Design and Research of Electronic Switch based on Proteus Circumstance

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Abstract. At present, most of the electronic switches used have single function, raise voltage or reduce voltage, and also have step-up and step-down, it has the step-up and step-down function, but the circuit structures simple is not much. In this paper, an electronic switch which can replace the step-up and step-down circuits is designed. Three different levels of step-up, step-down and constant voltage are designed through voltage gain, the circuit solves the problem that the original small and medium power circuit can only step-up or can reduce the voltage, and realizes the function that the same circuit can not only boost the voltage but also realize the step-down function, and meets the requirement of continuous and adjustable power. Through the simulation and calculation results verify the feasibility and correctness of the design, and provide convenience for users, especially in the use of small and medium power. The voltage gain can be adjusted precisely according to the requirement, so that the voltage can reach the exact voltage value that can be adjusted continuously, thus shortening the engineering design cycle and the R & D process.

1. Introduction
The application range of switching power supply is more and more wide, and it has become a research hot spot because of the large power system's power supply system and the mobile phone charger. Switching Power supply has developed high frequency, high power and small volume in the direction of development, the core unit of the power switch device in the electronic device has a high frequency conversion speed characteristics, the switch device is mainly used IGBT, IGCT, GTO, MOSFET and other devices, a common feature of these periods is switched on or off is using PWM control mode, switch on-off itself is not a continuous process, in order to get the continuous adjustable output requires a reasonable design with the external circuit parameters.

Typical switching applications have Boost circuit and Buck circuit, CUK circuit, Sepic circuit, Zeta circuit by Boost circuit and Buck circuit combination, these circuits can not only realize the function of boost and buck, but the circuit structure is complex and the parameter matching is not perfect, there are different shortcomings make it use is limited. In order to realize the continuous adjustable power, and make boost and buck for the perfect combination, in the design of the electronic switch circuit can replace a boost circuit and buck circuit function, realize the up and down continuously adjustable function, meet the needs of customers. Electronic switch is the use of power electronic devices to achieve the circuit off the operating unit, the electronic switch can be used for switching power supply,
signal detection and identification system, etc. Electronic switch has many advantages, such as non-contact, long life, fast speed, no restriction on the use of the environment and so on.

This paper mainly use the integrated chip MC34063 and LM358 to build up the electronic switch circuit, the electronic switch can realize step-up and step-down function in continuous mode, and in the Proteus environment to build the simulation model and simulation, the circuit parameters are calculated. The lifting pressure one, to reach the design requirement of function[1].

2. The working principle of the circuit

2.1. The structure of the Boost-Buck circuit

The schematic diagram of the go up and down circuit is described by a typical Buck-boost circuit which is not isolated. The main circuit of the Buck-boost circuit is the same as that of Buck or Boost, which is composed of a switch tube, a diode, an inductor, a capacitor, etc[2,3,4]. The circuit diagram is shown in figure 1.

![Figure 1. Buck-Boost changes in the main circuit schematic](image)

The working principle is that the inductance can be stored for a period of time, and the inductance energy can be transferred to the load in a later period of time. In one cycle, there are two kinds of working modes, that is, the inductor current is continuous and discontinuous. The first working state, when the switch Q is on when the power supply voltage applied on the inductance \( L_f \), this moment \( U_{L_f} = U_{in} \), inductance L energy storage, diode D withstand reverse voltage and cut-off, The voltage at both ends of the load is maintained by the capacitive C discharge, The state of the in a switching cycle T of the time is \( T_{on} ( T_{on} = \alpha T , \ 0 < \alpha < 1 , \ \alpha \) is duty ratio \( ) \). Second working state, when \( T_{on} < t < T \), Q opens, in order to maintain continuous inductor current \( i_L \), Diode D is switched on at inductive voltage, The energy of the inductor \( L_f \) is supplied to the load, and at the same time, the capacitor \( C_f \) is charged, and the state is maintained at \( (1 - \alpha) T \). In the two case, the power supply voltage and the load voltage polarity are opposite, that is, the average gain of the Buck-boost circuit M is negative, Under ideal conditions, the gain is

\[
M = \frac{U_o}{U_{in}} = -\frac{\alpha}{1 - \alpha} \tag{1}
\]

when the duty ratio \( \alpha < 0.5, \ M < 1 \), the circuit is in the step-down state; when the duty ratio \( \alpha > 0.5, \ M > 1 \), the circuit is in the boost state; when the duty ratio \( \alpha = 0.5, \ M = 1 \), circuit is the energy transfer, neither boost nor buck. Figure 2 represents the equivalent conversion circuit of the DC/DC when the Q is turned on and off.

