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Design of a Cordless Lawn Mower with Rechargeable System

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ABSTRACT: A cordless lawn mower with rechargeable system designed and fabricated. It was designed to recharge itself when cutting the grass. This was done by connecting an alternator to the Direct Current (D. C.) motor with the aid of pulley to transmit the speed of D.C. motor to recharge the battery used. The depth of discharge (DOD) of a battery determined the fraction of power that was withdrawn from the battery. The DOD of a battery as given by the manufacturer was 25%, and signified that only 25% of the battery capacity was available for use by the load. Charging a lead acid battery (dry cell) was done using the developed circuit capable of replenishing the depleted supply of energy that the battery lost during usage. The developed lawn mower had operation efficiency of 84.6%, and is sustainably cordless and rechargeable.

KEYWORDS - Lawnmower, Cordless, Rechargeable System, Energy Sustainability

I. INTRODUCTION

The aesthetic value of his environment is as important as food and shelter to the modern man. In general, grasses are found to survive in a variety of conditions and thus the need to curtail their growth in order to enhance the beauty of our habitat environment. As man evolved intellectually, grass cutting inevitably developed to an art. As technology advanced grass cutting developed, away from use of machetes, hoes and cutlasses to motorized grass cutters. Technology had continued to advance and better techniques of grass cutting has been invented and constantly improved upon. This gave birth to the invention of lawn mower (Victor and Verns, 2003; Mary 2010; Susan, 2011). A lawn mower is a machine used for cutting grass or lawns. A lawn is any area of grass; mostly tough grass which is neatly cut like in a private garden or a public park. In the past, cutting of grasses in the schools, sports track, or field, industries hotels, public center, etc. was done by cutlass. This method of manual cutting is time consuming as it is human effort that is needed for cutting. There was also inaccuracy in cutting level using the manual cutting system. Apart from drudgery in these old methods of cutting there is also risk of accident (Costilla and Bishai, 2006). Therefore, lawn mower helps in cutting of grasses to equal height or level for speedy cutting. In study's lawn mower, the accident is rare, labour and personnel needed for operation are reduced with great portion of land easily be cut. Again, to encourage beauty in our environment this study considered keeping our environment clean by mitigating poisonous emissions of the old designs (Brian, 1993; Hessayon, 2007; Chery, 2011; 2014). We decided to fabricate a self-power cordless lawn mower to overcome the problem of electricity and as such this our lawn mower can be used everywhere even where there is no electricity. Early before now, the peasant farmer depends on the hoe and cutlass for practically all farm operations. These farm operations depend entirely on the energy of the farmer using the tools which he has at his disposal. Later, came the lawn mowers in different types and generations to the generation of cordless lawn mowers (Okoro, 2010; Mary 2010; Kinnander, 2012; Lucas, 1999; Kepner et al., 1980; Jeremy, 2005; Jason, 2002; Hollis, 2005; Hessay 2007; Everett, 1869; Dakogo et al, 2007; Rodney, 1986), but there is still problem of run out of energy from the accumulator (Brian, 1993; Bill, 1997; Costilla and Bishai; 2006; Cheryl 2011; 2014). The challenge of bush clearing with reduced hazards and sustainable energy usage that is confronting the farmers globally triggered this study for providing lasting solution through development of self-rechargeable cordless lawnmower. In design realm, lawn mowers are classified as cylinder or reel mowers, rotary mowers, gasoline (petrol) mowers, electric mowers, hand mowers, hover mowers, robotic mowers, tractor pulled mowers, riding mowers, and mulching mowers (Susan, 2011).

There are scanty efforts towards the design of lawn mower which incorporated both cordless and rechargeable characteristics. This is the challenge this study has addressed.

II. MATERIALS AND METHOD

2.1 Design Analysis

The lawn mower is made up of an induction motor, a battery, an alternator, two blades, and a link mechanism. The power and charging system comprise of an alternator which charges the battery while in operation. The D.C. motor forms the heart of the machine and provides the driving force for the blades. The system is powered by an electrical switch which completes the circuit comprising the induction motor and the battery. The revolving front wheels ensure easy maneuverability whilst a lift system activates the link mechanism with which the height of cut is altered.

2.2 Operation Principle

Electrical energy of the battery is converted to mechanical energy through a set of blades designed to achieve cutting operation. The electric circuit ensures power transfer from the battery to run the D.C. motor, whilst the alternator utilizes the mechanical power to continuously recharge the battery while in operation. The cutting blades tap power from the D.C. motor. When the power switch is on, the electrical energy from the battery powers the motor which in turn actuates both the blades and the alternator shafts. The rotating motion of the alternator shaft generates current to recharge the battery, thereby compensating for the battery discharge. The rotating blades continuously cut the grass as the mower is propelled forward and the height of cut is adjusted by means of the link mechanism via the wheel of the mower (Fig. 1).

