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***Research paper***

# The BLDC and Stepping Motor Control Firmware Programming to Improve Efficiency of SVF Extraction

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## Abstract

One of the most accessible and abundant amounts of adult stem cells is the isolation of adipose stem cells from adipose tissue. Centrifugation techniques are very important for obtaining these adipocytes. We used MCU to control high-speed BLDC motors and used stm32f407 of Cortex-M4 series which can perform high-performance and many processing. The motor was controlled by can communication for centrifugation, and PWM control of the stepping motor was performed to separate the extract. The optical sensor was also used to determine the type of extract. The optimal rpm of the improved product is expected to be 6,000. We confirmed the normal operation of the motor with the firmware program created through this study. The protocol optimized for SVF is implemented by controlling the rate of motor speed control and deceleration acceleration

***Keywords***: *Bldc motor; Optical sensor; Stepping motor;Stm32f407; SVF*

## 1. Introduction

Stem cells are precursor cells that have the ability to self-replicate by appropriate signals and to differentiate into various tissues. It plays an important role in the formation of organs from the developmental stage and restoration of organ and tissue function after growth [1]. Studies on obtaining mesenchymal stem cells from adult stem cells have been performed mainly on bone marrow, and many studies have been conducted on bone marrow stem cell differentiation into various tissues [2]. However, cell harvesting in the bone marrow is accompanied by patient pain and there is a burden to collect several times in order to obtain a sufficient amount of cells for clinical application. The adipose tissue, which is derived from mesenchyme-like mesenchyme and contains various stromal cells, is another source of stem cells, and there are cells presumed to be stem cells in the fat extract. This is adipose-derived stem cells (ASCs)[3][4].
Liposuction can be achieved by liposuction, which is performed for cosmetic purposes in obese patients. Liposuction has been performed with safe and easy procedures 30 years ago. In the past, these tissues have been abandoned, but recently they have been used clinically for autologous fat transplantation and are being used by stem cell researchers to obtain stem cells.

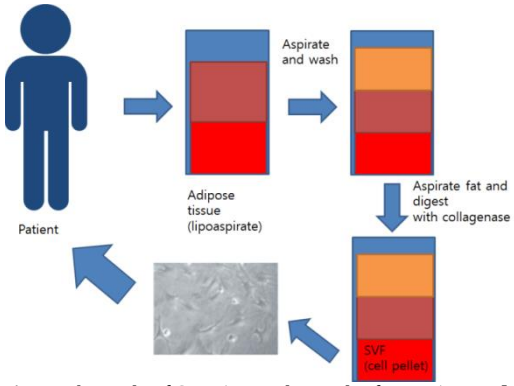


**Fig. 1:** The cycle of SVF (stromal vascular fraction) usage[5].

At present, ASCs are obtained by removing mature adipocytes, red blood cells, etc. from adipose tissue and then isolating SVF [5]. SVF is an adult stem cell present in adipose tissue and is usually obtained by treating the adipose tissue with an enzyme. However, this SVF contains various components depending on the stage of differentiation of fat cells such as lipid precursor cells and lipoblasts. Although methods for separating proteins using surface-specific antibodies present on the surface of cell membranes have been developed [3], they are limited in their cost and difficult to use publicly. More specifically, in the procedure for obtaining SVF, the collected tissues are washed with a buffer solution and enzymatically treated to separate the substrate and the cells. At this time, when the suspended tissue is centrifuged, it is divided into an extracellular matrix and an oil layer in the upper layer and a cell layer precipitated in the lower layer. The layer deposited at the bottom is called SVF, which contains adipocyte stem cells. In this paper, we propose a control method to discriminate SVF by using high speed control, optical sensor and stepping motor to realize automatic system to acquire SVF automatically.
Since this system is important for noise and stability and requires high speed rotation, BLDC type is suitable. Hall sensors and en-

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coders are built in, and driving with PWM or CAN communication method is advantageous to ensure stable rotation speed. Motor control mainly uses PLC or microcontroller, and it is advantageous to use MCU to improve complement and control efficiency. Cortex-m series is used as MCU. The ARM Cortex ™ -M4 processor-based microcontroller series is optimized for use in a variety of motor control applications. In particular, three 12-bit, 16-channel ADCs are included, four on-chip comparators support fast response overcurrent / voltage monitoring and protection, and several Timers / PWM timers minimize the load on the CPU. As a result, these MCUs are optimized for use with a wide range of motors, including BLDC (brushless DC) motors. It is also well suited for use in industrial applications where highly accurate data sampling and real-time control is required.

