



# DESIGN OF SYNCHRONOUS BUCK CONVERTER FOR HEARING AID APPLICATION

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**Abstract—** In this paper, we study on buck dc/dc converter of high efficiency by soft switching technique. The paper will focus on design and simulation buck converter architecture. The converter is designed in CCM (continuous conduction mode ). The voltage mode control strategy is proposed by using pulse width modulation (PWM) with a proportional-integral (PI). The effectiveness of the buck converter is verified through simulation results using control oriented simulator like MATLAB/Simulink tools.

**Keywords—** DC-DC converter, Buck converter, PI controller.

## I. INTRODUCTION

In the past few decades, due to the explosive growth of the microelectronics industry and semiconductor technology, the electronic products, which are becoming not only smaller and smaller but also more and more complex, have played a very important role in shaping human society[1]. The emergence of many electronic products has changed the lifestyle of the human beings, such as the laptop or the mobile phone. The booming development of electronic devices has promoted a lot to the advance of the biomedical technology, which causes the situation that various kinds of implantable electronic devices are currently being used to monitor, diseases for personal healthcare, such as the neuro-stimulator, the pacemakers and the cochlear implant.

It is common sense that any electronic device cannot operate without power[2]. Hence, the implantable biomedical devices need to be powered by some power supplies. Here, we have focused on a hearing aid. In the consideration of the volume and convenience, a hearing aid generally use tiny batteries assembled on the devices as the power source. But accordingly, a great challenge occurs, that is how the batteries can be replaced or recharged when the energy is depleted. Obviously, it is quite difficult or even infeasible to replace the batteries of the biomedical devices which have been implanted into the human body[5]. Therefore, many efforts have been made on exploring an efficient method to design power supplies for the implantable devices. Thus, in this paper we

propose a high efficient synchronous buck converter as the power source.

## II. DC-DC CONVERTERS

The Direct-Current to Direct-Current (DC-DC) converter is an electronic circuit which can convert a DC voltage into another DC voltage. It has been widely used in current portable electronic devices for regulation of supply voltages[3]. Since the current electronic devices are generally constituted by several sub-circuits, each of which requires its own supply voltage perhaps different from the voltage supplied by the battery or the external supplier, a DC-DC converter can be used to realize the step-up or step-down conversion of the supply voltage.

### A. Conventional Buck Converter

A Buck converter is basically a voltage down converter that uses two switches which may be a diode, inductor and a load. The schematic representation of a simple conventional buck converter is shown in the fig.1 below.

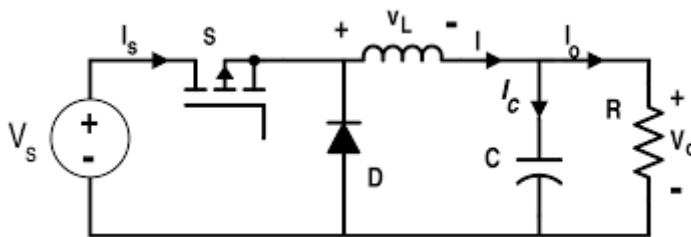


Fig.1 Conventional buck converter

the buck Converter circuit consists of the switching transistor, together with the flywheel circuit (D, L and C). While the transistor is on, current is flowing through the load via the inductor L. The action of any inductor opposes changes in current flow and also acts as a store of energy. In this case the switching transistor output is prevented from increasing immediately to its peak value as the inductor stores energy taken from the increasing output; this stored energy is later released back into the circuit as a back e.m.f. as current from the switching transistor is rapidly switched off.

When the switching transistor is switched on, it is

supplying the load with current. Initially current flow to the load is restricted as energy is also being stored in L, therefore the current in the load and the charge on C builds up gradually during the 'on' period. Throughout the on period, there will be a large positive voltage on diode D cathode and so the diode will be reverse biased and therefore play no part in the action.

When the transistor is turned off, the energy stored in the inductor causes current to flow around the circuit via the load and diode D, which is now forward biased.