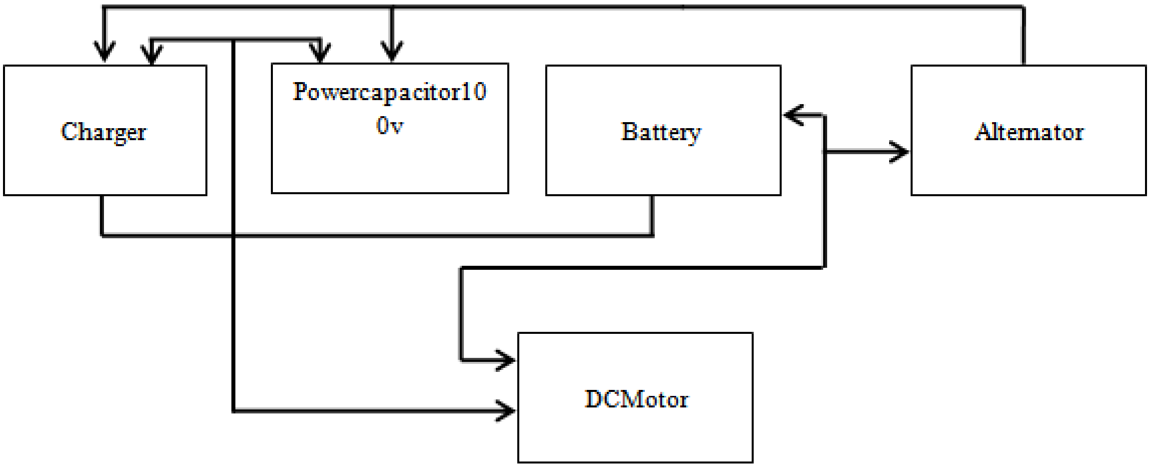


Figure 1. Working Operation Block Diagram

2.3 D.C. Motor Specifications

Established dimensions are**:**

(i) Weight: 7.7oz (218g)
(ii) L: 2.24in (57mm) D: 1.52in (38.5mm)
(iii) Shaft Diameter: 0.12in (3.2mm)
(iv) Shaft Length: 0.3 in (7.6mm)
(v) Mounting holes (2): M3

Established specifications are:

(i) Operating Voltage: (90V Nominal)
(ii) No Load RPM: 1930
(iii) No Load Current: 1.2A
(iv) Stall Torque: 70.55oz-in (498.2mN-m)
(v) Stall Current: 85A
(vi) Kt: 0.83oz-in/A (5.9mN-m/A)
(vii) Kv: 1725 rpm/V
(viii) Efficiency: 70%
(ix) RPM Peak Efficiency: 1725
(x) Current Peak Efficiency: 5A

The rotary mower cuts grass by impacting the blade cutting edge against the grass blades at a very high velocity. This cutting action requires that the blade cutting edge is sharp and rotating at an adequate speed. Three basic requirements for acceptable performance are:

(i) The blade must be straight with sharp cutting edges.
(ii) The blade must have the proper attitude in relation to the ground surface.
(iii) The blade must rotate at the proper speed with an accommodating ground speed to get an acceptable clip.

2.4 Mower Deck and Handle

The deck of an existing lawn mower (which uses petrol engine for power generation) was used as the deck for this project since this project was focusing on the energy conversion of a cordless lawn mower and to carry out a test performance on it.

All the parts of the petrol lawn mower were removed and modifications were made on it to suit the design. The deck and handle that was selected for this design is a Craftsman Professional 88776 with a 190 cc 6 HP Briggs & Stratton engine. This model also includes an electric start which allows the engine to be started using the microcontroller. The front caster wheels were also a necessary option for this design so that the mower will be able to turn easily (Fig. 2).

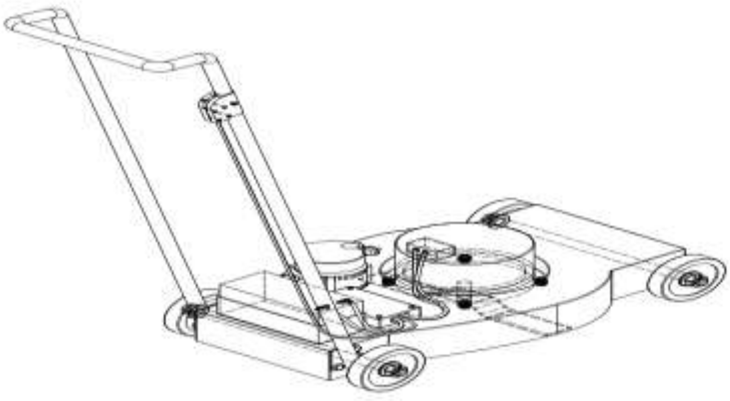


Figure 2. 3D Model of the Mower Deck and Engine

2.5 Selection of Electric Motor

Due to non-availability of wide range of DC motors in the market, a 3/4 hp (559.5 W) having a rotational speed of 1726 rev/min was used. This gives a sufficient torque with a high cutting force with an average blade radius of 210 mm (Atkins, 2005). Force required by cutting blade to shear the grass is given by (Khurmi 2003; 2005; Hall et al., 1980);

$$F = T/R \qquad (1)$$

Where T = blade shaft torque
R =radius of cutting blade but
Blade shaft torque is given by

$$T = P/2\pi N \qquad (2)$$

Where P = power developed by shaft,
T = Torque required; and N = shaft speed Rev/min

2.6 Design of Belt

$$L = \pi/2(D1 + D2) + 2C + (D1 - D2)\ 2/4C \qquad (3)$$

(Khurmi, 2003)

Where,
L = length of drive belt for pulleys 1 and 2
C = Centre distance between the two pulleys, 180 mm

Thus,

$L = 3.142/2\ (120 - 80) + 2(180) + (120 - 80)^2 / 4(80)$
$= 676$ mm

$2.3 \log (T1/T2) = \mu\theta\cos\beta$

$\sin\alpha = (R_1 - R_2) / C$
$= (60 - 40) / 180$
$= 0.1111;$
$\alpha = 6.38^o$

Where,
R_1 and R_2 are radii of pulleys 1 and 2 respectively.

Angle of contact, $\theta = 180^o - 2\alpha = 180^o - 2(6.38)$
$= 167.24^o$
$\theta = 167.24^o (\pi/180)$
$= 2.92$ rad.

$2.3 \log (T1/T2) = \mu\theta\mathrm{cosec}\beta;$

Where,
$\mu = 0.2$ and
$2\beta = 34^o$

Thus,
$T_1/T_2 = 7.379;$
$T_1 = 7.379T_2$
$P = (T_1 - T_2)\ v;$

Where,
P and v are transmitted power and peripheral velocity respectively.

