Cordless Electric Nail Gun

Design Review
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TABLE OF CONTENTS

Introduction

1. Title: Cordless Electric nail gun

1.1. Abstract

The most common methods of implementing a nail gun have been by using use batteries and electric motors, combustible gas charges or pneumatically with compressed air. Each of these types of nail guns has their disadvantages. The nail gun from the electric motor is found to be very bulky and heavy. Meanwhile, the pneumatic nail gun consists of extra accessories which make it very hefty and expensive. The explosive gas charge nail guns require regular maintenance and also needs a battery to function. It is evident how much inconvenience each of these nail guns can cause the user. It would be so much easier if we had a battery powered cordless nail gun.

The main goal of the project is to develop the drive mechanism that converts rotational energy from a battery powered open frame motor to translational energy to drive a fastener through a wood substrate. The rotational energy of the motor will be used to compress the spring. The design solution aims to deliver approximately 40 J to the fastener.

1.2. Features

- The nail gun will operate by a rechargeable battery source, making it portable.
- Since the nailer will run on a battery source, a low cost and low powered DC motor controller is to be designed.
- Display that informs user when battery requires charging.
- Control circuit involves circuit breaker protection.

1.3. Benefits

- The rechargeable battery makes the nailer portable. User does not have to buy combustion liquid every time like in the combustion nailer.
- The current electric nailers available in the market use gas compression. The compression chamber makes the nailer heavy. We expect our design to be lighter and cheaper than other designs.
- Thus cost effective and user friendly.
- Eco-Friendly. Does not emit any waste gases like the current combustion nailer.