### B. Synchronous Buck Converter

In the proposed synchronous converter, the uncontrollable switch (diode) is replaced by another controllable switch (MOSFET) which is showed in the figure[2] below.

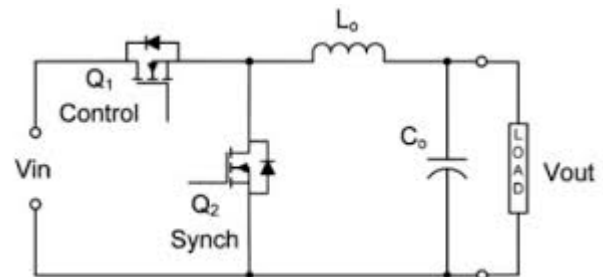


Fig.2. Synchronous buck converter

In this proposed synchronous buck converter, the current through the inductor is controlled using the switching time of the two switches.

### C. PI Controller

A variation of Proportional Integral Derivative (PID) control is to use only the proportional and integral terms as PI control. The PI controller is the most popular variation, even more than full PID controllers. The value of the controller output  $u(t)$  is fed into the system as the manipulated variable input.

$$e(t) = SP - PV \quad (1)$$

$$u(t) = u_{\text{bias}} + K_c e(t) + K_c / \tau_I \int e(t) dt \quad (2)$$

The output voltage  $V_{\text{out}}$  is fed back and compared with the reference voltage  $V_{\text{ref}}$  to produce an error signal. The error signal will be sent to a PI controller which would vary the duty cycle of the saw tooth waveform. The PI controller has two parameters namely  $K_P$  and  $K_I$ . The two terms work independently and can take any real values which could be calculated by different methods for tuning the PI controllers. The Simulink schematic of Buck converter with analog PID controller is shown in fig.3

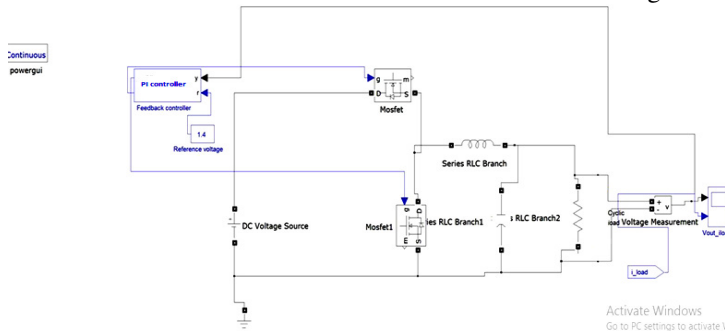


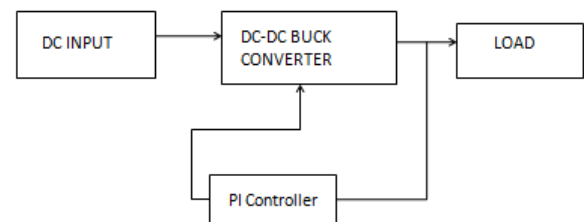
Fig.3 Closed loop simulation using PI controller

### III. MEDICAL APPLICATIONS

In the recent years, high frequency switching converters applications in the dc power distribution are increasing. Particularly in the area of biomedical systems, the main focus is on medical implants. As the power conversion system is becoming miniaturized, increasing the power density is one of the challenging issues. Nowadays, switching mode converters with higher power density and low electromagnetic interference (EMI) is required. Several types of switch-mode dc-dc converters (SMDC), belongs to buck, boost and buck-boost topologies, have been developed and reported to meet variety of applications. Major concern in medical, automotive and telecom power supply systems, is to meet the increased power demand and to reduce the burden on the primary energy source. Battery life is an important issue in all portable electronic devices. The matter becomes even more crucial

when the battery enabled devices are medical implants. In these devices, life itself might become dependent on the battery life. Naturally, as with all battery-powered devices, the battery of an implant must be replaced after a certain period of time. A frequent change of an implant's battery is not desired because it requires surgical procedure. Whether the implant is powered by a battery, inductive link, piezoelectric source, or a combination of these sources, it is important to have circuits with ultra-low-power consumption that would efficiently use these energy resources.[4] Reducing the power dissipation in these circuits also helps to reduce the risk of damaging surrounding tissues due to dissipated heat. Thus the application of buck converter in medical field is vast. Here, our application is focused on a hearing aid, where it is noted that from various investigations, the voltage requirement of a hearing aid is about 1.4V. Thus, in our closed loop response using PI controller, the reference voltage is set as 1.4v