![Figure 2. Buck-Boost state diagram](image)
2.2. integrated chip introduction

2.2.1. The characteristics of MC34063
Micro control chip MC34063 is a small, powerful integrated pulse control chip. He internal integration of the current limiting circuit, with the temperature compensation of the reference voltage source circuit and pulse drive control logic circuit, the periphery only a few devices can achieve DC - DC power conversion and other functions. Therefore, the use of MC34063 to build a boost, buck and the inverting circuit is a convenient and economic method. Working conditions of chip MC34063: input voltage range is 2.5V to 40V, the output voltage range of 1.25V to 40V, the output switch current can reach 1.5A (without external transistor), the scope of work of the oscillation frequency is 100Hz ~ 100KHz, which can boost and buck or reverse power converter, and has the characteristics of low quiescent current and the short circuit current limit.

2.2.2. The characteristics of LM358
LM358 includes a dual operational amplifier two independent, which are suitable for dual power mode and have a wide range of applications. Its scope of use includes Sensing amplifier, DC gain module, audio amplifier, industrial control, DC gain components and all other available single supply operational amplifiers.

LM358 features: high DC voltage gain (about 100dB); the unit gain bandwidth (about 1MHz); a wide range of power supply voltage: single power supply (3~30V); double power supply (±1.5 ~±15V); low power current, suitable for battery power supply; output voltage swings high (0 to Vcc-1.5V).

Parameters: input bias current 45nA; current input 50nA; input offset voltage 2.9mV; input common mode voltage maximum VCC~1.5V; common mode rejection ratio (CMRR) 80dB; power supply rejection ratio (PSRR)100dB.

3. Circuit design based on the chip
3.1. Proteus software introduction
Proteus software can complete the experiment content of analog electronics, digital electronics, MCU and embedded system, support all electrical and electronic virtual simulation, this software platform can realize the intelligent ISIS principle drawing, code debugging, CPU peripheral device simulation collaborative VSM virtual system model, the debugging is finished, it also can be a key to switch to the ARES generation of PCB plate. Proteus software is very powerful, it can be simulated 51, AVR, PIC series. Widely used in production and research and development.

3.2. Circuit Design
In the Proteus environment designed the circuit diagram shown in figure 3. The circuit is composed of two modules, one is the buck-boost main circuit module controlled by the MC34063 integrated chip, and the other is the reverse proportional amplifier module which is composed of LM358 integrated chip. Because the buck-boost output voltage is negative voltage, but the control IC can only deal with the forward voltage, so the need for LM358 chip this reverse proportional amplifier module[5,6].

Figure 3. Schematic diagram of electronic switch circuit
3.3. The choice of circuit components and the corresponding calculation

1). Input voltage: DC 12V voltage

2). According to the calculation formula of the output voltage \( V_o = 1.25(1 + \frac{R_{\text{rheostat}}}{R_4}) \), the output voltage range is 1.25V - 28.6V. Here the design output voltage limit is best not more than 40V, if more than will lead to unstable working condition, which is decided by the characteristics of this integrated chip of MC34063.

3). Capacitor selection: C1=0.1μf, C2=1nf, C4=47uf.

MC34063 chip 3 pin connected to the C2 (timing capacitor) =1nf (to determine the internal operating frequency), the formula of C2 is: \( C_2 = 0.4 \times 10^{-6} \times T_{on} \) (Fixed formula of MC3406 chips), \( C_4 = 47 \mu F \), C4 is a filter capacitor, which determines the output voltage ripple coefficient, the formula is: \( C_4 = I_0 \times T_{on} / V_p - p \), P is the ripple coefficient.

4). Inductance selection: L2=470uh, the formula is:

\[
L_2 = (V_{\text{imin}} - V_{\text{ces}}) \times T_{on} / I_{\text{pk}}
\]  
(2)

Resistance: R1=R2=200K Ω, \( R_{\text{rheostat}} = 0 \sim 100K \ Ω \), R4=4.7K Ω, R5=2K Ω, R6=10K Ω.

5). The relevant parameters used in fixed value calculation

Rectifier diode forward voltage \( V_f=1.0V \), MC34063 internal triode emitter and collector saturation voltage drop \( V_{\text{ces}}=1.0V \),

\[
\begin{align*}
\alpha &= \frac{V_o + V_f - V_{\text{imin}}}{V_{\text{imin}} - V_{\text{ces}}} \\
\end{align*}
\]  
(3)

4. Simulation results and analysis

4.1. Selection of resistance in various modes

4.1.1. Select the buck mode resistance

When the sliding rheostat resistance \( R_{\text{rheostat}} < 40.2K \Omega \), \( M = \frac{U_o}{U_{\text{in}}} = \frac{\alpha}{1-\alpha} \), \( \alpha < 0.5 \), \( M < 1 \), at this time, the circuit is equivalent to buck circuit. The simulation results are shown in Figure 4 and figure 5.

