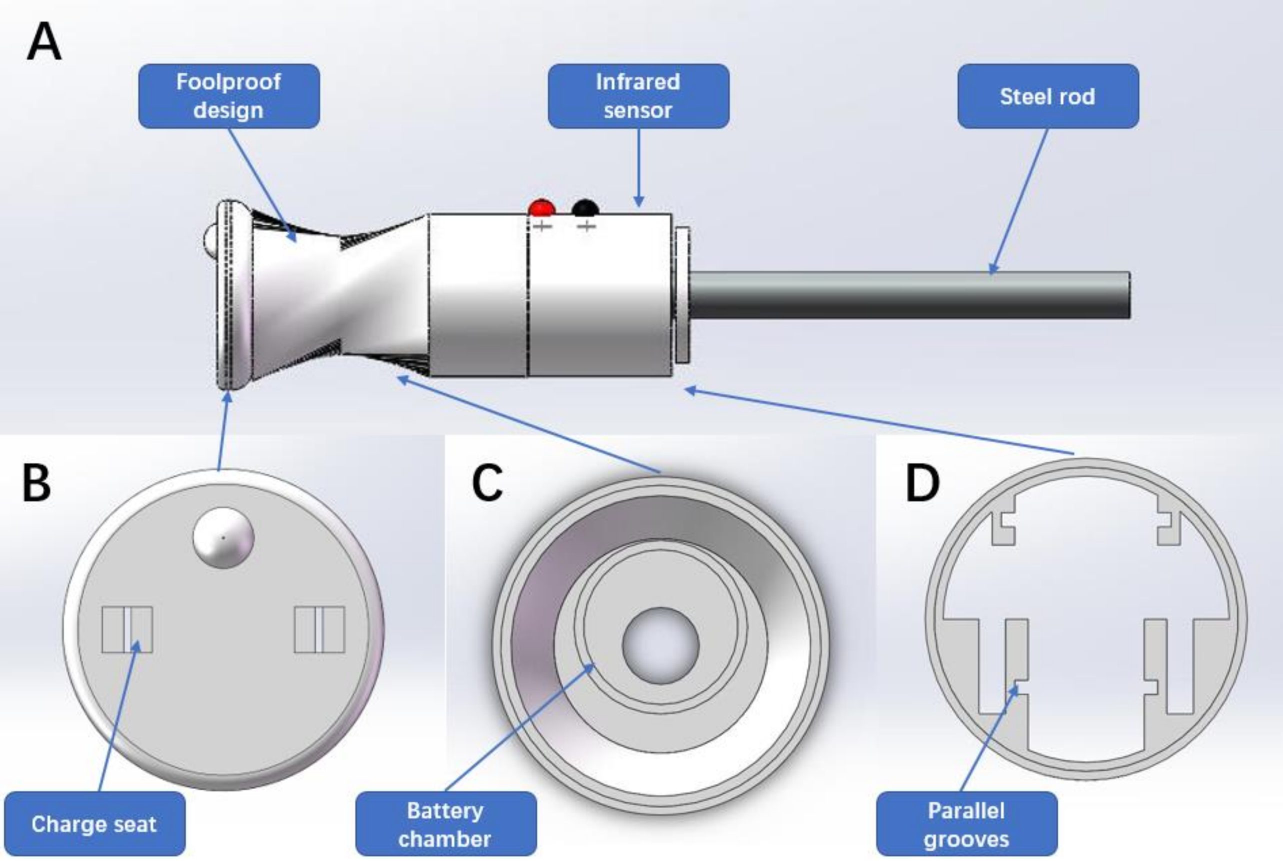


Figure 1 :main structure

### 3.2 Circuit Design and Battery System

We have two parts in the circuit and battery system and we design two PCBs separately.

The first PCB works for the infrared sensor. We inspect the circuit from the SHARP user guide and add some interfaces.

