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Design and Development of Buck Converter for 9V DC motor for Electric Vehicle

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Abstract: The demand for high performance and cost effective systems are increasing in today's world hence the DC-DC converters with higher efficiency and power saving are being used in many industrial applications such as communication systems, computers etc. Many battery operated systems employ DC-DC converters to operate small motors for developing many applications such as Compact Disc Drives (CD), automotive applications. This paper presents the design and development of a buck converter fed from battery to analyze the performance of a small DC motor for applications like CD drive, Toy car, line following robot etc. The hardware prototype of the system was designed and the output values were analyzed and shown in this paper.

Keywords: Buck Converters, DC Motor, Battery.

I. INTRODUCTION

An application through a DC motor has being operated from many years. The first machine to be designed and operated was DC motor for many applications such as mills, industry, aerospace applications etc. The DC motor applications vary from big systems such as aircraft's to small systems such as toy cars, CD drives etc. Control of a motor has become essential when it comes to demanded and reliable operation. Speed control techniques are used for the control of motor for various closed loop or open loop operations. Chu-Hsiang China [1] has implemented a novel DCM/CCM PWM DC-DC buck converter and designed with standard CMOS process. The proposed buck converter verifies that the proposed DCM technique provides an exact output voltage, low output ripple, and high efficiency from 1mA to 500mA loading. Sanjay Murmu [2] has presented variation of load as well as variation in supply voltage. N. R. Kulkarni [3] has shown since Sliding mode controller is not operating at a constant switching frequency and converters have a highly nonlinear and time varying nature therefore it is selected to control such kind of DC- DC converter. Therefore it is also selected as control technique for performance analysis

M. M.Shanmugapriya [4] has shown that the Continuous output is maintained for portable medical device; thereby medical implant battery life is increased. To reduce switching losses at light loads, the proposed dc-dc converter is able to select a number of switches to operate while it keeps additional switches off. The papers studied shows the consequences in software form but none of them has built a hardware prototype to analyze the consequence and reduce it in physical world. In this report the main focus

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is on understanding the basics of buck converter and designing of the same for the small DC motor application. The DC Motor can be controlled through many technologies, but for smaller applications such as toy cars or the CD drives, they can be operated and controlled through a DC-DC converter from a battery. A buck converter (also step-down converter) is a DC-to-DC power converter which steps down voltage from its input (supply) to its output (load). The name "Buck Converter" presumably evolves from the fact that the input voltage is bucked/chopped or attenuated, in amplitude and a lower amplitude voltage appears at the output. A buck converter, or step-down voltage regulator, provides non-isolated, switch-mode dc-dc conversion with the advantages of simplicity and low cost. Fig.1 represents the basic circuit diagram of Buck Converter with a switch, diode and an inductor.

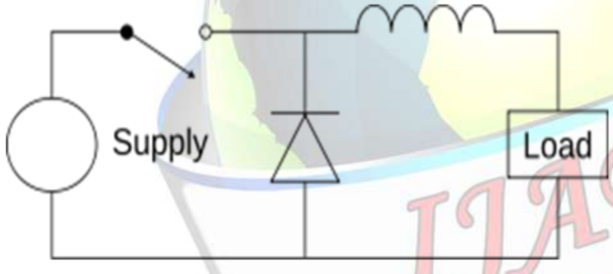

Fig. 1. Buck converter circuit diagram

Fig.2 represents the basic block diagram of the buck converter with motor which is used in this paper to design the hardware prototype for 9V DC motor.

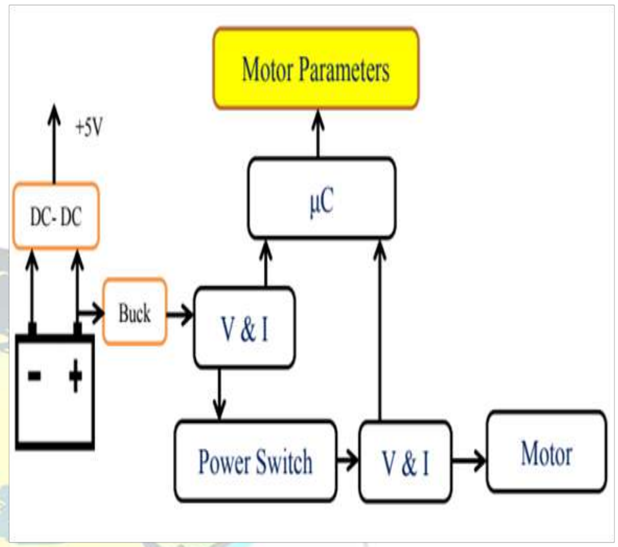

Fig. 2. Block diagram of buck converter with motor

The methodology used in controlling the DC motor is by using the Micro-controller to detect the voltage and current out of the DC-DC converter and the Battery which is used to supply the converter.