2. Design:

2.1. Block Diagram:

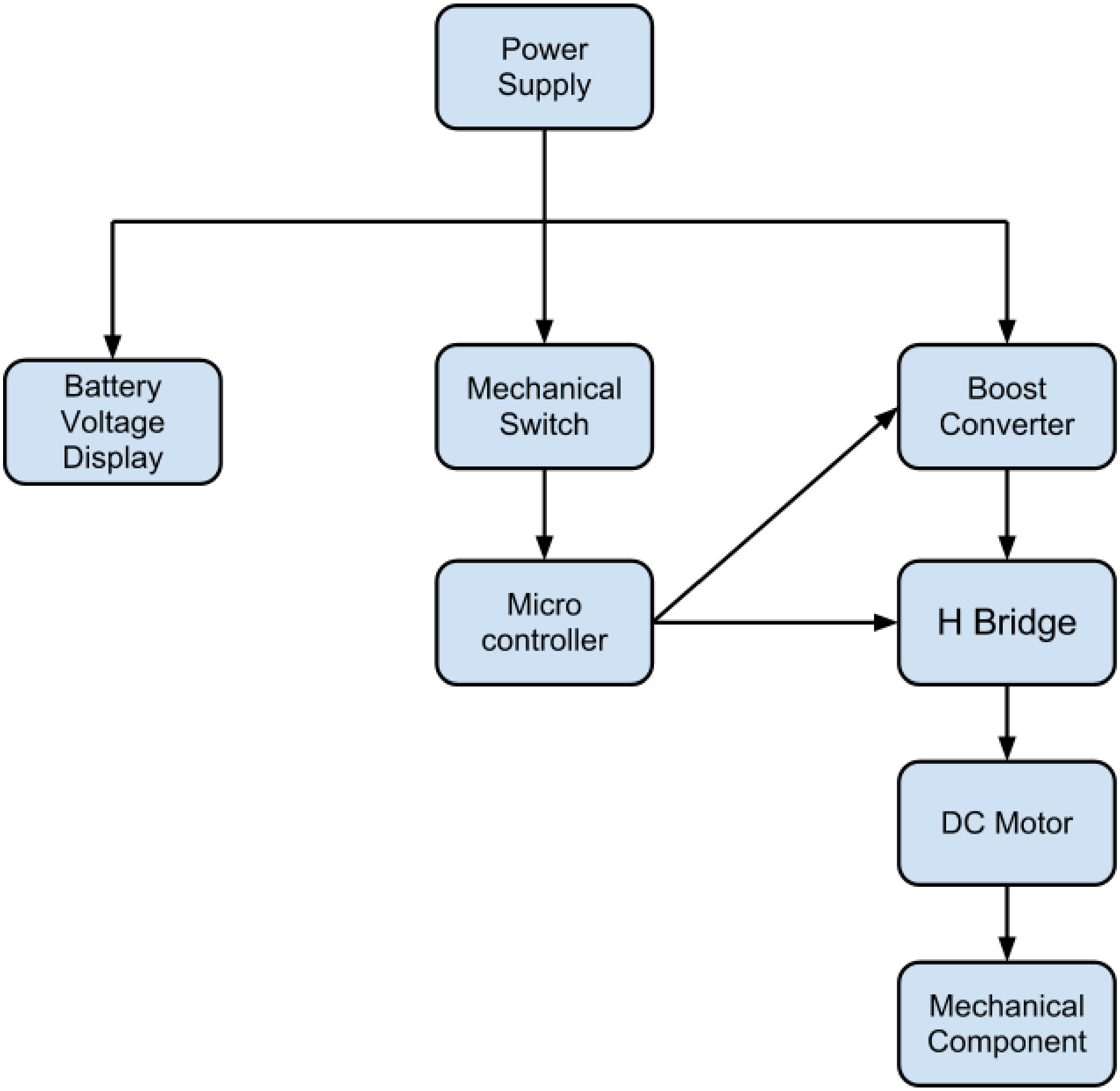

Fig 1. Block Diagram

3. <u>Block Descriptions:</u>

3.1. Power Supply:

The input source is taken directly from a conventional 12V lead-acid battery. The reserve capacity of the battery is fully dependent on the quality and cranking amps. The output to the boost converter is 9-15 Vdc with a current range of 56 amps depending on the speed setting.

3.2. Boost Converter

The boost converter, or step-up converter, is a switching dc/dc converter that produces an output voltage greater than the source. As of now, our input source voltage is 12 V. We are assuming that the least voltage input is about 10V and the maximum boosted voltage output will be about 15V. The boost converter design consists of four main elements: Inductor, MOSFET, MOSFET Control, and Diode. A general layout of the boost converter in the below figure:

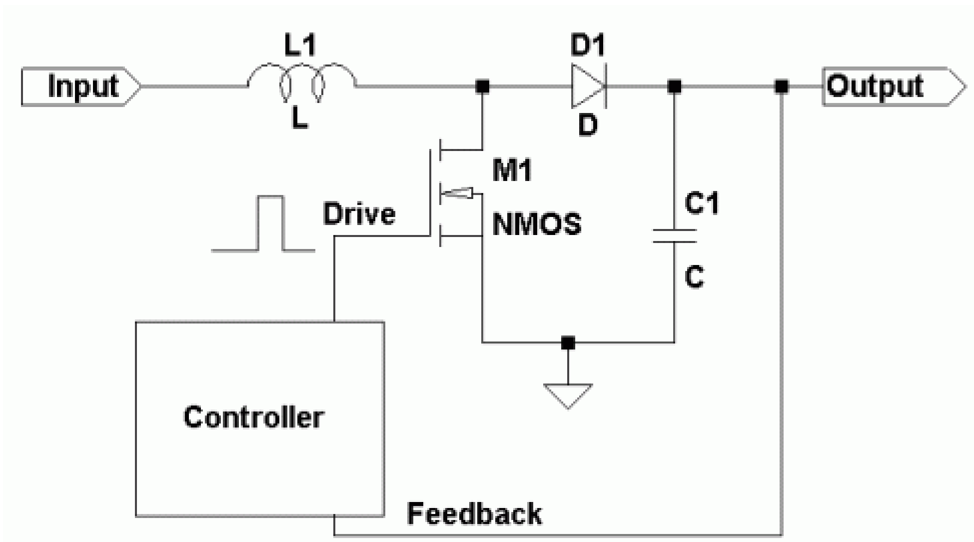

Fig 2. General Boost Converter Design

3.2a Inductor

One of the major components of the boost converter is the design of the inductor.We chose the core based on its ability to handle high current.There will be a lot of saturation and hysteresis at such high current levels. After doing some research,we decided to use a T225-26 core for its permeability and size.With a frequency of 30 Khz,the inductance came out to be close to a value of 60 microH. WE used this frequency because the hysteresis losses are higher for high frequencies.

