EWB DC-DC CONVERTER PROJECT

ECE 445 Senior Design Project
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Qian Liu
Joel Lau
Mark Wong

TA: Wayne Weaver

Project Team: 7

ABSTRACT

We designed and built a DC-DC buck converter to meet the specifications set by our client, Engineering Without Borders (EWB). Essentially, our buck converter is used to charge 12V lead-acid batteries by stepping down the high voltage input from the wind turbine to a lower voltage level.

Our buck converter consists of a MOSFET, diode and inductor. The MOSFET acts as a switch and is turned on and off by a Pulse Width Modulated (PWM) controller. This means that by controlling the duration when the switch is on, the voltage or current at the output can be regulated. Our controller is able to sense the battery's voltage level and apply the appropriate charging algorithm accordingly. 3 LEDs are used in combination to inform the user of the charging status.

To ensure that our device works, we will simulate the battery for testing. Efficiency is a crucial parameter of our converter. Therefore, we took a series of measurements for the range of input voltages and determined if the efficiency values are within our acceptable benchmarks.

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1. INTRODUCTION

1.1 PURPOSE

We chose this project because we would like to help out in the Maharshtra Project, India, via Engineering Without Borders (EWB). Through this project, we can support the use of clean, renewable energy sources; the DC-DC converter is used to step down the voltage output of a wind turbine. It should be more economical to build it on our own than purchasing one. The design would be simple to implement and can be used to build more converters in India if necessary.

Developing it from start to finish, we would learn how different areas of electrical engineering, such as power, control, semiconductor devices, etc, are related to one another, and applied in a comprehensive way.

1.2 SPECIFICATIONS

The DC-DC converter steps down the high input voltage from the turbine to charge 12 V lead-acid batteries. The device will handle a range of input voltages from the wind turbine. It would also monitor the load and perform maintenance charging when the battery is fully charged. The converter would also have safety features to protect itself and the load from sudden surges or malfunction. The following is our design specifications:

- Input voltage ranges between 40 to 70V.
- Maximum output current = 10A.
- Targeted efficiency = 85% (65% minimum)
- Battery monitoring with dynamic charging
- Safety features using fuses and diodes

1.3 SUBPROJECTS

We broke down our design into sub-components, each with a specific task. Each sub-component was tested individually to ensure that each one performed to specifications. The sub-components are shown in Figure 1.

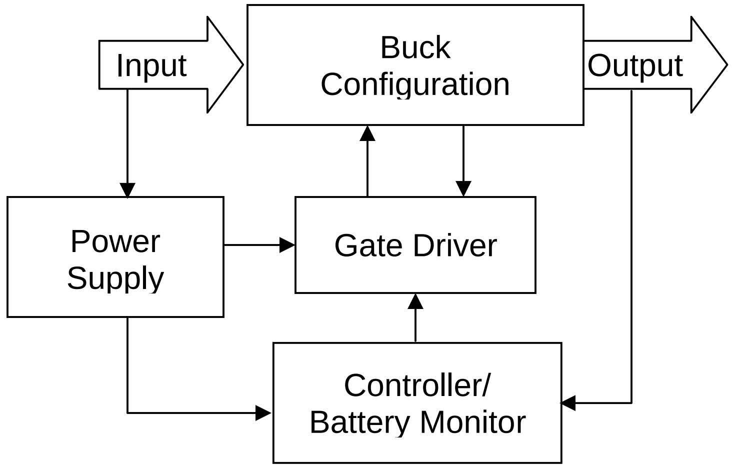

Figure 1 *Block diagram*

1.3.1 Power Supply

This component supplies the 5V and 12V needed by the controller and driver respectively. This is implemented by using a 12V regulator, zener diodes and resistors.

1.3.2 Controller

We chose the TI controller BQ2031, which also acts as a battery monitor. It can sense the voltage level of the battery and apply the appropriate charging algorithm. Through the use of 3 LEDs, it can display the charging status to the user.

1.3.3 Gate Driver

This device amplifies and translates the PWM control signal from the controller to allow proper switching of the MOSFET. Since the source voltage is floating, the gate driver is necessary for proper referencing.

1.3.4 Buck Configuration

The buck configuration consists of the MOSFET, diode and inductor. The main bulk of the input power would pass through these components before being delivered to the output. Therefore, it is critical to select efficient components. The MOSFET acts as a switch and by controlling the duration it is on, the output voltage or current can be regulated.

2. DESIGN PROCEDURE

2.1 Power Supply

Our power supply is designed to provide a stable source of power to our controller and gate driver. The controller requires 5V to operate whereas the gate drive components both require 12V each. We used the LM340, a 12V voltage regulator, to provide the 12V supply needed. We could also use another voltage regulator to give the required 5V. However, we easily obtained the 5V supply by tapping off the already available 12V supply. This is implemented in our circuit using two resistors and one 5.1V zener diode. By doing so, our power supply circuitry is more compact.

2.2 Controller

We decided to use the BQ2031 as it incorporates 3 desirable functions:

- Monitors the battery's voltage level.
- Provides dynamic charging via various charging algorithms.
- Displays charging status through LEDs.

By incorporating these functions into one device, the BQ2031 significantly reduces the number of discrete components and keeps our circuitry compact. It is noted that the required resistors for sensing have to be 1% precision resistors. These resistors are readily available in the parts shop.

2.3 Gate Driver

The maximum amplitude of the control signal is 5V referenced to ground. This is insufficient to switch on the MOSFET since the source voltage is floating. Therefore, a high-side gate driver is required. We have 3 different alternatives: IR2117, transformer or driving a PMOS. Our first choice was the IR2117 but it did not work. After trying all 3 alternatives that failed, we discovered that our breadboard was faulty. We managed to get the IR2117 to work when a new breadboard was installed.