II. Design and Development

The buck converter is designed using MC34063 device, which has clock, error and switching blocks in built. Thus it reduces most of the circuit complexity and increases the reliability of the system. Buck converter is designed for input voltage of 12V and output voltage of 9V with frequency of 100kHz.The Buck converter consists of a switch (MOSFET used in this) which requires duty cycle. The inductor and the capacitor are designed using the formulas shown below.

The time period is given by

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$$t_{on} + t_{off} = \frac{1}{f} \quad (1)$$

The ratio of $\frac{t_{on}}{t_{off}}$ is given by

$$\frac{t_{on}}{t_{off}} = \frac{v_{out} + v_F}{v_{in(\min)} - v_{sat} - v_{out}} \quad (2)$$

$$t_{off} = \frac{t_{out} + t_{off}}{\frac{t_{on}}{t_{off}} + 1} \quad (3)$$

The on period (t_{on}) is given by

$$t_{on} = (t_{on} + t_{off}) - t_{off} \quad (4)$$

The peak current of buck switch is given by

$$I_{peak(switch)} = 2I_{out(\max)} \quad (5)$$

The short circuit current is given by

$$R_{sc} = \frac{0.33}{I_{peak(switch)}} \quad (6)$$

The output inductor is given by

$$L_{\min} = \left(\frac{v_{in(\min)} - v_{sat} - v_{out}}{v_{peak(switch)}}\right) t_{on(\max)} \quad (7)$$

The output smoothing capacitor is given by

$$C_o = \frac{I_{peak(switch)}(t_{on} + t_{off})}{8v_{ripple(pp)}} \quad (8)$$

The output voltage setting resistors are given by

$$R_2 = R_1\left(\frac{v_{out}}{1.25} - 1\right) \quad (9)$$

The Basic flow chart for the designed hardware prototype has been shown.

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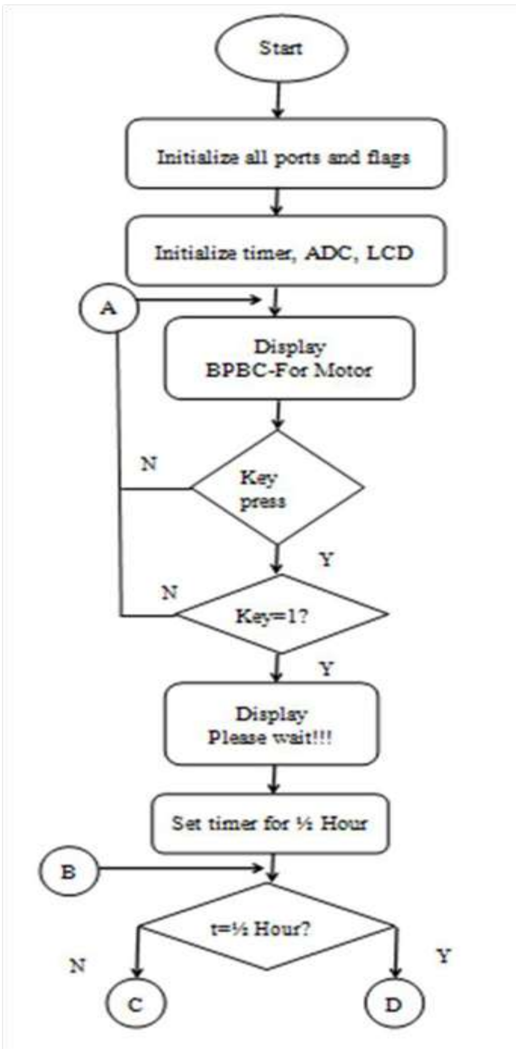

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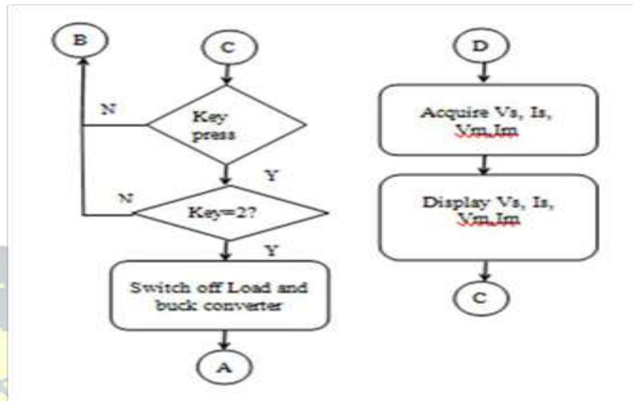

Fig. 3. Flowchart of the system

III. Hardware Prototype

The hardware prototype is shown in the figure below. The buck converter of output voltage 9V is designed as per the design formulas shown and the performance of the whole system has been analyzed and tabulated below.