$599 = (T_1 - T_2) \times 10.44$
$T_1 - T_2 = 35.73$ N
$7.379T2 - T2 = 59.36;$
$T_2 = 9.3$N and $T1 = 68.66$N

2.7 Slip of the Belt

$\frac{N1}{N2} = \frac{(D1+T)}{(D2+T)} (1- \frac{S}{100})$ (Khurmi and Gupta 2005) (4)

1725/2589 = (120 +6.50)/(80 + 6.5) x (1- s/100)

S = 2.5%

Centrifugal tension in the belt is given by;

$T_c = mv^2$

Where,

m = mass of belt per meter, and

v = peripheral velocity.

v = Πdn/60

v= (3.142 x 1726 x 120)/60

=10.84 m/s

mass of the belt per meter length

m = area x length x density

M= ℓ x L x A (Khurmi and Gupta 2005) (5)

ℓ = density of rubber belt $1140kgM^{-3}$

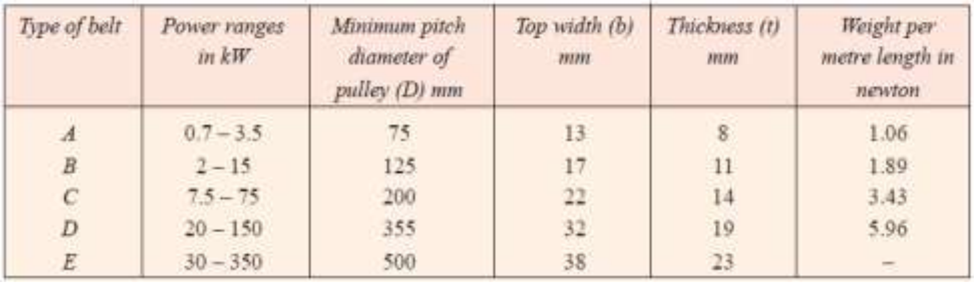
L = length of the rubber belt

A = cross sectional area of the rubber belt (0.000567)

T_c = (1140 x 1 x 0.000567) kg/m x 10.44^2 = 70.45N

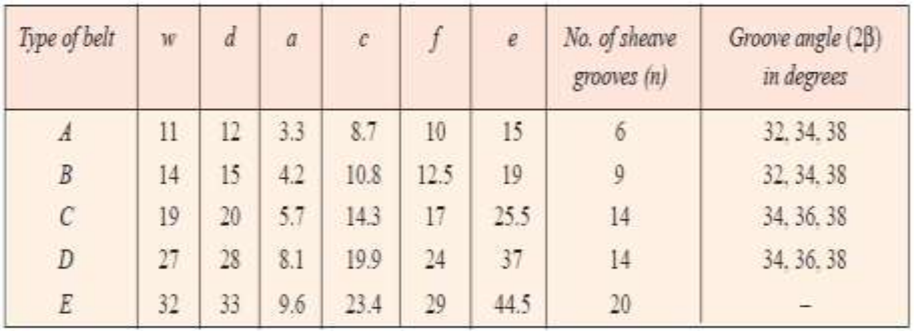
Where face width (b) = (n – 1)e + 2f (Tables 1, 2, and 3).

Table 1: Dimension of Standard V-belts According to IS:2494 - 1974



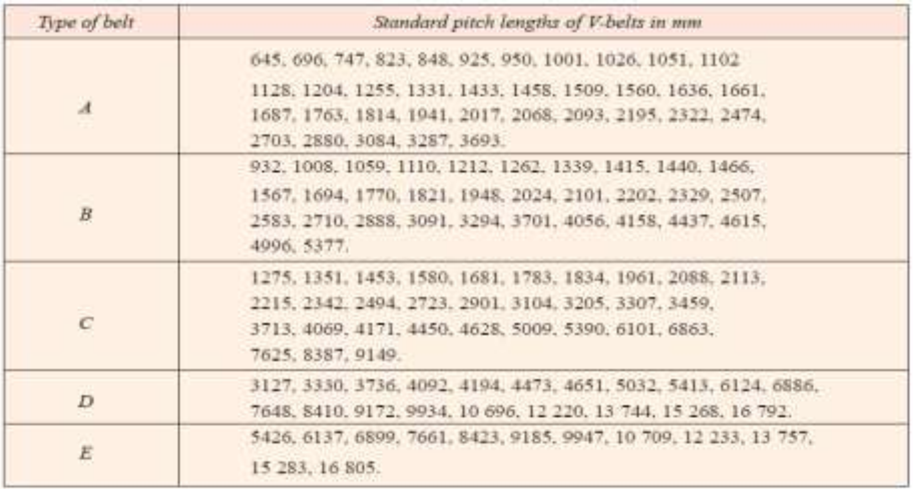
Type of belt	Power ranges in kW	Minimum pitch diameter of pulley (D) mm	Top width (b) mm	Thickness (t) mm	Weight per metre length in newton
A	0.7 – 3.5	75	13	8	1.06
B	2 – 15	125	17	11	1.89
C	7.5 – 75	200	22	14	3.43
D	20 – 150	355	32	19	5.96
E	30 – 350	500	38	23	–

Table 2: Dimension of Standard V – grooved Pulleys According to IS: 2494 - 1974



Type of belt	w	d	a	c	f	e	No. of sheave grooves (n)	Groove angle (2β) in degrees
A	11	12	3.3	8.7	10	15	6	32, 34, 38
B	14	15	4.2	10.8	12.5	19	9	32, 34, 38
C	19	20	5.7	14.3	17	25.5	14	34, 36, 38
D	27	28	8.1	19.9	24	37	14	34, 36, 38
E	32	33	9.6	23.4	29	44.5	20	–