The IR2117, a high side gate driver, takes the incoming logic signal and references it to the source. In addition, it ensures that logic '1' is at least 10V higher than the source voltage, thereby leading to hard switching of the MOSFET.

The setback with using IR2117 is that it only considers an input voltage higher than 9.5V as logic '1' [1]. Therefore, the 5V logic '1' control signal would fail to trigger the IR2117 properly. To solve this issue, we initially used a comparator to amplify the control signal. However, this required a reference voltage and introduced significant additional components. By using the MIC4420, no additional components are needed. Furthermore, it can operate with the available 12V supply.

2.4 Buck Configuration

The MOSFET switch should have a low $R_{DS(on)}$. The Fairchild FDP3651U N-channel MOSFET was chosen as our switching component with a $R_{DS(on)}$ of 13 mΩ [2]. We wanted a diode with low forward voltage, ultra fast recovery and the ability to withstand at least 70V. Therefore, the MBR41H100CTG Schottky diode from On Semiconductors was chosen. It is a 100V, 20A diode with a low forward voltage of 0.67V [3].

The inductor ensures that the current does not ‘jump’ instantaneously. The inductance also determines the size of the ripple current. Therefore, the inductance must be appropriately selected, which is in turn determined by the number of turns and core material. We were also aware that the inductor must not saturate and the magnetic wires should be capable of handling the maximum possible current. It is important to note that we want our converter to be in continuous conduction mode. This means that the current flowing through the inductor must not reach 0 [4]. We are using the inductor given by our TA and so far, it has not given us any problem.

Since our objective is to charge battery and the battery sets the output voltage, the ripple voltage is not a concern and the capacitor at the output is not necessary.

3. DESIGN DETAILS

3.1 Power Supply

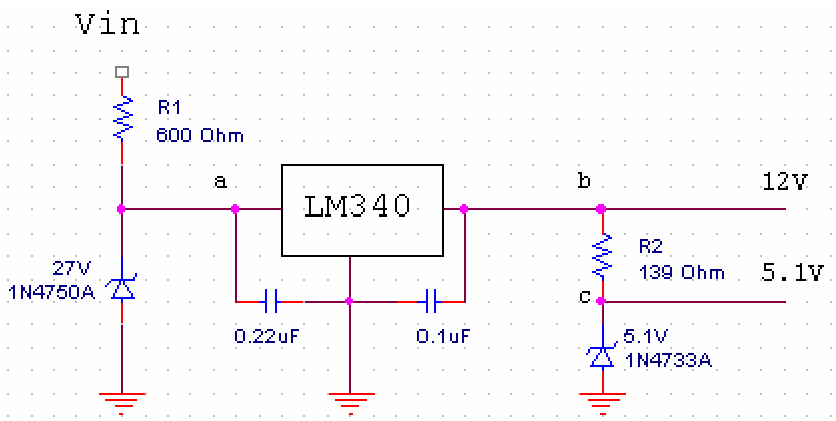

Figure 2 *Power Supply*

As shown in Figure 2 above, the power supply is designed with a 12V voltage regulator, LM340. The LM340 outputs the desired 12V voltage level. Instead of using another voltage regulator, the 5V voltage level can be derived from the LM340 output by using a resistor R2 and a 5.1V, 1W zener diode (1N4733A); we used the 5.1V zener diode rather than a 5V one since that is the closest value available in the ECE store.

$$R2 = \frac{12V - 5.1V}{50mA} = \mathbf{138\Omega}$$

The IR2117 draws current in the μA range [1]. The bq2031 controller draws currents in the low mA range (about 2 to 4mA) [5]. Considering these factors and the current needed to keep the zener in reverse bias, we set the current flowing through R2 as 50mA. As calculated above, the value of R2 turns out as 138Ω. Due to the availability of resistors in the shop, we chose R2 = 139Ω by using a 100Ω and a 39Ω in series.

Power dissipated in 5.1V zener = (5.1V)(50mA)
= **0.255W < 1W**

Power dissipated in R2 = $(50mA)^2(140\Omega)$
= **0.35W < 1W**

From the calculations shown, the 5.1V zener diode and resistors are operating well below their ratings. The resistors are each rated at 1W.

Since the maximum voltage input into the LM340 is 35V, a resistor R1 and 27V zener diode are used to step down the higher input voltage range

(40V to 70V) to about 27V [6]. To ensure that these devices are operating well below their power ratings, the case when the input voltage is 70V is considered. We also had to ensure that sufficient current flows through R1 when the input falls to 40V.

At input of 70V, we can assume that the zener diode is in reverse bias with voltage drop of 27V. At lower input of 40V, we want the LM340 to continue maintaining 12V at the output. This would require the voltage level before the LM340 to be higher than 12V, which we assume to be 13V. We set R1 as 600Ω.

Input 40V, current through R1 $= \frac{40V - 13V}{600}$
= **45mA**

Input 70V, current through R1 $= \frac{70V - 27V}{600}$
= **72mA**

These currents are sufficient to keep the 5.1V zener in reverse bias.

Maximum power dissipated in 27V zener = (27V)(72mA – 56.5mA)
= **0.42W < 1W**

Maximum power dissipated in R1 = $(72mA)^2(600\Omega)$
= **3.11W**

The 600Ω resistor consists of 3 x 1.8kΩ, 2W resistors connected in parallel. Therefore, maximum power dissipated across each 1.8kΩ resistor is 3.11/3 = **1.04W < 2W**. The 27V zener also operates below its rating.