3.2b MOSFET

We decided to use the STB200NF04 by STM.The ratings for this MOSFET consist of 120A, 40V and a minimal on state resistance of 3.7mΩ The NFET has a duty cycle ranging up to approximately 33% that was determined by the Unitrode gate drive control chip, UC3825.

3.3. Control

The control portion of the circuit is mainly responsible for regulating the input voltage to the motor. The main control unit of our circuit is the microcontroller.It governs the entire voltage conversion and motor rotation The user sets the maximum input voltage to the motor which in turn sets the duty ratio for the boost converter.The control unit also adjusts the inputs to the MOSFETs of the H-Bridge to vary the motor direction and has built in dead time to assure that all four MOSFETs are not on at the same time within the H-Bridge. A potentiometer is utilized within the control to adjust the input voltage to the MOSFETs by adjusting the duty cycle.

3.4. Dynamic Braking

Before the H-Bridge, a resistor and a switch will be placed in parallel. When current flows between the H-Bridge and boost converter the switch closes. This braking resistor is provided to protect the boost converter from any reverse power flow.

3.5. H-Bridge

The H-Bridge can be used to either change the direction of the motor or stop it entirely. The control unit adjusts the inputs to the MOSFETs to accommodate the user defined action.The mosfets for the H-bridge were chosen based on their low resistance. The low resistance will allow the motor to interact with the control unit in a more timely and efficient manner

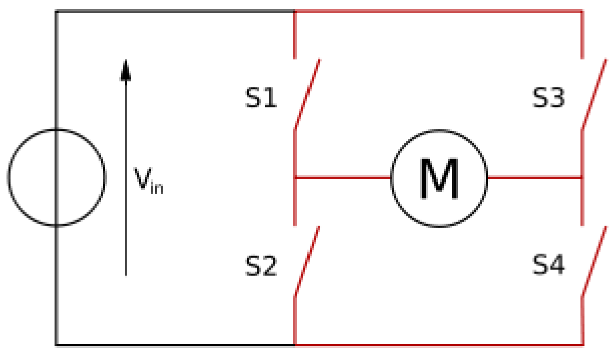

Fig 3. Basic H-Bridge circuit

3.6. DC Motor and Mechanical Component:

We will be using a basic dc motor which is capable of taking loads up to a peak of 500W for one minute and loads with a continuous amount of 250W. It receives the output voltage from the boost converter. The motor is used to drive the gear and thus mechanical component of the nail gun. A spring will be attached to the piston. The piston will be attached to the gear as shown below. The piston will press compress the spring when the gear is driven clockwise. The stored potential energy of the spring will be used to fasten the nail. Below is the rough diagram the idea:

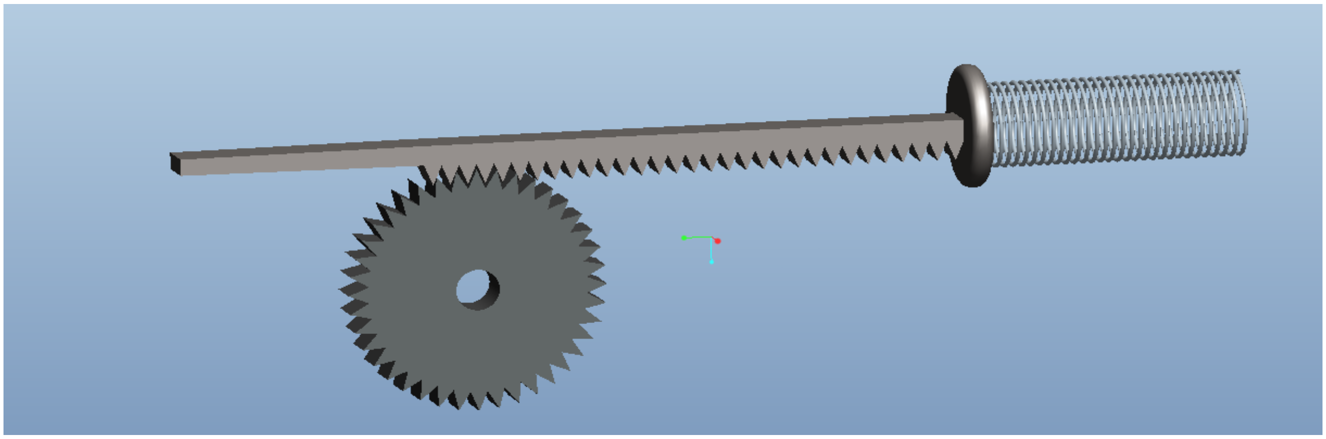

Fig 4. Collapsed Spring

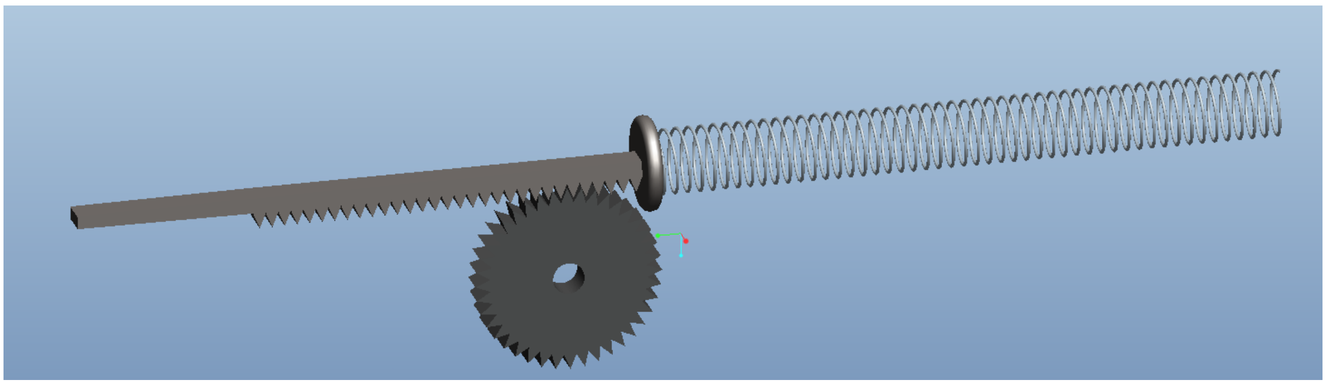

Fig 5. Expanded Spring

3.7. Battery Voltage Display Circuit

As the battery continues to discharge with each shot, we would like to know when the battery is getting low.This circuit consists of 3 LED’s which will light up for specific voltages. If the battery is full, then we expect the green LED (D1) to light up and if the battery goes below a certain level then we intend for the red LED to light up(D3).If the battery is between the two threshold voltages,then we intend for the yellow LED(D2) to light up.