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Fig. 4. Hardware Prototype of the buck converter

The parameter or components used for the hardware design have been shown in Table I

TABLE I

COMPONENTS AND THEIR VALUES USED IN HARDWARE PROTOTYPE

Component	Value
Battery	12V, 7Ah
DC Motor	9V, 2A, 12W motor
Buck converter	V_{in} = 12V V_{out} = 9V f = 100KHz I_{out} = 750mA L = 24 μ H C = 10 μ F
Microcontroller	PIC 16F877A

IV. RESULTS AND ANALYSIS

The designed buck converter is operated with input voltage 12V and the system parameters are recorded and tabulated.

The graphs for buck voltage (Vb) and buck current (Ib) are shown in figures. These are obtained when battery is used.

TABLE III

VM V/S IB VALUES

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Vb(mV)	Ib(mA)
12.5	193
12.4	192
12.3	187
12.5	183
12.4	187
12.5	180
12.4	183
12.4	178
12.6	193
12.4	185

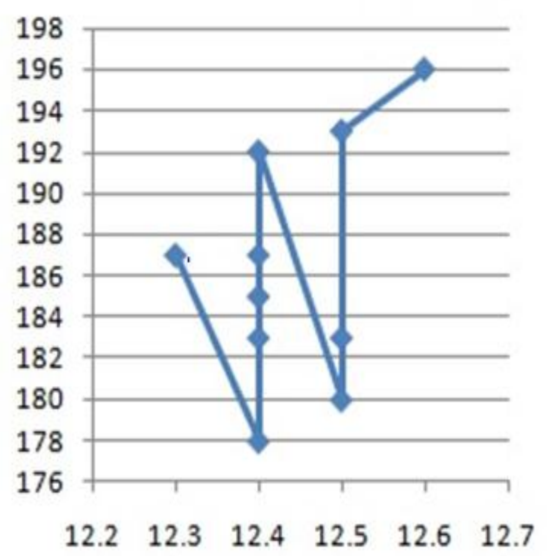

Fig. 4.Vm v/s Ib Graph

TABLE IIIII

VM V/S IM VALUES

Vm(mV)	Im(mA)
9.7	406
9.6	355
9.1	255
9.7	353
9.6	404
9.5	310
9.6	372
9.4	401
9.4	382
9.6	308

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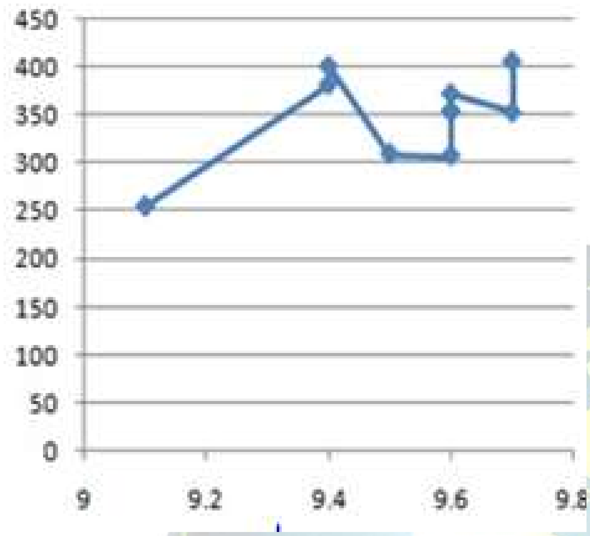

Fig. 5.Vm v/s Im Values and Graph

The buck converter and the motor voltages and currents are measured and tabulate. The readings are also represented graphically.

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TABLE IVV

Sl no.	Vb(mV)	Ib(mA)	Vm(mV)	Im(mA)	Efficiency %	Pb	Pm
1	12.5	193	9.7	406	61.2	2412.5	3938.2
2	12.4	192	9.6	355	69.8	2308.8	3408
3	12.3	187	9.1	255	99.1	2300.1	2320.5
4	12.5	183	9.7	353	66.8	2287.5	3424.1
5	12.4	187	9.6	404	59.7	2318.8	3878.4
6	12.5	180	9.5	310	76.4	2250	2945
7	12.4	183	9.6	372	63.5	2269.2	3571.2
8	12.4	178	9.4	401	58.5	2207.2	3769.4
9	12.6	193	9.4	382	67.7	2431.8	3590.8
10	12.4	185	9.6	308	77.5	2294.0	2956.8

VOLTAGE AND CURRENT VALUES OF BUCK CONVERTER AND MOTOR

V. CONCLUSION

The design and development of battery powered buck converter for small motor drive applications have been done in this paper. The voltage and current values of battery and buck converter are recorded and tabulated. The graph of V_bVsI_b and V_mVsI_m are tabulated and plotted for Buck converter and DC motor respectively. The operation and performance of the developed system has been analysed, checked and found satisfactory according to the permitted rules. The system is also designed in such a way that whenever buck converter input voltage drops below 11V then the system stops functioning. The system has a provision of disconnecting the load when battery reaches its minimum charge level of 11V because of which the motor stops working and the system comes to a standstill.

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BIOGRAPHIES

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