3.2 CONTROLLER

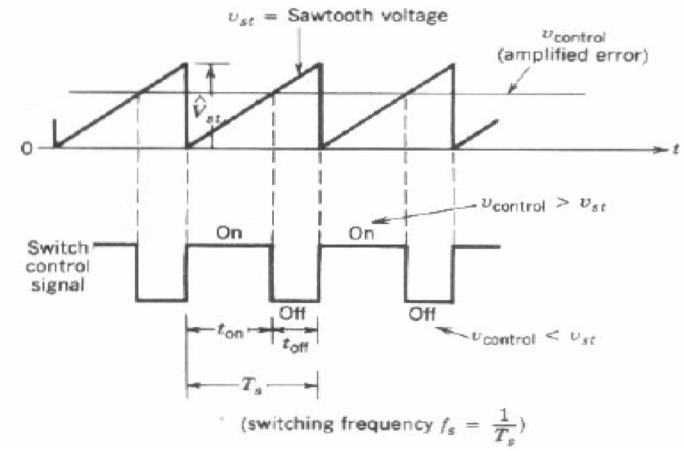

Figure 3 *PWM control [7]*

Pulse Width Modulation (PWM) is used to implement the duty cycle control effort as shown in Figure 3 above [7]. The control signal is compared to a repetitive reference waveform at the desired frequency. The switch control signal changes according to the output of the comparison.

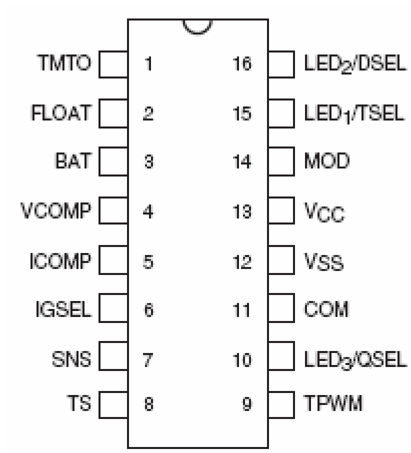

Figure 4 *BQ2031 controller [5]*

We have chosen a controller that combines 3 desired features in one. The BQ2031 from TI operates as a PWM controller, a battery monitor and has in-built dynamic charging algorithms. This controller is designed to charge lead acid batteries, which fits the operation of our DC-DC converter. Our controller will be operating at a frequency of 100 kHz [5].

Algorithm/State	QSEL	TSEL	Conditions	MOD Output
Two-Step Voltage	L	H/L Note 1	-	-
Fast charge, phase 1			while $V_{BAT} < V_{BLK}$, $I_{SNS} = I_{MAX}$	Current regulation
Fast charge, phase 2			while $I_{SNS} > I_{MIN}$, $V_{BAT} = V_{BLK}$	Voltage regulation
Primary termination			$I_{SNS} = I_{MIN}$	
Maintenance			$V_{BAT} = V_{FLT}$	Voltage regulation

Table 1 *Charge algorithm [5]*

The controller gives us 3 different algorithms in charging the battery. We chose the two-step voltage algorithm. The charging algorithm is shown in Table 1 [5]. The charging waveforms are shown in Figure 5 [5].

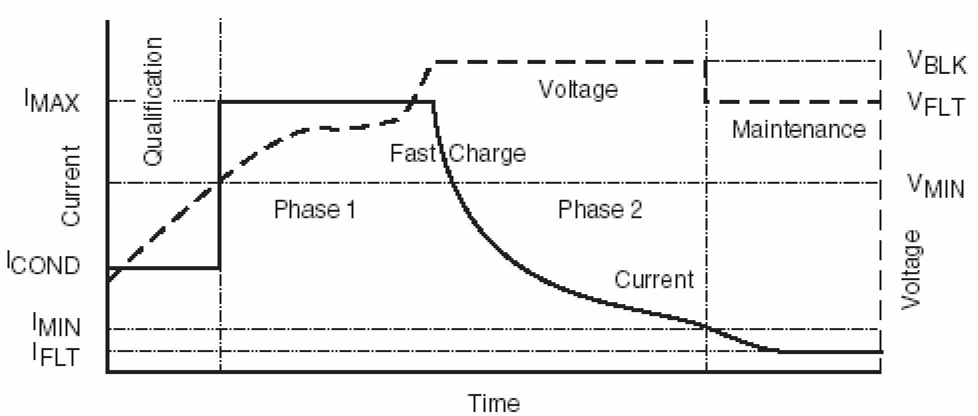

Figure 5 *Charging waveforms [5]*

The controller also outputs the charging status via 3 LEDs. The LEDs light up accordingly as shown in Table 2 below [5]. The colors of LED_1, LED_2 and LED_3 are chosen as green, blue and red respectively.

Mode	Charge Action State	LED_1	LED_2	LED_3
DSEL = 0 (Mode 1)	Battery absent or over-voltage fault	Low	Low	High
	Pre-charge qualification	Flash	Low	Low
	Fast charging	High	Low	Low
	Maintenance charging	Low	High	Low
	Charge pending (temperature out of range)	X	X	Flash
	Charging fault	X	X	High

Table 2 *LED display [5]*

In order to implement the controller, careful calculations and component selection have to be done. Through some research, we found that for a lead-acid battery, the typical bulk voltage charge is 2.45V/cell and the typical float voltage charge is 2.25V/cell [8, 9]. Therefore, for a 6-cell 12V lead-acid battery, the typical bulk and float voltage levels are *14.7V* and *13.5V* respectively. Further information and formulas in the BQ2031 datasheet were reviewed in detail and produced in Table 3 [5, 8]. The resistors used for sensing, ie RB1, RB2, RB3, R_{SNS}, RT1 and RT2 are all precision resistors.