Table 3: Standard Pitch Lengths of V-belts in mm According to IS: 2494 - 1974

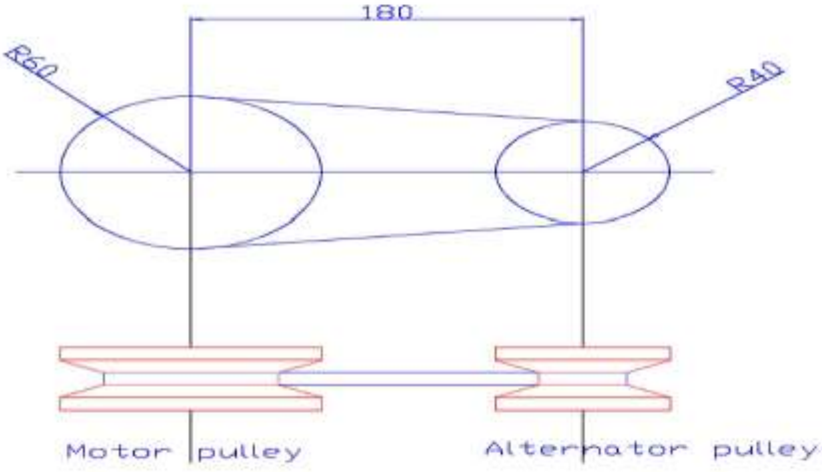


Type of belt	Standard pitch lengths of V-belts in mm
A	645, 696, 747, 823, 848, 925, 950, 1001, 1026, 1051, 1102 1128, 1204, 1255, 1331, 1433, 1458, 1509, 1560, 1636, 1661, 1687, 1763, 1814, 1941, 2017, 2068, 2093, 2195, 2322, 2474, 2703, 2880, 3084, 3287, 3693.
B	932, 1008, 1059, 1110, 1212, 1262, 1339, 1415, 1440, 1466, 1567, 1694, 1770, 1821, 1948, 2024, 2101, 2202, 2329, 2507, 2583, 2710, 2888, 3091, 3294, 3701, 4056, 4158, 4437, 4615, 4996, 5377.
C	1275, 1351, 1453, 1580, 1681, 1783, 1834, 1961, 2088, 2113, 2215, 2342, 2494, 2723, 2901, 3104, 3205, 3307, 3459, 3713, 4069, 4171, 4450, 4628, 5009, 5390, 6101, 6863, 7625, 8387, 9149.
D	3127, 3330, 3736, 4092, 4194, 4473, 4651, 5032, 5413, 6124, 6886, 7648, 8410, 9172, 9934, 10 696, 12 220, 13 744, 15 268, 16 792.
E	5426, 6137, 6899, 7661, 8423, 9185, 9947, 10 709, 12 233, 13 757, 15 283, 16 805.

The minimum shearing force of most annual and perennial grasses found on most lawns is usually between 9.2N (Hall et al., 1980).

2.8 Design of the Pulley System

D_1 = Diameter of motor pulley, 120 mm
D_2 = Diameter of alternator pulley (Figure 3).



Pulley 1 Pulley 2

Figure 3. Motor and Alternator Pulley

$\pi D_1 N_1 = \pi D_2 N_2$ (Khurmi 1997) (6)

$D_1/D_2 = N_2/N_1$
Where, N_1 = speed of motor pulley = 1725 rev/min
N_2 = desired alternator speed $\geq$ 2500 rev/min
$D_2 = D_1 N_1 / N_2$
= (120 X 1725)/2500
= 82.8mm
Thus;
Let D2 = 80mm;
N2 = (120 x 1725)/80
= 2588 rev/min

2.9 Power Transmission

Power transmitted from the motor to the alternator per belt is given by;
P = (T1 – T2) v (Khurmi 2003)
Where,
T1 = tension on tight side of belt;
T2 = tension on slack side of belt and
P = (68.66 – 9.3) x 10.84
= 643.46w
Use was made of group A; v-belt design haven a power transmission range of 0.7 ~ 3.5k

2.10 Cutting Blades Design

Volume of the blade
= length of the blade (L) x its breath (B) x its height (H)
Where,
L = 420mm
B = 40mm
H = 1.5mm
V = 420 x 40 x 1.5
= 25200mm^3
V = 2.52 x 10^{-5}
Mass of the blade
= density (D) x volume of the blade (V)
Where density of the blade = 8030kg/M^3
M = 8030 x 2.52 x 10^{-5}
= 0.2024kg
Speed of blades = 1725 rev/min
Power transmitted = 560W
Torque transmitted by motor, T = P/2πN
= (560 x 60) / 2 x 3.142 x 1725
=3.1N-m
But,
T = F.r
F =T/r
= 3.1/0.21
=14.76N
Since 14.76N is higher than the minimum cutting force, therefore cutting of the grass can be done easily
Shear stress failure of the blade is obtained from the;
Permissible shear stress for mild steel (Ss) = 340N/M^2
Where $F = \frac{Ss}{AZ}$
Z = factor of safety and A = projected area of the blade in M^2

$$A = \frac{14.76 \text{ X } 2}{340} \text{ x } 10^{-6}$$

$$A = 0.08682 \text{ x } 10^{-6} M^2$$

2.11 The Handle

The handle is made of a cylinder steel pipe of diameter 20mm which is folded to a length of 1000mm, and 450mm orientation toward the machine frame at an angle of 600 which is adjustable for the operator's convenience (Figures 4, 5 and 6). The handle is subjected to both axial and bending forces due to the inclined position as given by Khurmi, (2005).