![Figure 4](image1.png)

Figure 4. When the sliding rheostat is 0Ω, the output voltage is 1.28V

![Figure 5](image2.png)

Figure 5. When the sliding rheostat is 25KΩ, the output voltage is 8.08V
4.1.2. Selection of resistance value of fixed value mode
When the sliding rheostat resistance R=40.2K, the circuit is equivalent to a constant value circuit, which does not boost or buck. Only complete the power’s transfer, the simulation results are shown in Figure 6.

**Figure 6.** When the sliding rheostat is 40.2KΩ, the output voltage is 12V

4.1.3. Select the boost mode resistance
When the sliding rheostat resistance \( R_{\text{rheostat}} > 40.2K \Omega \), \( M = \frac{U_o}{U_{in}} = -\frac{\alpha}{1-\alpha} \), \( \alpha > 0.5, M > 1 \). At this time, the circuit is equivalent to the step-up circuit, that is, Boost circuit. Simulation results shown in Figure 7, as well as other resistance changes, will also get the corresponding simulation results, no longer mentioned here.

**Figure 7.** When the sliding rheostat is 50KΩ, the output voltage is 14.9V

4.2. Result analysis

4.2.1. The range of output voltage
Through the analysis of the circuit, the voltage output range is 1.28V~28.6V.

4.2.2. Equivalent circuit
When \( R_{\text{rheostat}} > 40.2K \Omega \), the circuit is equivalent to a boost circuit. When \( R_{\text{rheostat}} < 40.2K \Omega \), the circuit is equivalent to buck circuit.

4.2.3. Circuit power:
Input current is 1.5A, the input voltage is 12V. So the maximum power is \( P=1.5*12=18W \). If the efficiency is 80%, the maximum output power is \( 18*0.8=14.4W \).

4.2.4. Duty cycle of the circuit
\[ R_{osc} = 0.33 / I_{pk}, \text{ that is } I_{pk} = 0.33 / R_{osc}; I_{pk} = 2 \times I_{omax} \times T / t_{off} \] \( I_{omax} \) is the maximum output current, \( R_{osc} \) is the external resistor, \( I_{pk} = 2 \times I_{omax} \times ( t_{on} / t_{off} + 1) \), \( I_{omax} = I_{pk} / 2 ( t_{on} / t_{off} + 1) \), that is \( t_{on} / t_{off} = I_{pk} / 2I_{omax} - 1 \).

From the above two formulas can be seen, MC34063 accounted for only two parameters: \( I_{omax} \) and \( R_{osc} \) ratio of air, and these two parameters are interrelated, and this circuit is by changing the feedback.
resistance and the external resistance to change the size of the duty ratio. Because the MC34063 uses an open loop current feedback mode to control the real time variation of duty cycle, the duty cycle adjustment range is about 9%--80%.

4.2.5. The working frequency of the circuit
MC34063 operating frequency is determined by the capacity of the timing capacitor $C_t$, that is, $T_{on} = \frac{4 \times 10^{-6} \times T_{on}}{C_t}$; Load does not change, the input power supply voltage change $T_{on}/T_{off}$ also change. Voltage decreases, $T_{off}$ increases, $T_{on}/T_{off}$ becomes smaller. The above changes, the constant is $T_{on}$, the change is $T_{off}$ and $T_{on}/T_{off}$.

4.2.6. Design notes
It is possible to use IN4148 diode in the simulation circuit, But in the actual circuit IN4148 is not up to the required requirements, Because Boost circuit fast recovery diode reverse recovery problems exist, when the hard switching Boost circuit working at high frequency, the diode reverse recovery current will cause considerable energy loss and high di/dt in the circuit, Endanger the safe operation of switching devices and produce serious electromagnetic interference (EMI). Therefore, in the actual circuit should be replaced with IN4148 Schottky Barrier Diode (SBD).

5. Conclusion
This paper establishes the electronic switch can achieve step-up, step-down and the power transfer function in the Proteus environment, can replace the boost circuit and buck circuit under certain conditions, simplify the circuit, provides convenience to users, improve the working efficiency of the DC/DC transform, the simulation results show the feasibility of the design to meet the application on many occasions, to achieve the purpose and requirements of the design.

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