Parameter (shown in Appendix A)	**Calculations**	**Available Quantity**
RB1	$\frac{RB1}{RB2}=\frac{N*V_{FLT}}{2.2}-1$ $N*V_{FLT}$ = 13.5V, ⇒ **RB1 = 260 kΩ**	1 x 270kΩ *Note:* *150kΩ< RB1 + RB2 <1MΩ*
RB2	**RB2 = 49.9kΩ** (datasheet)	1 x 51kΩ
RB3	$\frac{RB1}{RB2}+\frac{RB1}{RB3}=\frac{N*V_{BLK}}{2.2}-1$ $N*V_{BLK}$ = 14.7V, ⇒ **RB3 = 475kΩ** (datasheet)	1 x 470kΩ
R_{SNS}	$R_{SNS}=\frac{0.250V}{I_{max}}$ Imax = 5A, ⇒ **R_{SNS} = 0.05Ω**	1 x 0.05Ω
RT1/RT2	**RT1 = RT2 = 100kΩ** (datasheet)	2 x 100kΩ *Note: temperature sensing not in use*
MTO RC	$t_{MTO}=0.5*R*C$ **C = 0.1μF** (datasheet) t_{MTO} = 5 hrs ⇒ **R = 100kΩ**	1 x 100kΩ 1 x 0.1μF
C_{PWM}	$C_{PWM}=0.1/F_{PWM}$ F_{PWM} = 100 kHz ⇒ **C_{PWM} = 1nF**	1 x 1000pF
LED/Mode selection Resistors	For LED, **R = 1kΩ** (datasheet) For selection, **R = 10kΩ** (datasheet)	3 x 1kΩ 3 x 10kΩ
Feedback	**Rv = 100kΩ** (datasheet) **Cv = Ci = Cf = 0.1μF** (datasheet)	1 x 100kΩ 3 x 0.1μF

Table 3 *Controller calculations [5]*

3.3 Gate Driver

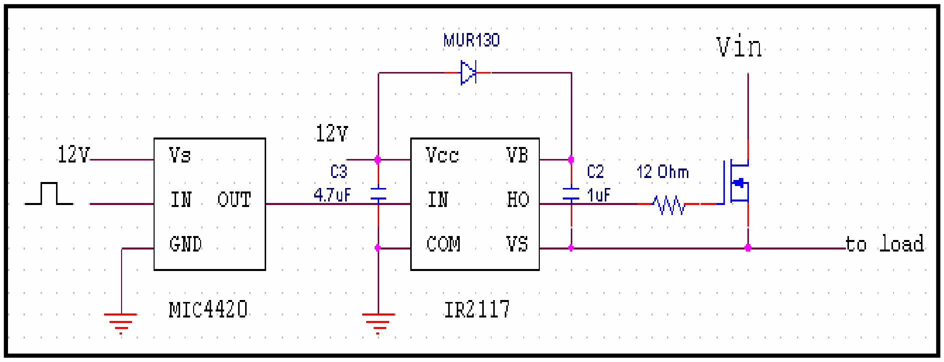

Figure 6 *Gate Driver*

The gate driver circuit consists of the IR2117 and MIC4420 as depicted in Figure 6. The IR2117 is a high side gate driver that is capable of referencing the control signal to the floating source voltage. The MIC4420 amplifies the logic ‘1’ signal of the BQ2031 from 5V to 12V. The logic ‘0’ control signal remains unchanged. By doing so, the IR2117 is able to translate the control signal and drive the MOSFET switch properly.

<u>IR2117</u>

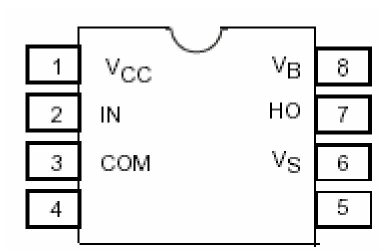

Figure 7 *IR2117 [1]*

We followed the guidelines in the correct set-up of the IR2117 [1, 10]. The source and gate of the MOSFET are connected to the V_s and HO pins respectively. The 12V supply is connected to V_{cc} and the output of MIC4420 is connected to the IN pin. COM is connected to ground.

C2 is the bootstrap capacitor and is set to 1μF. The bootstrap capacitor provides the charge required to pull the output signal higher than the source when the logic input is ‘1’. An ultra fast recovery diode, MUR130 is used in the IR2117 set-up. The MUR130 diode prevents negative spikes from affecting the operation of the IC and provides additional noise immunity [10].

MIC4420

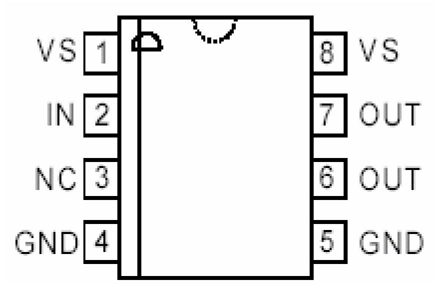

Figure 8 *MIC4420 [11]*

The MIC4420 is easily set up [11]. The input pin, IN receives the control signal from the controller. The output, OUT pin, delivers the amplified control signal to the IR2117. Pins V_S and GND are connected to 12V and ground respectively.

3.4 BUCK CONFIGURATION

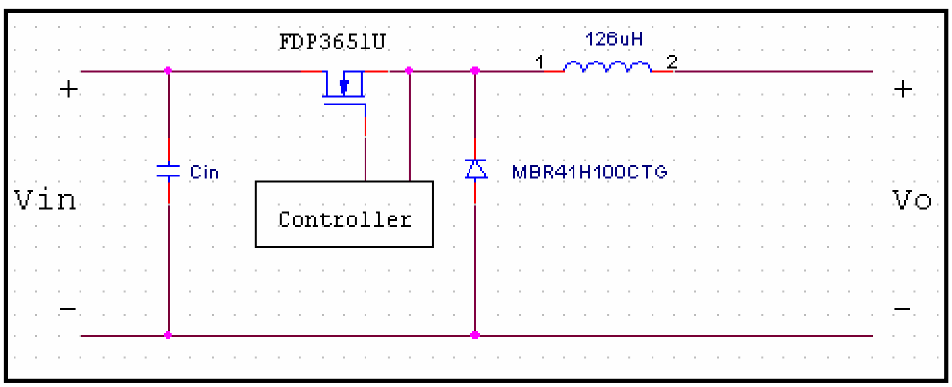

Figure 9 *Buck Configuration*

The MOSFET switch is turned on/off by an external controller. When the switch is closed, the voltage across the inductor increases and the current rises. When the switch is open, the voltage and current through the inductor falls. Hence, the output voltage can be regulated by adjusting the switching duty ratio, as shown in Figure 10 [7].