# 2. Methods

## 2.1 The STM32F407

ARM-based MCUs, including the STM32F407, provide clocks only when peripheral operations are required to achieve low power. These functions can be controlled through the RCC (Reset Clock Controller). It also has 14 timers, including advanced control timer, general purpose timer, and basic timer. There are three ADCs (ADC1, ADC2, ADC3) with 12 bit resolution for reading sensor values. The ADC has 19 channels, 3 built-in channels and 16 channels (IN0 ~ IN15) that can use the alternate functions of GPIO. USART communication is used to communicate with PC for GUI. In the case of stm32f407, there are 6 UARTs, 2 UARTs, 4 UARTs. This chapter covers only the UART. When data is transmitted / received through the UART, it is generally possible to determine the time of transmission, but the time of reception cannot be determined. Therefore, the UART Rx handles the interrupt and the UART Tx handles the polling.

## 2.2 PWM for stepping and BLDC motor

DC motors, speed reducers, small motors, geared motors, stepping motors, servo motors, BLDC motors, coreless motors, encoder motors, linear motors, AC motors, and synchronous motors are used for precise control of medical devices and robots. . Among them, stepping motor which is easy to control precision position for position control is mainly used. The stepping motor drive is a motor driven by a pulse input current (0 to 20 mA) that changes the amount of current instantaneously at a constant interval to the stepping motor. The stepping motor drive principle is controlled so that the motor rotates at a certain angle every time a pulse is input. At this time, the rotation angle is called a step angle. What you need to know about driving stepping motors is that by decreasing the degree of step, you can improve the accuracy of positioning the motor. In addition, the faster the pulse speed, the faster the stepping motor rotates.
The STM32F407 which we use as MCU has an advanced control timer, a PWM add-on for the general purpose timer, and a basic timer that does not have a PWM function. Up to 4 channels can be used as a PWM in one timer. The "timer" is implemented by using the counter, and the "PWM" is also implemented by using the counter. In the "timer" implementation, the counter counts the clock, generates an interrupt when the count reaches a predetermined value, Likewise, in the implementation of "PWM", the counter counts the clock, and when the count value reaches the specified value, the output of the GPIO pin becomes High or Low. That is, the PWM waveform is generated. In PWM mode, a pulse is generated with a desired pulse width from 1 to 4 channels by a timer

## 2.3 Stepping motor

The stepping motor drives MD5-HD14 used here is Bipolar constant current pentagonal drive, automatic current down, self-test function and many other features. Microstep drive for low noise, low vibration rotation is possible, and step angle can be freely used with switching signal. The maximum number of divisions is 250 divisions. A 5-phase stepping motor with a basic step of 0.72 ° rotates 0.00288 ° when one pulse is input, and 125,000 pulses are required to make one rotation of the motor. It has many functions such as automatic current down and self-diagnosis function circuit, and adopts Photo Coupler input insulation method to minimize influence of external noise.

## 2.4 BLDC motor and controller

The BLDC motor structure has a magnetic element for detecting the position of the rotor or an optical encoder built into the motor. This position detector sends a signal to the drive circuit. The motor winding is a 3-phase star connection. The rotor uses a permanent magnet. Hall ICs are used for the magnetic elements for detection. There are three inside the stator, and a digital signal is output from the hall IC every time the rotor is rotated. A switching transistor is connected to the motor winding, and the inverter consists of six transistors. Up-and-down transistors alternately repeat on-off in a certain order and change the direction of the winding current.
For BLDC motor controller, two kinds of speed control and current control are possible through digital input terminal. The analog input has a range of -10V ~ 10V and speed control and current control are set through potentiometer and analog input terminal. Fixed speed control and current control can be set in ESCON studio through fixed set value. In the case of speed ramp setting, it is applied through two setting methods, analog ramp and fixed ramp. The analog ramp is available through the potentiometer, and the fixed ramp is motor driven through the set acceleration / deceleration.

## 2.5 ADC for getting the analogue information

An analog-to-digital converter (ADC) is a device that converts an analog signal to a digital value. In the STM32F407 ADC, the conversion of the analog signal to digital is handled by a successive approximation ADC. If the ADC is 12 bits, the voltage change is distinguished in steps (0 ~ 4095). This number of bits is called resolution. If the voltage to be measured is 0V to 3.3V and the resolution is 12 bits, the minimum discriminated voltage can be obtained from the following equation.

$$\frac{3.3V}{4095} = 0.8mV$$

The analog signal is A / D converted and the data value is stored in the memory. In the process of storing the converted data value in the memory, the A / D converted digital value is continuously stored in the memory address of 16 bit unsigned short variable, ADC3ConvertedValue. Direct memory access (DMA) is a device that accesses direct memory. The added feature of this function is that the peripheral devices (USART, ADC, SPI, etc.) are slower than the CPU core and that the CPU does not directly participate in data transfer, which can increase the CPU utilization. For example, when storing data (result value) in SRAM after ADC completion, if CPU core stores data in SRAM, CPU core should operate slowly according to peripheral speed. In this case, the CPU core will suffer a time loss. If DMA, rather than CPU core, directly fetches the data from the ADC and stores it in the SRAM, the CPU Core will be able to handle that much else.