### IV. BLOCK DIAGRAM

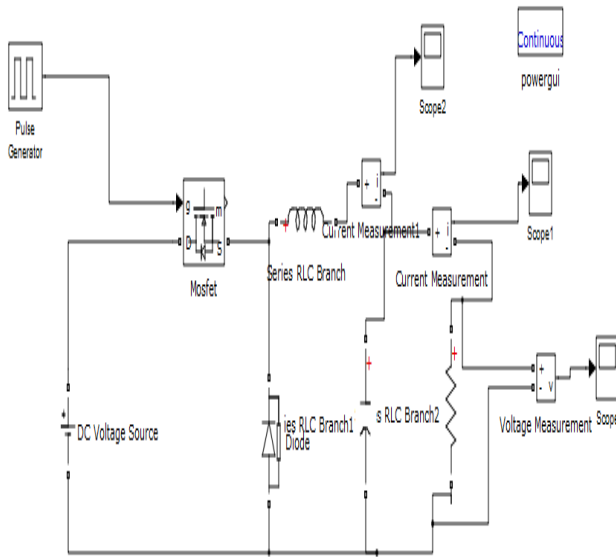


In the above block diagram, a dc input voltage of 5 volts is given to a synchronous DC-DC buck converter. The DC-DC buck converter is used for stepping down the supplied input voltage. The output of the buck converter is given as input to the load. In order to achieve the desired voltage level, output from the buck converter is fed back as input to a PI Controller. Since this paper is focused on the application of a hearing aid, by referring various resources we have come to know that the suitable voltage range of a hearing aid is about 1.4V. Thus in the PI Controller we have applied the reference voltage as 1.4V. By tuning the PI Controller with suitable techniques we have achieved the desired voltage range in which a hearing aid can operate.

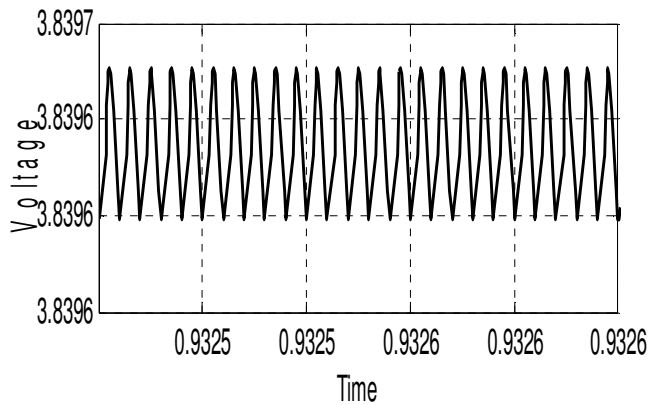
### V. SIMULATION RESULTS AND DISCUSSION

#### A. Conventional buck converter

The simulation model for the conventional buck converter was designed as follows.

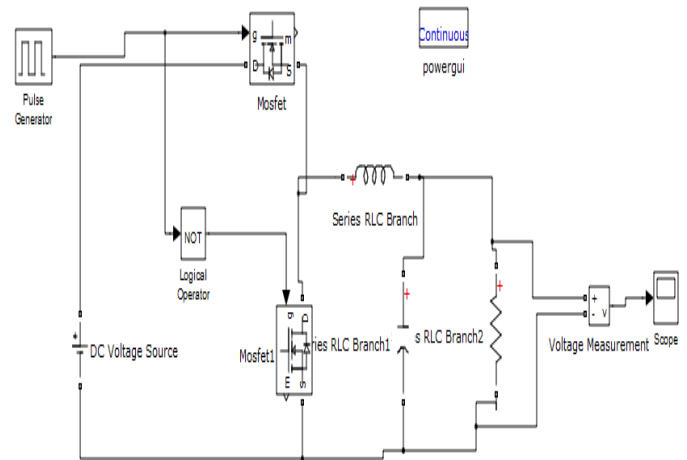


It is seen that the output voltage obtained by simulating the conventional converter is about 3.839V.