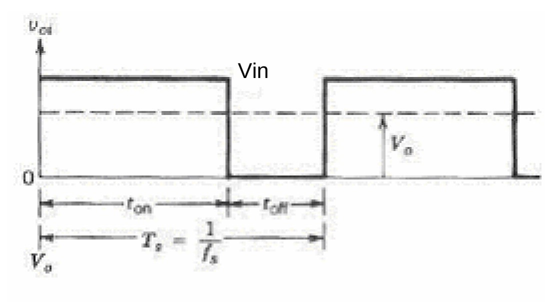

Figure 10 *Duty Ratio [7]*

$$D = \frac{V_0}{V_{in}} = \frac{t_{on}}{T_s}$$

The theoretical form of the duty ratio is given above. T_s is the switching period and t_{on} is the time during which the MOSFET is on.

<u>MOSFET/Diode</u>

As mentioned earlier, the FDP3651U MOSFET from Fairchild Semiconductors is chosen since it can withstand 100V and has a low $R_{DS(on)}$ of 13mΩ [2]. The MBR41H100CTG Schottky diode from On Semiconductors was chosen due to its low forward voltage and ultra fast recovery. It is a 100V, 20A diode with a low forward voltage of 0.67V [3].

<u>Inductor</u>

The desired value of our inductor is derived below in 2 ways:

Formula from textbook	Formula from datasheet [5]
$L = \frac{V_0(1-D)}{f * \Delta L}$	$L = \frac{N * V_{BLK} * 0.5}{f * 2 * I_{min}}$
D (duty ratio) = 12/70 (smallest) Ripple current = 20% of Imax	(*for continuous conduction mode*) N*V_{BLK} = 14.7 V Imin = Imax/10
$L = \frac{12(1-12/70)}{10^5 * 1}$ = **99μH**	$L = \frac{14.7 * 0.5}{10^5 * 2 * 0.5}$ = **73.5μH**

Table 4 *Inductor calculations*

Therefore, a minimum inductance of 100 μH is required. We are using the 126μH inductor given by our TA.

4. DESIGN VERIFICATION

4.1 Testing

Individual sub-components of our DC-DC converter were tested for their specific functionality before incorporating them into the final layout of Appendix A. When we were satisfied with the performance of each sub-component, the overall circuit was tested. We had to ensure that the converter performs the correct operation as indicated by the LEDs. Once this was verified, efficiency was calculated. Ultimately, we aim to achieve an efficiency of at least 65%.

4.1.1 Power Supply

The power supply was set up as shown in Figure 2. We first supplied an input of 40V and measured the voltages at nodes a, b and c as indicated on Figure 2. These node voltages correspond to the voltages at input, output of LM340 and 5V supply output respectively. Next, the input current and currents through the 5.1V and 27V zeners are measured using the DMM. The power dissipation in each component was calculated using P = IV to ensure that the power ratings were not exceeded. The same process was repeated by stepping up the input by 10V each time until 70V was reached. The collected data is tabulated below in Table 5.

Vin		**5.1V Zener**			**27V Zener**			**LM340**	
V (V)	**I (mA)**	**V (V)**	**I (mA)**	**P (W)**	**V (V)**	**I (mA)**	**P (W)**	**V_{out} (V)**	**I_Q (mA)**
40	46	**5.12**	42.4	**0.22**	12.46	0	**0**	**10.96**	3.6
50	55	**5.14**	50.6	**0.26**	17.05	0	**0**	**12.14**	4.4
60	56	**5.14**	50.6	**0.26**	26.9	0.84	**0.02**	**12.14**	4.56
70	71	**5.14**	50.6	**0.26**	28.79	14.75	**0.42**	**12.14**	5.65

Table 5 *Power Supply Data*

The 5V supply was consistent for the range of input voltages. At 40V, the LM340 outputs about 11V, which was still sufficient to drive the targeted devices. The quiescent current in the LM340 was obtained by using KCL. This value is below the maximum quiescent current of 6.5mA [6]. At 70V, the two zeners were operating well below their power rating of 1W. By using KCL, KVL, the resistors were also found operating below their power ratings as shown in Table 6 below. The 1.8kΩ is a 2W resistor, while the rest are 1W resistors.

Vin	600Ω				139Ω				
	V (V)	I (mA)	P (W)	$P_{1.8k}$ (W)	V (V)	I (mA)	P (W)	$P_{100\Omega}$ (W)	$P_{39\Omega}$ (W)
40	27.54	46	1.27	**0.42**	5.84	42.4	0.25	**0.18**	**0.07**
50	32.95	55	1.81	**0.6**	7	50.6	0.35	**0.25**	**0.1**
60	33.1	56	1.85	**0.62**	7	50.6	0.35	**0.25**	**0.1**
70	41.21	71	2.93	**0.98**	7	50.6	0.35	**0.25**	**0.1**

Table 6 *Resistor Power Dissipation*

4.1.2 Controller

Each Agilent E3631A, triple output DC power supply can provide up to a maximum of 50V. By connecting it with the bench supply of 24V in series, we can obtain our desired input supply range of 40V to 70V for testing.

Using the Agilent E3631A, we applied different DC voltage levels across the sensing resistors to simulate the battery output. Our goal was to determine if the controller was set up correctly to recognize these DC levels and perform the right operation. By observing how the 3 LEDs behave and cross-referencing with Table 2, we determined if the controller was responding accordingly.