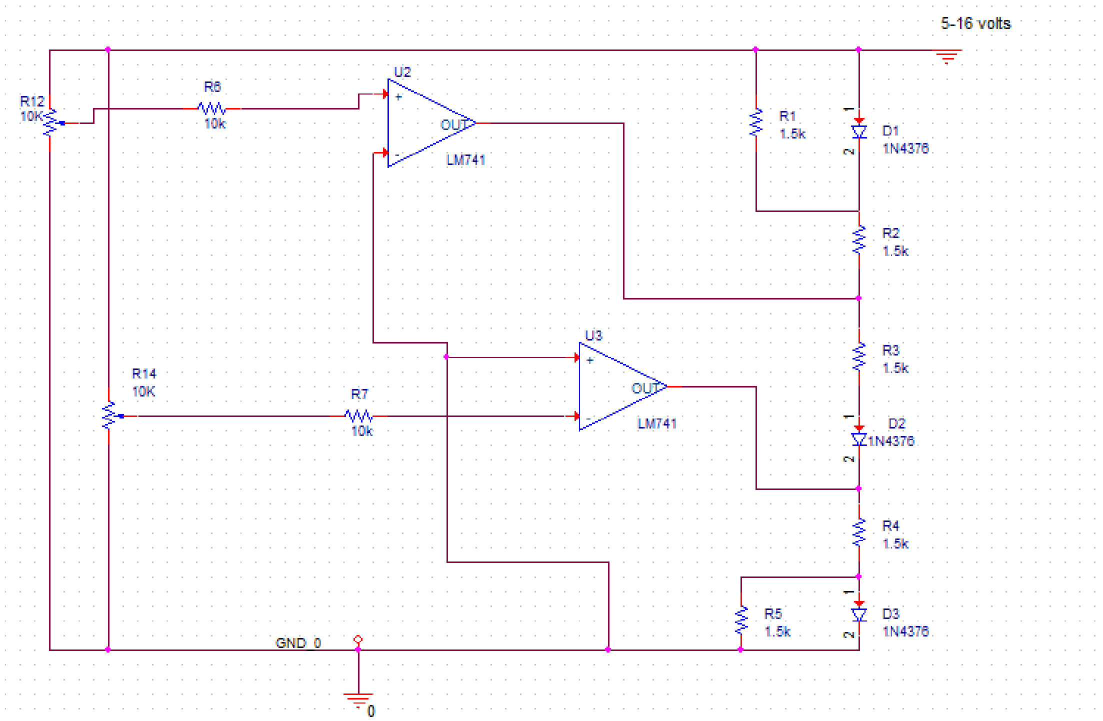

Fig 6. Battery Voltage Display Circuit

4. <u>Design Schematic</u>

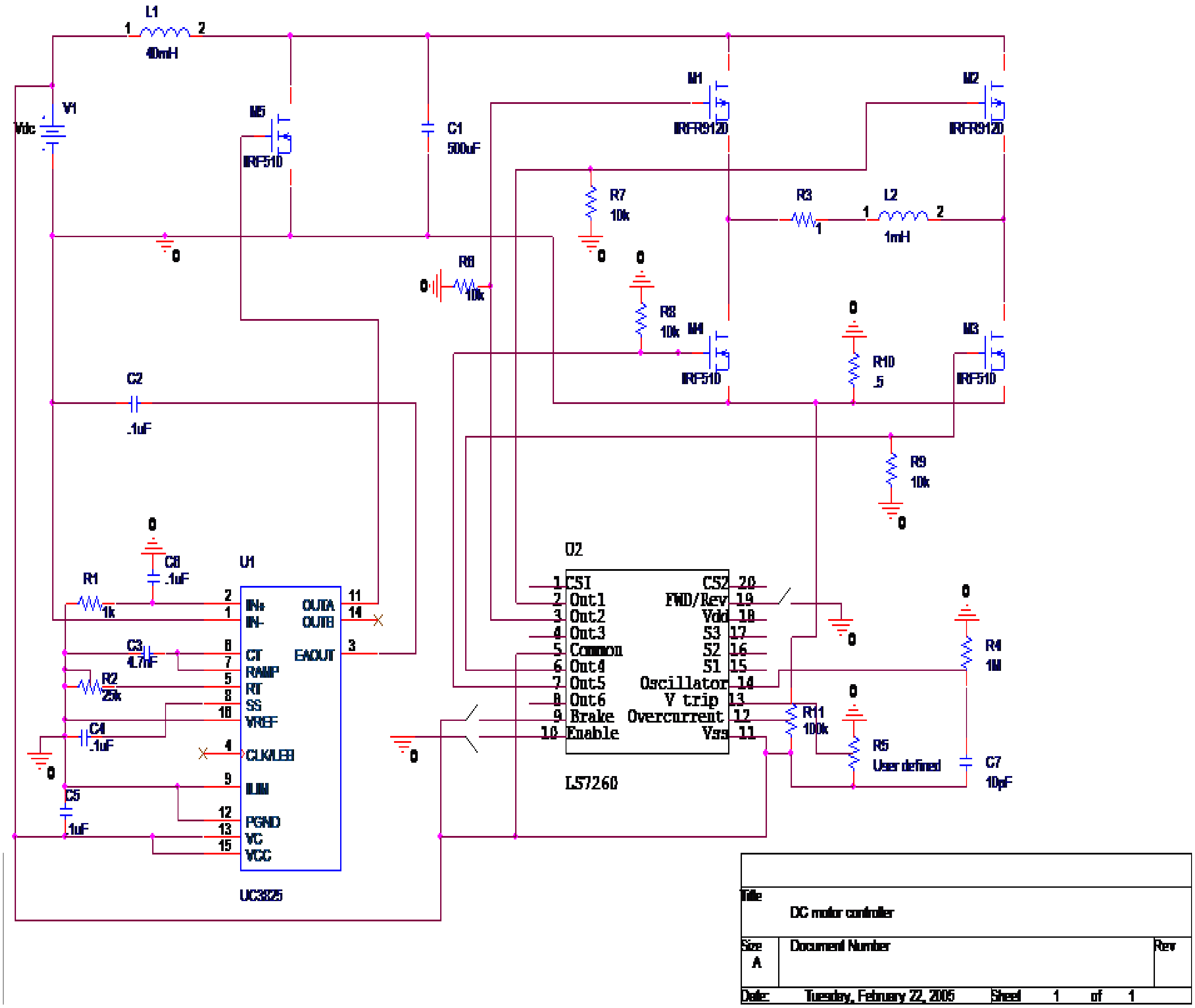

Fig 6. DC Motor Controller Schematic

5. Design Verification

5.1. Requirements and Testing

Performance Requirements	Verification

Power Supply: Supply constant and enough voltage to power to the circuit. All the individual components power on and work consistently	1. A load of 200 W will be connected to the batter to verify the discharge time. The required discharge time is 6 minutes. We wish to shoot apprximately 360 nails in one complete battery discharge.
2.Mechanical Switch: Ensure that switch is properly connected	We can test this by using a multimeter to detect current flow across a switch.
2.Battery Monitoring Display Circuit. The battery monitoring circuit consists of LEDs that need to flash when the battery reaches a certain voltage. The green LED flashes when battery is 12 volts, the red LED flashes when the battery is 11 volts and the the yellow one will flash when the voltage is in between 11 and 12 volts.	The battery is 40 percent when red, 40 to 70 yelo 70 to 100 green. Once the circuit has been assembled,we will apply different voltage sources to the circuit and we should see the LED's reaction to the applied voltage.The procedure is as follows · Set power supply to 12Vdc · The green Led should flash.If it does not flash,then use an oscilloscope to measure the diode voltage. ·This will determine if the LED is faulty. ·We change the power supply and see if the respective LED will light up.If it does not light up,then we repeat the above procedure with the oscilloscope.

3. Boost Converter: The boost converter will increase the voltage from the 12 volt power supply to the required 15 volts for the motor.	The output voltage of the boost converter will be tested by using batteries with varying input voltages(10-15 volts).The procedure to test the boost converter would be as follows · Set power supply to 10Vdc · Measure and record output of the converter using an oscilloscope · Increase power supply voltage incrementally to 15Vdc while keeping a record of the output voltage ·The converter should maintain a set voltage level with minimal ripple of about 5% to satisfy the requirements. - Check the duty cycle based o the input ad output olateges. Ex: If the input voltage is 10V and output voltage is 15V, then the duty cycle should be 50 percent. The output of the duty cycle from the PWM will be connected to the oscilloscope.