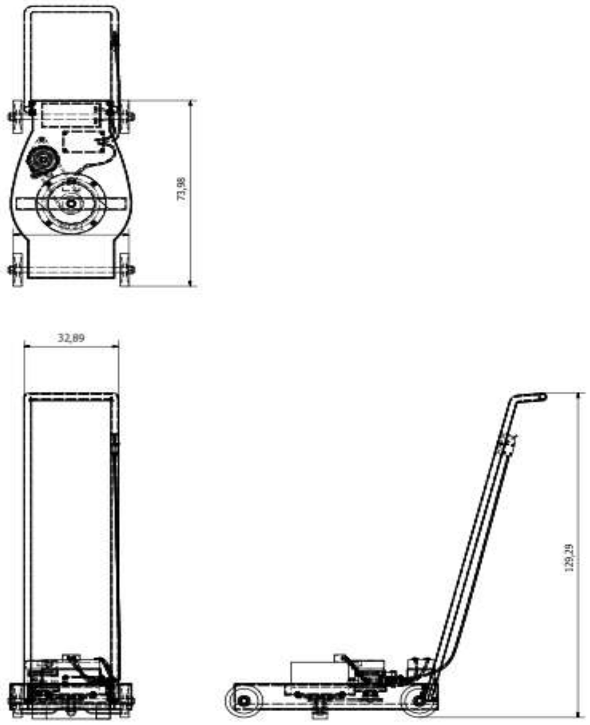


Figure 4. Orthographic View of the Design

Figure 6. Design Isometric View of the Mower

2.12 Battery Charging Unit

A battery charging circuit is shown in Figure 7. The battery is charged with a constant current until fully charged. The voltage developed across the sensing resistor is used to maintain the constant current. The voltage is continuously monitored, and the entire operation is under the control of a microcontroller which may even have an on-chip A/D converter. Temperature sensors are used to monitor battery temperature and sometimes at ambient temperature depending on the battery type, the charge may be terminated based on monitoring battery voltage, voltage change vs. time, temperature change, temperature change vs. time, minimum current at full voltage, charge time, or various combinations of the above.

Figure 7. 12V, 6.5Amps Battery for Mower Recharging

2.13 Alternator

LIN controlled alternator voltage regulator was used (LIN Website located at www.lin-subbus.org.) with features (Figure 8):

(i) 9600 Baud Rate
(ii) 10.7 to 16.0V Setpoint Control
(iii) Programmable Load Response Control
(iv) Programmable Field Excitation
(v) Full Diagnostic Capability
(vi) Self-Excitation
(vii) Short Circuit Protected
(viii) EMI and ESD Immunity
(ix) < 200uA Standby Current

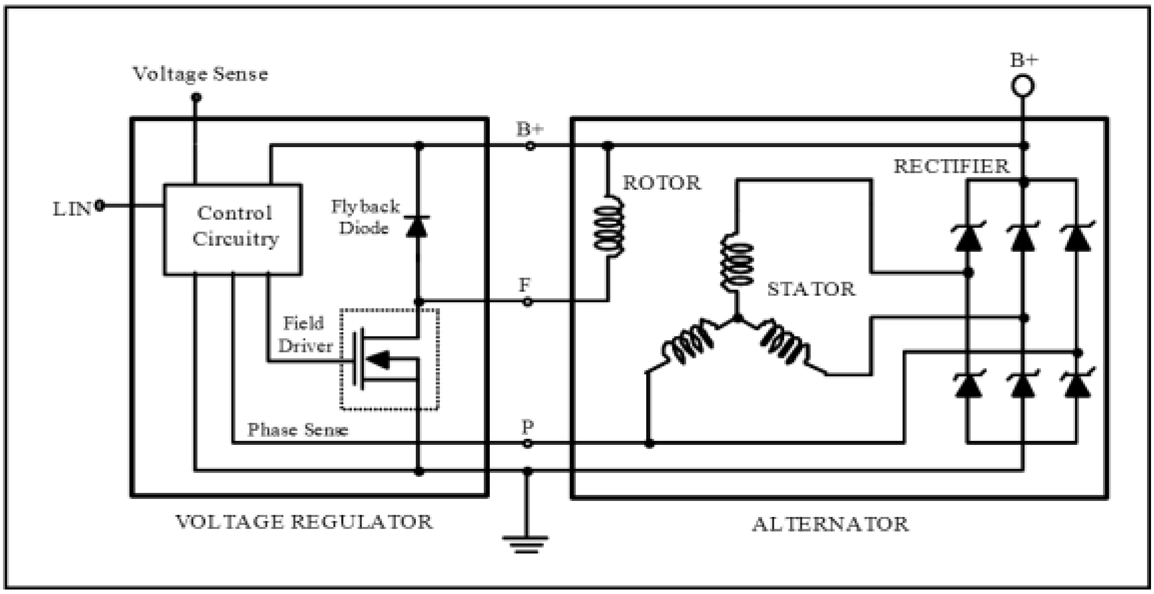


FIGURE 8. CIRCUIT DIAGRAM OF ALTERNATOR

The IRVR101 is an integral alternator voltage regulator that allows for external control of the set point voltage in an automotive charging system where optimized alternator output control is desired. The set point control is achieved using the Local Interconnect Network (LIN) serial communications protocol. Slew rate control and filtering of the interface lines provide electromagnetic compatibility. The regulator consists of a control ASIC, discrete low side power MOSFET (field driver), re-circulation diode, and passive components. The discrete circuitry allows for optimal flexibility with respect to the alternator rotor circuit and charging system requirements. The