When an appropriate voltage, eg 5V, was applied across the sensing resistors, the controller registered that a battery was present and the green LED begins flashing. This indicates pre-charge qualification from Table 3. When the controller's output signal was measured using the oscilloscope, a PWM control signal was observed as shown in Figure 11. The duty cycle was found to be 82.8%. This is expected since the controller sensed only the voltage and not the current through the load, it output the maximum duty cycle possible. This primary testing showed that the controller was responding as expected.

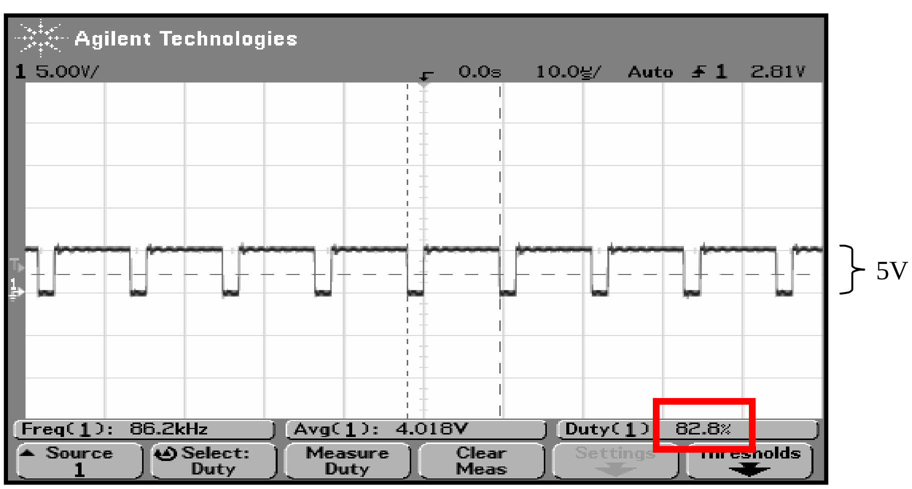

Figure 11 *Controller PWM signal*

4.1.3 Gate Driver

The control signal can be simulated using the function generator Fluke PM5139. A 100kHz square waveform was set with 5V peak-to-peak with a DC offset of 2.5V. This ensured that logic ‘0’ and ‘1’ correspond to 0V and 5V respectively. The duty cycle was set at 50%.

The control signal was firstly fed into MIC4420 and the output was measured with an oscilloscope. The input control signal and the output of MIC4420 were captured and shown in Figure 12. From Figure 12, the MIC4420 did its job of amplifying the logic ‘1’ signal to 12V.

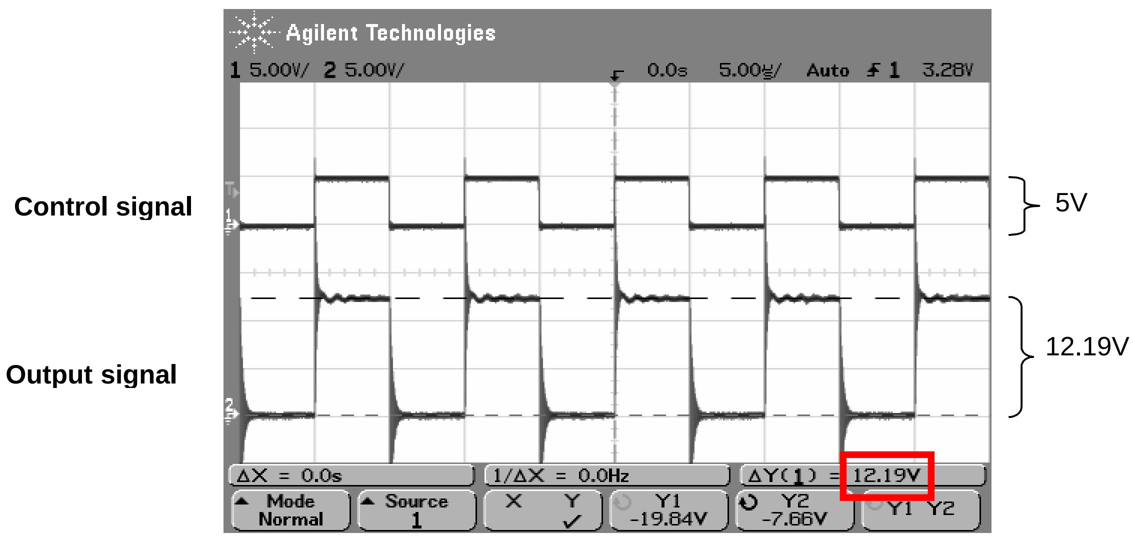

Figure 12 *Input control signal & MIC4420 output*

The output of the MIC4420 was then connected to the IR2117 driver. When the source pin Vs was connected to ground, the control signal passed through the IR2117 unchanged as shown in Figure 13.