4. H bridge: This will control the direction of the motor and cause the motor to brake immediately.	We want to test the performance of h-bridge by hooking them up to the lab equipment and obtaining information. We test the H-Bridge to see if the voltages are as expected for the relevant situations: forward, reverse, braking. This would be done with the assistance of the oscilloscope.Once it is tested alone connect to motor and see if the motor responds as expected for those states.

5. PIC	1. The PWM will vary its duty cycle based on the output from boost converter. Hence different voltages will be supplied to PWM which will be measured and the corresponding duty cycle will be seen if it is accurate or not. 2. The time taken to stabilize the voltage will also be measured. The time taken to stabilize should not be more than 0.2 seconds.This will be done by setting measuring the duty cycle on the oscilloscope. 3.
5. Motor: The motor should rotate at 240 rpm and with a torque rating of 500 inches pounds.	A tachometer will be used to measure to the number of rotations of the motor and the axle. The motor should reach 240rpm witha load of 200W. It should provide 500 inches pound of Torque.

6. **Tolerance Analysis:**

1. The most part of the circuit is making sure that the boost converter creates a reliable and steady output voltage of 24 volts.We need to ensure that there is an error of approximately 2%.This means that we will need an output voltage that does not differ by more than 2% for a certain period of time.. We will have to do rigorous testing to ensure that the necessary voltage and power is being supplied to the DC motor.With the assistance of a variable power supply, we measure the output voltage and test it. The voltage can be measured with a voltmeter or an oscilloscope. This process is outlined above in the testing section. We will test it for one battery discharge cycle or 360 nails being shot.