IRVR101 is characterized over the temperature range of –40 ^{o}C to 150 ^{o}C.The IRVR101 is manufactured using thick-film hybrid technology. The hybrid circuit can be customized for your application to optimize performance and reliability. The hybrid circuit can also be assembled in a custom housing with an insert–molded lead frame specifically designed for flame-soldering or heavy wire bonding. Thick-film hybrid technology offers reliable high temperature operation with excellent parametric stability over the entire operating temperature range. Resistor values are trimmed within +/-1% using laser equipment that provides precise calibration of voltage and current sensing circuitry. The control IC is attached to the substrate using flip chip technology in order to optimize space and reliability. Bare die is also used for the low side field driver and re-circulation diode in order to optimize space and heat transfer.The voltage regulator is activated by a wake-up signal that consists of the character '0x80'. The regulator is also capable of waking up with the presence of any normal motor activity. Once the regulator has been activated, the regulator will wait until a valid message is received prior to turning on the field driver. The regulator will then hold the field duty cycle at 18.75% until a cut-in phase signal is recognized at which time the regulator will soft start ramp to normal regulation. The cut-in phase voltage and frequency must be greater than 2V and 1200 Generator RPM (GRPM) respectively. De-activation requires a bus timeout in combination with a phase signal timeout. Bus timeout occurs 2s after the last valid message is received. Phase signal timeout occurs 500mS after the phase voltage and frequency have fallen below 0.6V AND 600 GRPM, respectively.In the event of a LIN bus fault, the voltage regulator is capable of self-excitation if a phase voltage and frequency of greater than 0.6VAND 1200 Generator RPM is detected. This signal is only possible if the residual magnetism in the alternator rotor core is sufficient enough to generate a magnetic field capable of inducing the voltage signal in the stator windings. If this signal is detected, the regulator will apply an 18.75% duty cycle until the cut-in phase signal is recognized at which time the regulator will soft start ramp to default regulation. The regulator will return to sleep mode at any time when the phase signal has timed out as described above.System voltage sensing can be achieved via the dedicated battery sense input or through machine sensing from the rectifier B+ output via the F+ input to the regulator. The battery sense input is optional and can be deleted. If the battery sense option is exercised, an open or short circuit at this input will cause voltage sensing to transfer to the machine voltage sense input (an electrical fault can be indicated if the regulator is configured for this fault option). The machine voltage setpoint can be set to a different value than the battery sense voltage to compensate for system voltage variation between the alternator and the battery.Voltage regulation is achieved using fixed frequency pulse width modulation. The base frequency is typically 150 Hz and the proportional control range for regulation is 100mV. This provides for very stable regulation over the entire speed and electrical load range.Load response control is programmable and can be varied from 0.426 seconds to 13.2 seconds in 16 steps. Additionally, the load response control cut-off speed is programmable and can be set to "always active" or varied from 2400 to 8000 Generator RPM. The load response at startup is equal to the programmed value for the load response control. The load response will always be executed on the first ramp to full field after engine start regardless of frequency in order to assist in achieving a smooth engine start. The alternator specifications, signal characteristics and terminal functions are presented in Tables 4, 5 and 6, respectively.

Table 4: Alternator Specifications

Condition	Symbol	Rating	Unit
Power Supply			
Continuous DC Voltage	VBATT	25	V
Transient Voltage (load dump)	VMAX	40	V
Reverse Battery (connector/other terminals)	VMIN	-12/-3	V
Temperature			
Operating baseplate temperature Storage temperature	T_A TSTG	-40 to +150 -50 to +170	^{o}C
Field Current			
Continuous @ -40 ^{o}C Continuous @ 25 ^{o}C	IFLD-40	11	A
Continuous @ 150 ^{o}C	IFLD+25	8	A
	IFLD+150	5	A

Table 5: Signal Characteristics

Signal	Type	Frequency Range	Normal Voltage Range	Maximum Voltage	Quiescent Current Drain
S	DC	N/A	12.5 to 16.0V	100V	100uA
C	PCM	9600 Hz	0.2 to 15.0V	100V	N/A
F-	PWM	100-150 Hz	0.5 to 17.0V	100V	100uA
P	AC	0-2000 Hz	-1 to 17V	100V	N/A

Table 6: Terminal Functions

Pin Name	Symbol	Description
LIN	C	Serial communication input/output
B+ Voltage Sense	B+	Alternator rectifier output. Provides machine voltage sense input and power supply input to regulator. Also used as re-circulation diode cathode connection.
Battery Voltage Sense	S	Optional input for remote battery voltage sensing
Low Side Field Driver	F-	Low side of alternator field coil. Connected to the drain of the FET when using a low side drive.
Phase Detection	P	Stator phase input to the regulator. Used for self-excitation and fault detection.
Ground	G	Ground connection

2.14 Charging Using Electricity A.C.

The mower charger circuit was modified using IC LM 317 which is an adjustable voltage regulator (Figure 9). This enabled mower charger to charge a Lead acid battery for powering the developed mower.

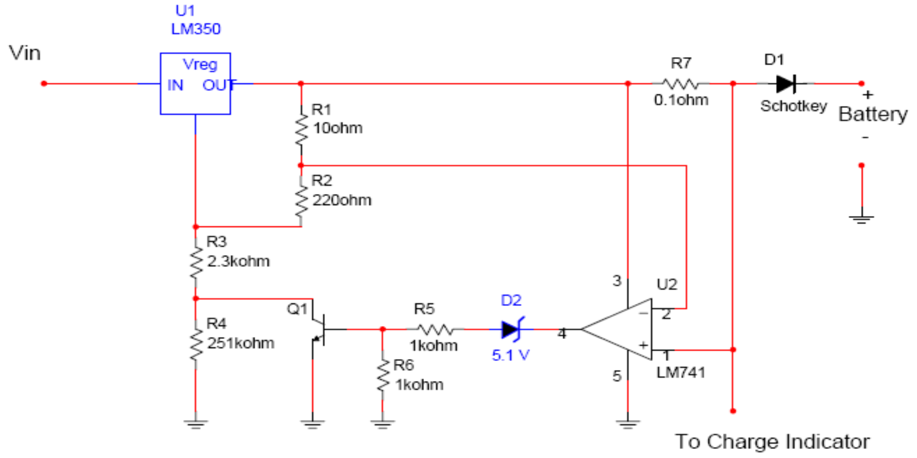


Figure 9. Modified Mower Charger Circuit for Charging Lead Acid Battery

2.15 Battery Indicator

Figure 10 depicts a quad-voltage comparator (LM324) that used to control a simple bar graph meter to indicate the charge condition of the 12-volt lead acid battery. A 5.4-volt reference, voltage (D1) is connected to each of the non-inverting inputs of the four comparators and the inverting inputs are connected to successive points along a voltage divider. The LED illuminate as the voltage at the inverting terminals exceeds the reference voltage. LED1 turns on at 11volts, LED2 turns on at 13 volts, LED3 turns on at 14 volts, and LED4 turns on at 14.3 volts.