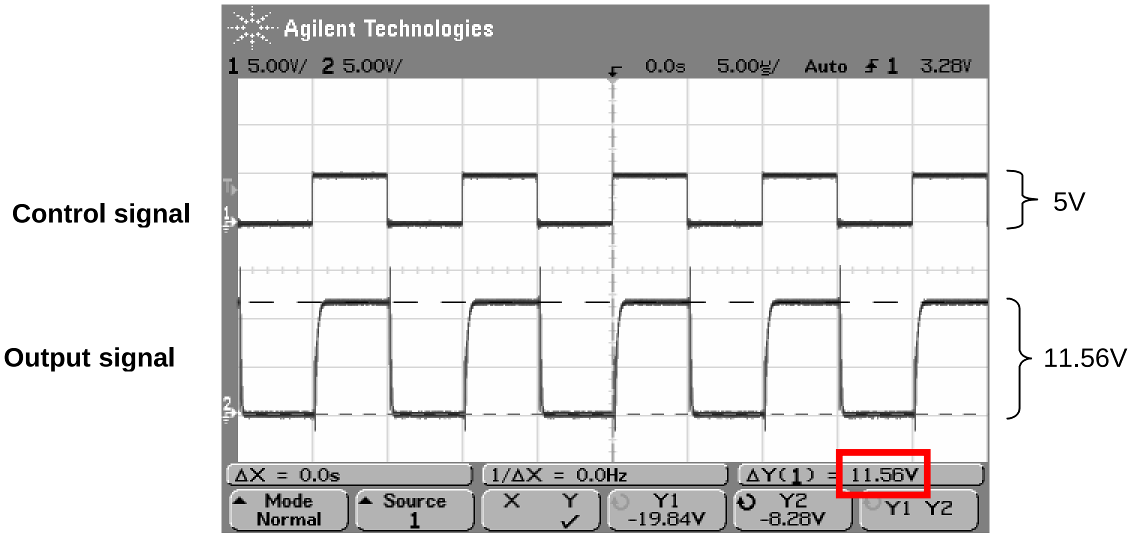

Figure 13 *Control signal & IR2117 output (V_s ground)*

When the source pin Vs was at 10V, the control signal was referenced accordingly in Figure 14.

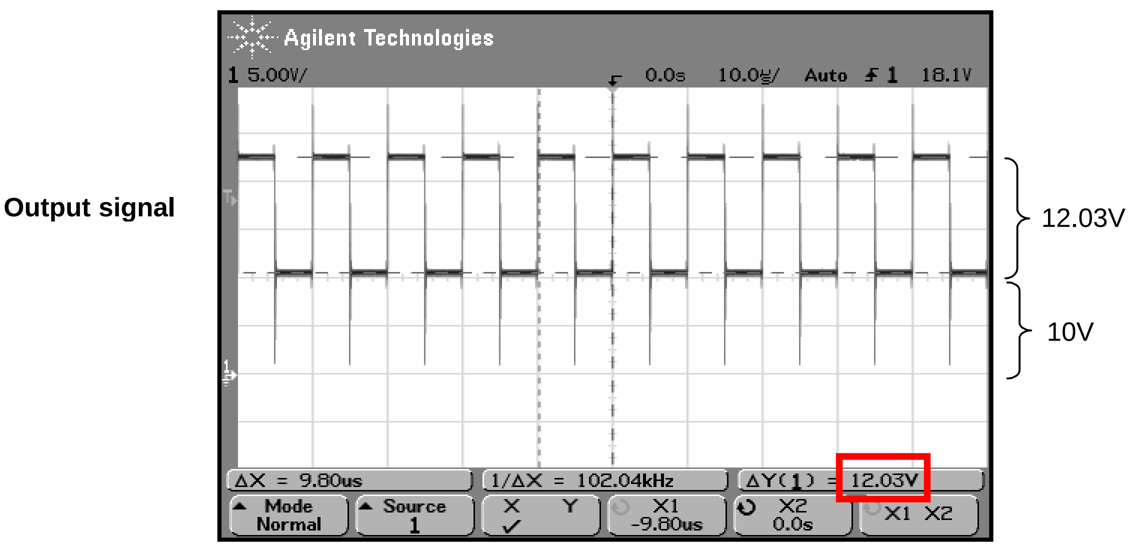

Figure 14 *Control signal & IR2117 output (V_s = 5V)*

4.1.4 Buck Configuration

The buck configuration was set up as shown in Figure 9. The load was a 100Ω resistor and a capacitor was added across it for the standard buck converter configuration. Instead of using the controller to drive the MOSFET switch, the function generator Fluke PM5139 was used to switch the MOSFET on/off. Since the duty cycle was set to 50%, we expected the output voltage to be about half the input voltage. Using the DMM, the voltage and current flowing into the input and output were measured and tabulated in Table 7. The input power, output power and efficiency were calculated as well.

$$P = IV$$
$$Efficiency = \frac{P_{out}}{P_{in}} \times 100\%$$

Input			Output			Efficiency (%)
V_{in} (V)	I_{in} (A)	P_{in} (W)	V_{out} (V)	I_{out} (A)	P_{out} (W)	
40	0.14	5.6	21.56	0.216	4.7	83.2
50	0.174	8.7	27.03	0.27	7.3	83.8
60	0.206	12.4	32.5	0.32	10.4	84.1
70	0.238	16.7	37.5	0.371	13.9	83.5

Table 7 *Buck Configuration Efficiency (50% duty cycle)*

The efficiency was plotted over the range of input voltages in Figure 15. The average efficiency was found to be **83.7%.**