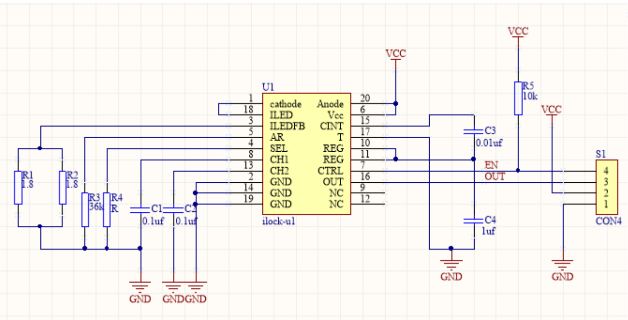

Figure 2 :PCB1-infrared distance sensor

The second PCB works for the CC2541 module and the battery system. Because we use the DX-BT05 module, we just design the interface of the module and prevent the interference between the battery and the antenna. We designed our battery system. The infrared sensor can be used in the 3V3 mode and the 5V mode and the DX-BT05 module can be used between 2.7V-4.2V. So we choose the 3V LDO to convert the voltage from the 4.2V to 3V. To ensure the quality of the sensor's power, we use two LDOs, one is for the BLE and the MCU and the other one is for the infrared sensor. We use the common chip for charging and the standard circuit for charging the battery.

For the DX-BT05 module, we add some peripherals on it. We add a vibration switch on it because we design a low energy operation method. Only if the user touch the lock pin and the vibration swith will switch on to wake up the mcu. In this way, only the mcu will consume the energy in the sleep mode. The smart lock pin would be used longer than before.

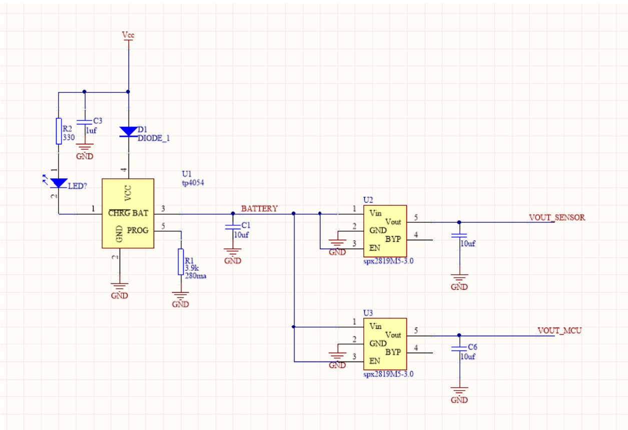

Figure 3 :PCB2-battery system

## 4 The method to detect the weight and the movement

We design this smart lock pin to detect the data automatically.

It can detect the weight the user select, the movement frequency, speed and state of the user. According to these information, the lock pin can give the user some advice on movements.

### 4.1 Get the raw data

The infrared sensor we choose will give out the analog signal. We use the ADC(analog to digital coverter) in the CC2541 to get the digital signal. The ADC in the CC2541 is 12 bits. The data we read out from the cc2541 is the raw data.

After getting the raw data, we send it to the smart phone via Bluetooth 4.0 Standard. And we draw the wave of the raw data to help us analyse these data.

### 4.2 Build models

Firstly, we need to detect the weight chosen by the user. After researching the strength training machines, we find the height of the weight block is about 1.5 centimeters to 3 centimeters. And different weight selection relates to different height of the lock pin. As for the equipment in our university, because they belong to the same brand, they have the same height of the corresponding weight selection. So we suppose that each weight selection corresponds to a small range of height or the digital data read from the MCU(Figure4).

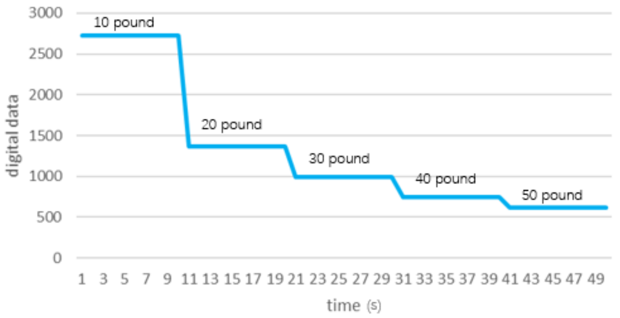


Figure4 :weight selection model

This is the static mode, when the user starts to move,we can get the dynamic frequency and speed from the data. We suppose the wave should be like saw tooth wave. And the slope of it can reflect the speed of the movement. The pulse frequency is related to the movement frequency. According to this model, we make three modes. The first one is uniform motion(Figure5.A). The second model is pull quickly and relax slowly which is right in bodybuilding(Figure5.B). The third one is pull quickly and relax quickly which is wrong in bodybuilding(Figure5.C).