## 3. Results

Isolation of adipocytes using adipose tissue is the most popular method of isolation and is currently the most commonly used method in plastic surgery [6]
(1) Remove impurities such as blood. The adipose tissue is washed three times with 1: 1 using physiological saline.
(2) Prepare 0.1% collagenase and 10% inhibitor in the same volume as adipose tissue.
(3) After thoroughly removing the washing solution of the adipose tissue after washing, mix the same volume of 0.1% collagenase.
(4) The above mixture is kept in a thermostat at 37 ° C for 30 minutes with gentle stirring.
(5) At the end of the reaction time, saline, 10% fetal bovine serum (FBS) or 10%
Treat synthetic serum (SS) with the same volume as the mixture.
(6) Mix uniformly using a pipette.
(7) After reacting at room temperature for 5 minutes, centrifuge at 300 xg for 5 minutes.
(8) The supernatant obtained after centrifugation is labeled with the active inhibition step and transferred to another tube.
(9) After centrifugation, add 10 ml of physiological saline to the remaining pellet and mix well.
(10) After standing at room temperature for 5 minutes, centrifuge at 300 xg for 5 minutes.

Experimental results on motor control and temperature detection, which are the core of this study, are as follows.

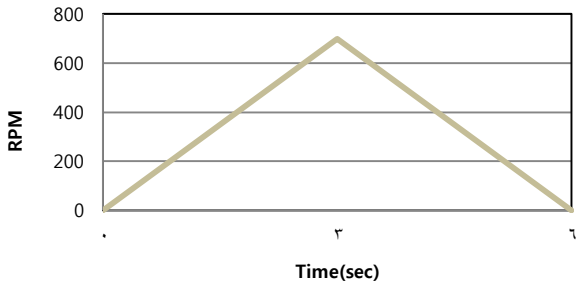


**Fig. 2:** The BLDC motor rpm for Fat washing

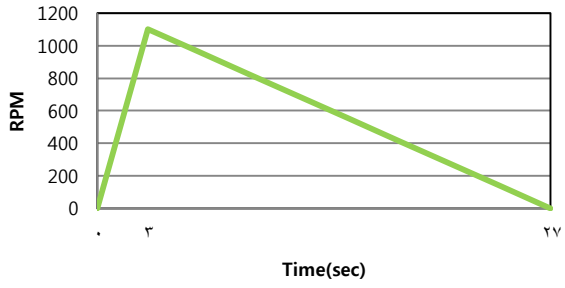


**Fig. 3:** The BLDC motor rpm for enzyme reaction

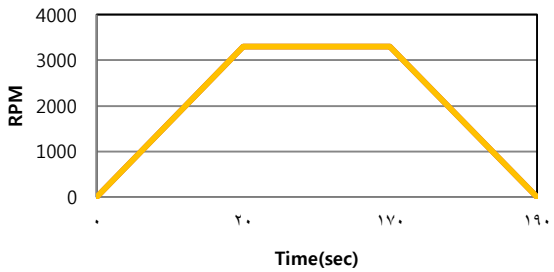


**Fig. 4:** The BLDC motor rpm for concentration.

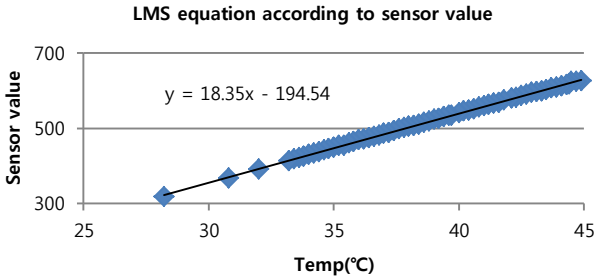


**Fig. 5:** Temperature measurement index and least mean square interpolation equation of infrared sensor

## 4. Conclusion

The shorter the time to isolate SVF from the adipose tissue in the hospital, the shorter the waiting time and the care time of patients, and the time difference of 30 minutes in large hospitals is evaluated as the difference in the efficiency of the operating room. In order to shorten the time, centrifugation speed is very important because the SVF should be rapidly separated from the treated adipose tissue and the centrifugation method is used. In case of the conventional method, the centrifugal separation of SVF is applied at 3,300 rpm. However, the improved technique is expected to recover the fast SVF by increasing the centrifugal force by applying the speed of about 6,000 rpm.

## Acknowledgement

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