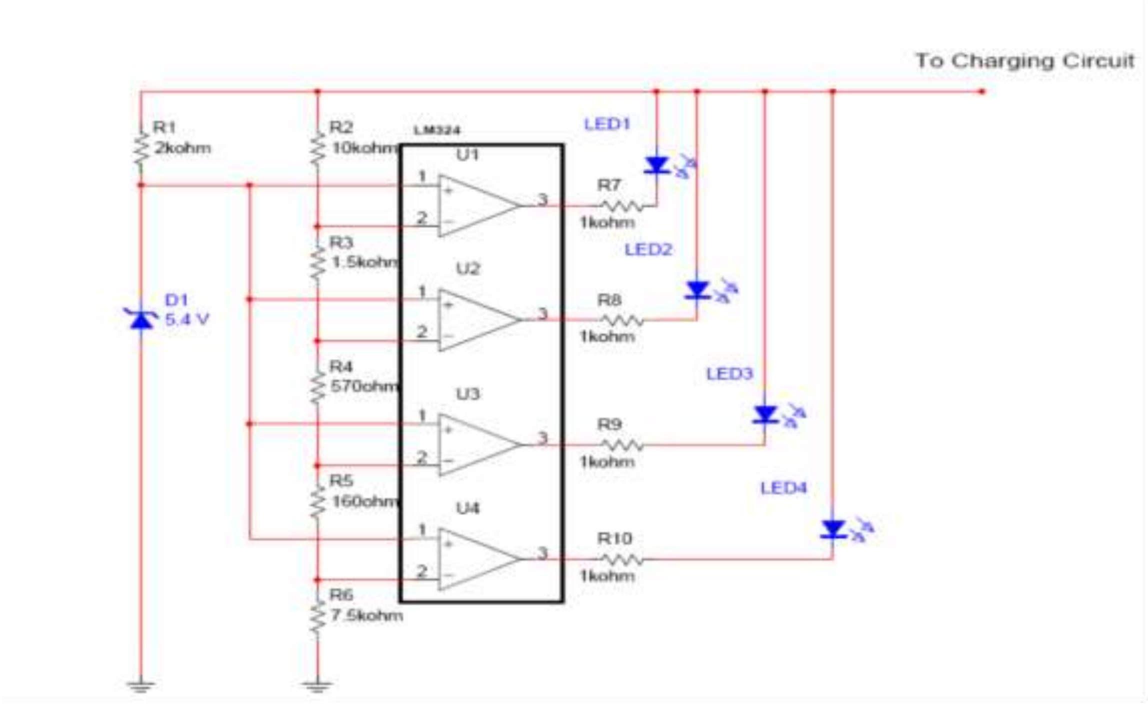


Figure 10. Complete Charging Circuit Module

2.16 Adjustable Voltage Regulator

Adjustable voltage regulator IC provides Line Regulation (irrespective of the changes in the input voltage, the output voltage remains constant) and Load Regulation (irrespective of the changes in load the output voltage is fixed). The output voltage was adjusted by varying the resistance across the adjust pin. This is needed to have a fixed voltage across the battery, as (Figure 11);

Vout = VR1*(1+R2/R1)+Iadj*R2.

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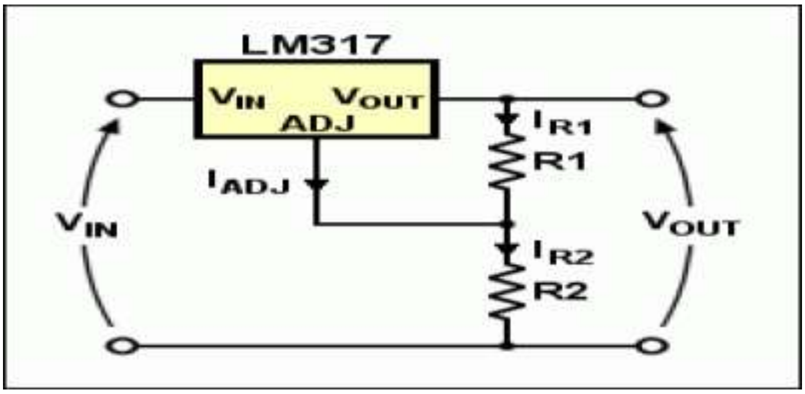

Figure 11. Adjustable Voltage Regulator

2.17 Material Selection

The materials used for the components of the machine were selected based on the (Fatunase, 2005): efficiency of materials, simplicity of design, strength of materials, availability of materials, and material cost (Table 7).

Table 7: Material Selection

Machine component	Material selected	Reasons for the selection
Blade	Mild steel	➢ Readily wieldable ➢ Readily available in the market ➢ High ductility ➢ Low strength ➢ Formability i.e easily formed into shape because of its low carbon contents (0.14% - 0.3%). ➢ Good heat resistance and cold work
Reinforcement of the base plate	Angle iron	➢ High compressible strength ➢ Good damping characteristics ➢ High tensional strength very rigid and machinable
Housing for the components	Mild steel sheet metal (SWG 16)	➢ High ductility ➢ Readily wieldable ➢ Good heat resistance ➢ Cold working
shaft from the motor	Mild steel	➢ Low strength ➢ High ductility ➢ Easily threadable ➢ Good heat resistance ➢ Cold work

III. PERFORMANCE TEST AND RESULTS

Area of grass cut = $5M^2$
Desired height of cut = 30mm
Time taken = 2min
Area of grass cut to desired height = $4.23M^2$
Therefore:
Cutting Efficiency of the mower = $\frac{\text{Area of grass cut to desired height}}{\text{Area of grass cut}}$ x 100
Thus: ʅ = $\frac{4.23}{5}$ x 100
= 84.6%

The lawn mower designed (Figure 12) works on the principle of the law of conservation of energy which states that energy can neither be created nor destroy but can be transform from one form to another.