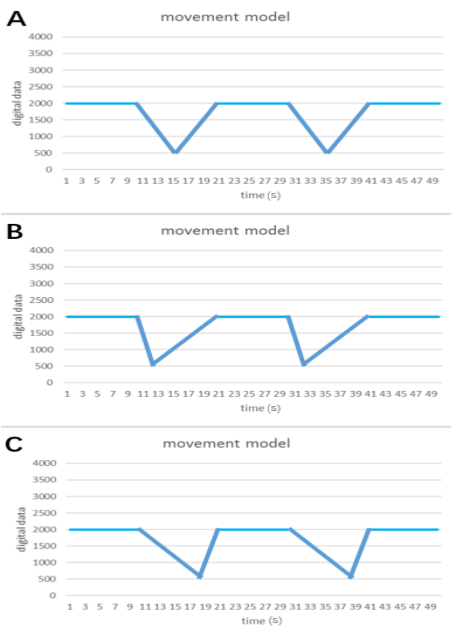


Figure5 :movement model

We can give some advice to the user. For example, if we detect that the user is exercising in the third model, we can advise him via his smart phone to pull quickly and relax slowly. And if we detect that the frequency is slower, the user might be tired, we can recommend him to reduce some weight and take a break to prevent injury.

### 4.3 Process data

We develop the algorithm to automatically calculate the raw data and give out the frequency, the speed,the weight selection and the state of the user.

This algorithm will be used in the software of the smart phone so that we can update it easily.

## 5 Results and Conclusions

We use the 3D printer to print the shell of the lock pin. We use the resin to print it. Its strength is good and can easily hold all the PCBs, battery and bearings in it. We use two pieces of bearing 698zz. It works stably. And we use the 15cm long and 8mm diameter stainless steel rod. We have test it and it can hold the weight of the blocks. We put two pieces of the small blocks into the shell and each of them is 5 grams. And it works well, the sensor always faces the ground(Figure6).

Figure6 :3D print model

The two pieces of PCBs work well. We assemble the blot together and we test it in our university's gym. We use the test app on an Android smart phone. And our system works well.

We measure the height and the weight and record it in the memory of our mcu. We can detect the weight. But the when the distance is near 10 cm, the accuracy reduces so one or two weight selection is not accurate. We can make the sensor face to the ceiling and add a reflection plane on the top of the equipment to solve the problem.

Then we test the dynamic data record function(Figure7). We can calculate the frequency and the times clearly. In the Figure7.A, user pulls slowly and in the Figure7.B, user pulls faster. We can figure out clearly from the wave that the frequency is high in Figure7.B and low in Figure7.A, and the slope in Figure7.A is low and the slope in Figure7.B is high.

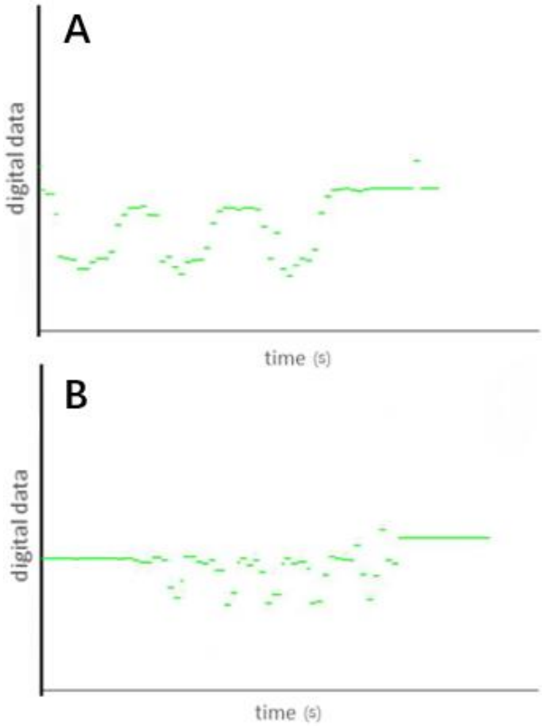


Figure7 :3D print model

We are still working on the next version of the app. We will add the algorithm into our app and make it automatically analyses the data.

Our smart fitness lock pin can detect the weight, frequency,speed and the state of the user. We want to optimize the lock pin to make it more reliable and more friendly. And we want to add some algorithms into our smart lock pin to give precise advice to users.

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