2. The speed of the microprocessor's data analysis and motor control is vital to the overall response time of the system.The microprocessor must respond to the changes in voltage which could signify the change in direction of the motor or the halting of the motor.All of this should happen with 1-2 seconds of the voltage being changed.We will test this using a varying voltage source and measuring the output of the microcontroller and its respective pins. We must program the microprocessor in the most efficient way possible in order to keep the response time to a minimum

3. Another concern about our design is the fact that the batteries should create a voltage that is very close to the threshold voltage drive the nail. It is imperative that the battery generates enough energy to send the nail out of the gun fast enough to penetrate the wooden surface. We must test the battery to motor circuit and check to see if the motor will spin at the appropriate speed to eventually drive the nail through the mechanical design (provided by ME 470 Students).

7. Cost and Schedule

7.1 Labor Costs

Team Member	**Dream Hourly Wage ($)**	**Overhead(* 2.5) ($)**	**Total Time Spent(hours)**	**Total Cost ($)**

Nithin Reddy	30	75	144	10800
Shaik Mohammad Farooq	30	75	144	10800

			Total	**20600**

Note: Total hours = 12 weeks of work at 12 hours/week.

7.2 <u>Cost of Parts</u>

Part #	Manufacturer	Description	Subckt	Price	#	Total

P5155-ND	Panasonic	470 uF cap	Boost	$0.45	1	$0.45
STB80PF55	STM	PMOSFET	H-B	$3.12	2	$6.24

STB200NF04	STM	NMOSFET	Both	$2.40	3	$7.20
MBR3060L	Gen. Semi.	Diode	Boost	$1.25	1	$1.25

UC3825	TI	Control chip	Boost	$1.60	1	$1.60
LS7260	LSI	Control chip	H-B	$3.05	1	$3.05

75-56AQ10	Vishay	10 pf cap	H-B	$0.43	1	$0.43
C0603C104J4RACTU	Kemet	0.1 uf cap	Boost	$0.32	4	$1.28

9C08052A1002JLHFT	Yageo	10 k res	H-B	$0.32	4	$1.28
P1.00KFCT-ND	Panasonic	1 k res	Boost	$1.67	1	$1.67

140-XAL450V4.7	Xicon	4.7 uF cap	Boost	$1.17	1	$1.17
270X232A253B1A1	CTS	25 k res	Boost	$2.71	1	$2.71

P100KFCT-ND	Panasonic	100 k res	H-B	$0.89	1	$0.89
CCF-07	Vishay	1 M res	H-B	$1.43	1	$1.43

P44229-UG	Dexter	Inductor core	Boost	$5.00	1	$5.00
	Radio Shack	PCB		$3.29	2	$6.58

Y92-A150N	Omron	Heat sink		$15	1	$15.00
3352W-104-ND	Bourns	Potentiometer		$0.60	4	$2.40

	Radio Shack	Switches	H-B	$3.00	3	$9.00
	Superbright LED	LED		$1.00	3	$3.00

	Radioshack	1.5k		$1.19	5	5.95
Total						$56.57

Total Cost = Parts + Labor = $56.57 + $20, 600 = $20, 656.57

8. Schedule:

Date	Responsibility	Student
9/19	Proposal	Nithin Reddy

9/19	Proposal	Shaik Mohammad Farooq
9/26	Learn about microcontroller programming for circuit	Nithin Reddy

9/26	Learn about microcontroller programming for circuit	Shaik Mohammad Farooq
10/3	Design and simulate the circuit for IR sensor	Nithin Reddy

10/3	Design the working battery to motor circuit.	Shaik Mohammad Farooq
10/10	Buy Parts/Assist with design	Nithin Reddy

10/ 10	Design battery monitoring circuit.	Shaik Mohammad Farooq
10/ 17	Build IR sensor circuit	Nithin Reddy

10/ 17	Build battery to motor circuit	Shaik Mohammad Farooq
10/ 24	Test IR sensor circuit	Nithin Reddy

10/ 24	Test Battery to motor circuit	Shaik Mohammad Farooq
10/ 31	Build Battery monitoring circuit.	Nithin Reddy

10/31	Build battery monitoring circuit	Shaik Mohammad Farooq
11/7	Mock-Up demos	Nithin Reddy

11/7	Mock-Up demos	Shaik Mohammad Farooq
11/ 14	Work on Presentation	Nithin Reddy

11/ 14	Look for demo locations	Shaik Mohammad Farooq
11/ 21	Thanksgiving	Nithin Reddy