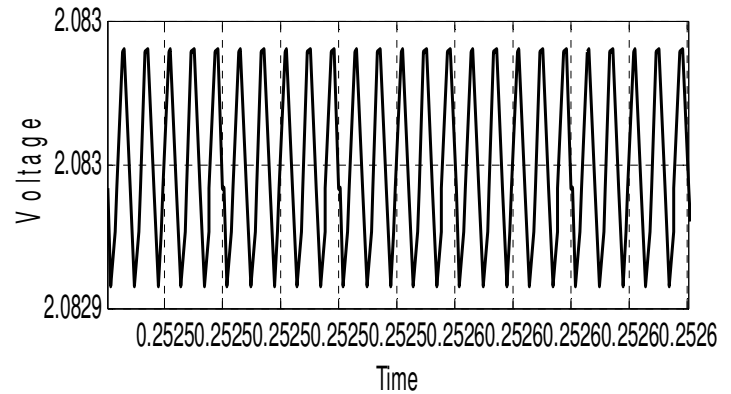


### B. Proposed Converter

The simulation connection diagram of the proposed buck converter is as follows.

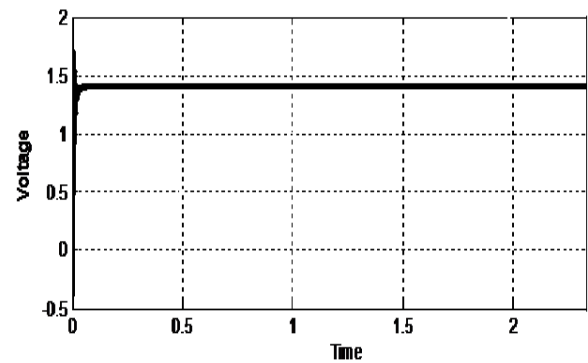


The output voltage obtained using the proposed synchronous buck converter is 2.083V.



### C. Closed loop response

Using the PI controller, a closed loop is achieved and it is observed that an output voltage of 1.4V is obtained.



#### D. Parameters used in simulation

The parameters used to create a Simulink model is shown in table.1

TABLE 1:PARAMETERS FOR SIMULATION

No.	Values used	
	Component	Value
1.	Inductance	0.143mH
2.	Capacitance	203uF
3.	Resistance	1000 Ohm
4.	Frequency	25 KHz
5.	Duty cycle	41.6%

#### V. COMPARISON

On comparing all the three methods, it is observed that for the same given input voltage, varying output voltages are obtained and also it is seen that the output voltage is stepped down in every trial. Finally, the desired output of 1.4V which is the required input for a hearing aid is achieved in the last method i.e. by using a PI controller.

TABLE 2 : COMPARISON TABLE

No.	COMPARISON			
	Parameters	Conventional Conerter	Synchronous Converter	Closed loop response
1.	Input Voltage	5V	5V	5V

No.	COMPARISON			
	Parameters	Conventional Conerter	Synchronous Converter	Closed loop response
2.	Output Voltage	3.839V	2.083V	1.4V

#### VI. CONCLUSION

The designing of buck converter has been carried out for constant voltage applications considering  $k_p$  and  $k_i$  are the performance parameter for PI Controller, the required output of 1.4V for a hearing aid is achieved. Performance and applicability of this converter is presented on the basis of simulation in MATLAB simulink. Buck converters are employed for low power applications. The parameter variation analysis of buck converter have been carried out for constant voltage application considering.

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