Figure 12. Cordless Lawn Mower with Rechargeable System

3.1 Battery State of Charge (BSOC)

A key parameter of a battery in use is the battery state of charge (BSOC). The BSOC is defined as the fraction of the total energy or battery capacity that has been used over the total available from the battery.Battery state of charge (BSOC or SOC) gives the ratio of the amount of energy presently stored in the battery to the nominal rated capacity. For example, for a battery at 80% SOC and with a 500 Ah capacity, the energy stored in the battery is 400 Ah. A common way to measure the BSOC is to measure the voltage of the battery and compare this to the voltage of a fully charged battery. However, as the battery voltage depends on temperature as well the state of charge of the battery, this measurement provides only a rough idea of battery state of charge.

3.2 Depth of Discharge

In many types of batteries, the full energy stored in the battery cannot be withdrawn (in other words, the battery cannot be fully discharged) without causing serious, and often irreparable damage to the battery.The Depth of Discharge (DOD) of a battery determines the fraction of power that can be withdrawn from the battery. For example, if the DOD of a battery is given by the manufacturer as 25%, then only 25% of the battery capacity can be used by the load.Nearly all batteries, particularly for renewable energy applications, are rated in terms of their capacity.

However, the actual energy that can be extracted from the battery is often (particularly for lead acid batteries) significantly less than the rated capacity. This occurs since, particularly for lead acid batteries, extracting the full battery capacity from the battery dramatically reduced battery lifetime. The depth of discharge (DOD) is the fraction of battery capacity that can be used from the battery and will be specified bythe manufacturer. For example, a battery 500 Ah with a DOD of 20% can only provide 500Ah x 0.2 = 100 Ah.

3.3 Charging and Discharging Rates

A common way of specifying battery capacity is to provide the battery capacity as a function of the time in which it takes to fully discharge the battery (in practice the battery often cannot be fully discharged). When the discharging rate is halved (and the time it takes to discharge the battery is doubled to 20 hours), the battery capacity rises to xxx. The discharge rate when discharging the battery in 10 hours is found by dividing the capacity by the time. Therefore, C/10 is the charge rate. This may also be written as 0.1C. Consequently, a specification of C20/10 (also written as 0.1C20) is the charge rate obtained when the battery capacity (measured when the battery is discharged in 20 hours) is discharged in 10 hours. Such relatively complicated notations may result when higher or lower charging rates are used for short periods of time.The charging rate, in Amps, is given in the amount of charge added the battery per unit time (i.e., Coulombs/sec, which is the unit of Amps). The charging/discharge rate maybe specified directly by giving the current - for example, a battery may be charged/discharged at 10 A. However, it is more common to specify the charging/discharging rate by determining the amount of time it takes to fully discharge the battery.In this case, the discharge rate is given by the battery capacity (in Ah) divided by the number of hours it takes to charge/discharge the battery. For example, a battery capacity of 500 Ah that is theoretically discharged to its cut-off voltage in 20 hours will have a discharge rate of 500 Ah/20 h = 25 A.

Furthermore, if the battery is a 102V battery, then the power being delivered to the load is 6.5A x 102 V = 663W (about the power drawn by xxx). Note that the battery is only "theoretically" discharged to its maximum level as most practical batteries cannot be fully discharged without either damaging the battery or reducing is lifetime.

3.4 Charging Process of Batteries

Charging a lead acid battery is a matter of replenishing the depleted supply of energy that the battery had lost during use. This replenishing process can be accomplished with several different charger implementations: “constant voltage charger”, “constant current charger” or a "multistage" constant voltage/current charger”. Each of these approaches has its advantages and disadvantages that need to be compared and weighed to see which one would be the most practical and realistic to fit with our requirements. If the battery voltage drops to 89V from 92V, the charger changes from any mode to Constant Current mode and restart charging.

3.7 Care and Maintenance of the Mower Battery

The battery must be well charged before operations. If it does not hold charge, it means the battery is bad or the charging circuit has a problem. First of all, charge the battery because if it the charge is low, it will not start or rotate the motor. Similarly, make sure that all the battery terminals are tight and cleaned up. Ensure that all the corrosions are free of corrosion. After charging, the battery should be tested using voltmeter (the reading must be between 11-13 volts), as well check the battery voltage with the engine running, if possible, it should be higher about 13.5volts. in this case the battery is ready to be ready for operation.

3.8 The Lawn and Machine Control

Clear the work area of debris, sticks, stones, etc that might be thrown by the blades. The lawn mower blades can throw out hit materials at about 250 to 300ft/second (about 200 miles per hour and 330 kilometers per hour). Do not leave the machine unattended while is running; avoid lifting the machine while running. During operation, mow straight up and down slopes rather than sideways for greater stability unless the machine is counterbalance. Reduce the machine speed on slopes and when making sharp turn, this will prevent tipping or loss of control.

IV. CONCLUSION

It can therefore be concluded that energy from the battery which powers the D.C. motor (which converts electrical energy to mechanical energy) could also be used to recharged the battery with the aid of alternator (which converts the mechanical energy to electrical energy) and capacitor (voltage booster). The rate at which the battery is charge was depended by the speed of the D.C. motor. Hence, the development of lawn mower with cordless and rechargeable opportunities was achieved.

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