11/ 21	Thanksgiving	Shaik Mohammad Farooq
11/ 28	Testing and Tune Ups	Nithin Reddy

11/ 28	Testing and Tune Ups	Shaik Mohammad Farooq
12/2	Final Demo	Nithin Reddy

12/2	Final Demo	Shaik Mohammad Farooq

9. <u>Citations</u>

http://www.electronicecircuits.com/electronic-circuits/battery-charge-nominal-discharge-indicator-circuit

http://electronicdesign.com/article/power/cascode-configuration-removes-miller-effect-boosts

http://zentronics.wordpress.com/tag/h-bridge-simulation/

http://www.micromo.com/Micromo/HighPower/GNM_4125.pdf

10. Ethics Discussion

"to accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment."

Our group is aware of the safety hazards involved with the nail gun. The speed with which the nail is shot is not enough to cause severe injury, but can cause minor ones. As of now, we will not be making a complete model of the nailer so there will not be any risk involved. However the nailer has a mechanical safety mechanism which allows a person to shoot the nail only when the nailer is pressed down against the surface. Moreover, our sponsors Passload have provided us the option of testing the nail gun, if made, in their testing center where every safety measure will be taken.

“to be honest and realistic in stating claims or estimates based on available data”
The most important factor is the accuracy of the information obtained from the system. We will be honest and will not falsify the data acquired from our test procedures.

“to improve the understanding of technology; its appropriate application, and potential consequences”
After this project, we will have learned a great deal about various real-world industrial systems such as the boost converter control system. This will improve our understanding of these technologies and their applications, and also improve our technical competence, as directed in the 5th and 6th codes of the IEEE Code of Ethics:

“to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others”
Furthermore, while working on the project, we will build an environment that promote engineer professionalism, which welcomes constructive and honest criticisms, acknowledges errors, assists peer workers with their professional and academic developments, and credits appropriate contributions, as cited in the 9th and 10th codes of the IEEE Code of Ethics:

PWM Programming for boost converter:

```
int batPin = 0;
int motorPin = 1;
int sensorValue = 2;
int switchPin = 3;
int sToB = 3;
int bToM = 5;
int bToH = 6;
int switchVal = 0;
int batVal = 0;
int dutyCycle= 130;
int count = 0;
int motorVal= 0;

void setup()
{
```

```
  pinMode(sToB,OUTPUT);
  pinMode(bToM, OUTPUT);
  pinMode(bToH, OUTPUT);
  setPwmFrequency(6,62500);

}


void loop()
{

  batVal = analogRead(batPin);
  if(batVal >= 210)
    analogWrite(sToB,0);
  else
    analogWrite(sToB,170);

  switchVal = analogRead(switchPin);
  batVal = analogRead(batPin);
  if(switchVal >= 120 && batVal >=190)
  {
   analogWrite(bToH,170);
   delay(1000); // otherwise use while and count
   batVal = analogRead(batPin);
   motorVal = analogRead(motorPin);
   if(motorVal < 240)
     dutyCycle = dutyCycle+5;
   analogWrite(bToM, dutyCycle);
  }
  else
  {
   analogWrite(bToH, 0);
   analogWrite(bToM, 0);
  }

}


void setPwmFrequency(int pin, int divisor) {
   byte mode;
   if(pin == 5 || pin == 6 || pin == 9 || pin == 10) {
     switch(divisor) {
       case 1: mode = 0x01; break;
       case 8: mode = 0x02; break;
       case 64: mode = 0x03; break;
       case 256: mode = 0x04; break;
```

```
      case 1024: mode = 0x05; break;
      default: return;
    }
    if(pin == 5 || pin == 6) {
      TCCR0B = TCCR0B & 0b11111000 | mode;
    } else {
      TCCR1B = TCCR1B & 0b11111000 | mode;
    }
  } else if(pin == 3 || pin == 11) {
    switch(divisor) {
      case 1: mode = 0x01; break;
      case 8: mode = 0x02; break;
      case 32: mode = 0x03; break;
      case 64: mode = 0x04; break;
      case 128: mode = 0x05; break;
      case 256: mode = 0x06; break;
      case 1024: mode = 0x7; break;
      default: return;
    }
    TCCR2B = TCCR2B & 0b11111000 | mode;
  }
}
```