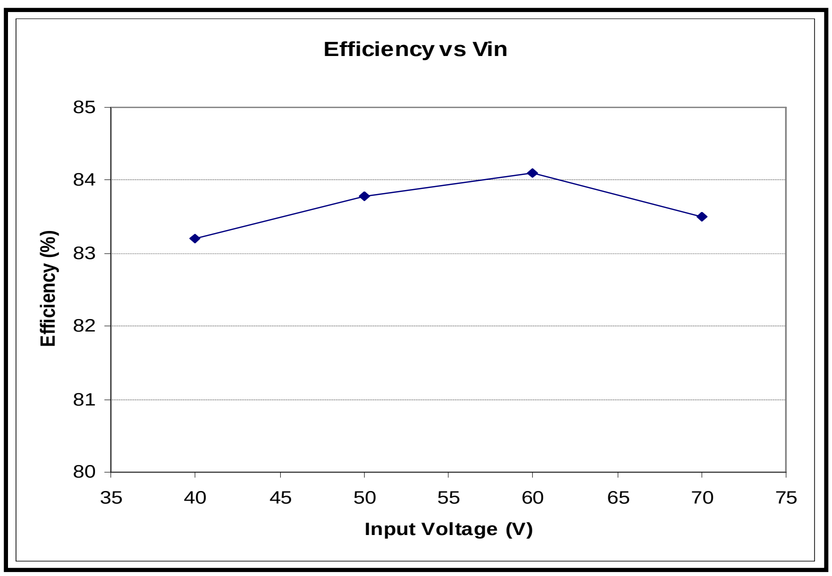

Figure 15 *Efficiency over input voltages*

4.1.5 Overall Circuit

We combined the 4 components together and tested it. The battery load was simulated with a 100Ω resistor and a 5V DC supply. The input voltage was increased from 40V to 70V. We measured the currents and voltages at the input and output. Subsequently, we calculated the input and output powers and the overall efficiency. These efficiency values were rated at the controller's maximum duty cycle of 82.8%. The results are shown in Table 8.

Input			Output			Efficiency (%)
V_{in} (V)	I_{in} (A)	P_{in} (W)	V_{out} (V)	I_{out} (A)	P_{out} (W)	
40	0.315	12.6	30.6	0.306	9.36	**74.3**
50	0.418	20.9	40.4	0.404	16.3	**78**
60	0.477	28.62	46.8	0.468	21.9	**76.5**
70	0.55	38.5	54.7	0.547	29.9	**77.7**

Table 8 *Overall Efficiency (80% duty cycle)*

The overall efficiency was plotted over input voltages and shown in Figure 16. The average efficiency was found to be 76.6%.

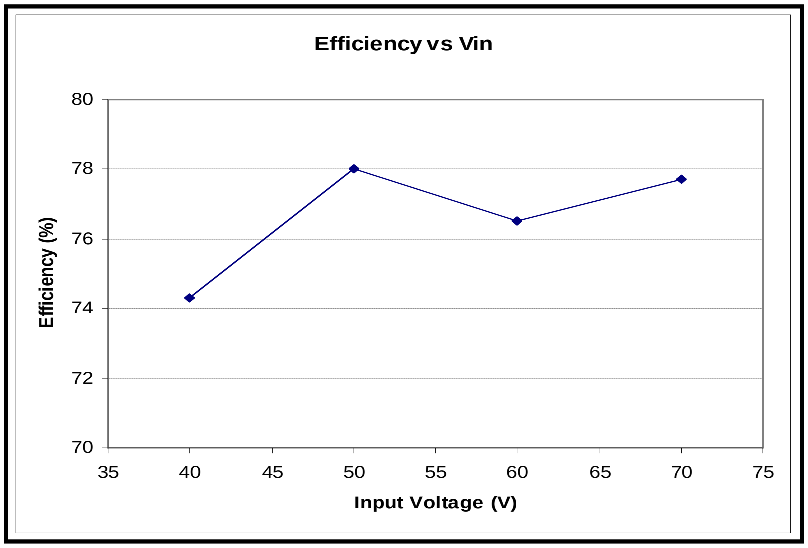

Figure 16 *Overall efficiency over input range*

4.2 Conclusions

Our overall buck converter worked successfully with the simulated battery load. We obtained 83.6% and 76.6% efficiencies for duty cycles of 50% and 80% respectively. Therefore, we managed to achieve our minimum efficiency goal of 65%.

5. COST ANALYSIS

5.1 Parts

Part Description	Quantity	Estimated Unit Cost ($)	Total ($)
MOSFET (FDP3651U)	1	2.32	2.32
Schottky Diode (MBR16100CTG)	1	1.40	1.40
Controller/Battery Monitor (BQ2031)	1	2.80	2.80
Zener diode (1N4733A, 1N4750A)	2	0.30	0.30
12V regulator (LM340)	1	1.74	1.74
IR2117 Driver	1	3.36	3.36
MIC4420 Driver	1	1.63	1.63
Common parts (capacitors, resistors, inductors etc)	Few	0.30	3.00
Total			**16.55**

5.2 Labor

Mark: ($30/hour)(2.5)(80 hours) = $6000
Joel: ($30/hour)(2.5)(80 hours) = $6000
Qian: ($30/hour)(2.5)(80 hours) = $6000

Labor total: ($6000)(3) = $18,000

Grand Total:

Labor + Parts = $18,000 + $16.55 = 18,016.55

6. CONCLUSION

Our overall circuit met the minimum efficiency of 65% for the voltage range of interest. We achieved 83.6% and 76.6% efficiencies for duty cycles of 50% and 80% respectively. A group doing a similar project in Spring 2006 only achieved an average efficiency of 8% [12]. We are able to obtain a higher efficiency by choosing more efficient components and ensuring minimum use of discrete devices. Furthermore, we added features, such as dynamic charging, battery monitoring and informative LED display, which are not present in the project done in Spring 2006 [12]. We also managed to complete the project at a lower cost.

Uncertainties/ Future Work

The next step is to test our circuit on an actual battery. We have to determine if the converter operates correctly via the LEDs, output voltages and currents. Since we are unable to get hold a battery in time for testing, this uncertainty would be documented and made known to EWB.

Heat sinking

Proper heat sinking assists high power devices dissipate heat more efficiently and increase their durability. Since we expect the MOSFET switch, freewheeling diode and 12V regulator to dissipate significant power, we plan to use heat sinks on them. Furthermore, since all three components have the same TO-220 packaging, we can use the same kind of heat sink for them. After considering their junction-to-ambient and junction-to-case thermal resistances, we plan to use three 591202B03100 components (Appendix B), which can be clipped on the TO-220 package.

Ethical Issues

One ethical issue is safety. To protect the user and the device from sudden current surges, fuses are used. However, the disadvantage is that the user has to manually replace the fuses when they blow. Also diodes are placed to ensure that the DC current flows in only one direction.

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- ECE Shop & Store Staff

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