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Electric Road Cleaner

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Abstract: Cleanliness is the most important aspect of every proper civilization. In this paper we look into the aspect of electric vehicles being used to maintain a city's cleanliness. We focus on the use of dc motors to create a vehicle that can be effectively used to maintain road cleanliness. This paper is aimed at designing a vehicle that can both maintain operational efficiency and stick to its task. The system comprises of dc motor systems and separate speed and current control circuits.

Keywords: Brushless DC motor (BLDC) , motor circuit (MC), sweeper circuit(SC), vacuum circuit(VC), ultrasonic sensor circuit(USC), Internal combustion(IC),Battery Electric Vehicle(BEV).

I. INTRODUCTION

With increasing vehicular traffic and road usage levels, it is necessary for a machine that can effectively maintain road related rubbish to be developed. The electric road cleaner aims to utilize the high torque that a DC motor can provide simultaneous vehicular propulsion and at the same time sweep and vacuum the road thereby combining the work conventionally done with different systems under one. Although conventional sweeping vehicles already exist, they are designed to operate on a small scale and use IC engines which are proving to be more and more expensive and polluting with increasing fuel costs and increasing global warming. The whole system comprises of three separate DC motor systems each of which control the vacuum system, the sweeping system and the overall propulsion system of the vehicle. The amount of carbon dioxide emitted is only 12.6 g/km while it is 60 to 130g/km in other internal combustion engine cars.

II. SYSTEM DESIGN

A. Propulsion System

It is the system that is used to propel the entire vehicle and comprises of a single DC motor complete with a controller circuit that automatically varies the speed of the motor in accordance to control inputs.

B. Vacuum System

It is the heart of the cleaning process and is used to suck in all the rubbish present on the road that is suitably swept in by the sweeper circuit.

C. Sweeper System

It is used to suitably push the rubbish towards the vacuum suction point. It consists of two DC motors coupled to four sweepers along with a stepper motor all of which work together as a unit.

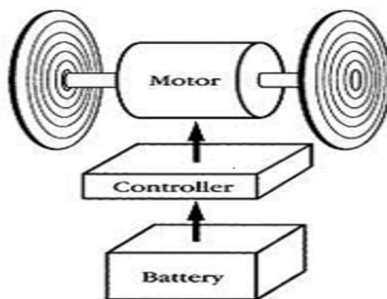
D. Sensor System

The sweeping system is connected to a mount that can be raised or lowered depending on the gradient of the road and obstacles. The sensor and sweeper systems work in tandem.

E. Stepper Motor System

It is used to lower or raise the sweepers according to the sensor inputs. It is controlled by a microcontroller and rotates 180 deg on each command pulse.

III. PROPULSION SYSTEM



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The above shows the basic block diagram of a BEV. The battery acts as the power source and the controller modulates the power supplied to the motor in accordance to the control inputs.

A. Battery System

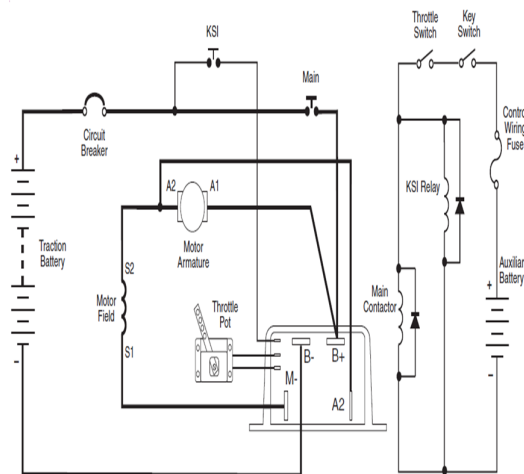
In place of an internal combustion engine, the proposed car has a bank of batteries -- the **battery system**. The battery system is composed of two subsystems 1. For the propulsion motor 2. For the sweeping and vacuuming systems.

- 1) *Propulsion Battery*: This battery system is used for propelling the main motor to drive the vehicle. The batteries produce an output of 120V and comprise of 5-24V batteries connected in series and have 6 rows of such batteries and the switch over between the rows is done by a micro-controller
- 2) *Sub-system Battery*: This is used to run the vacuum and sweeping sub-systems and produce an output of 12V and comprise of 5-12V batteries connected in parallel and again the discharging is controlled by a dedicated micro-controller.

B. Motor

The motor used is a BLDC motor. It can produce 10 HP output power with an input voltage of 120V. The current rating is 70A, maximum speed is 3450rpm. The motor gets its input from the controller. The motor is directly coupled to the wheels.

C. Controller



The controller used in this vehicle is a dc-dc controller manufactured in the name CURTIS 1231c-86XX. The above shows the block diagram of the DC-DC controller, it works akin to a chopper but has inner feedback and reference loops. The pedal press is converted into voltage level by a suitable throttle potentiometer which is given as the reference input to the controller. It has five terminals namely,

B+: Positive terminal of the battery pack.

B-: Negative terminal of the battery pack.

M-: Motor ground connection.

A2: Armature winding ground.

A1 of the motor is connected to the battery positive while S2 is connected to A2 and S1 is connected to M-. KSI is switch that connects the reference voltage to the controller.

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Controller characteristics:

Voltage (V): 96-144.

Current (A): 500.

2 MIN RATING (A): 500.

5 MIN RATING (A): 375.

1 HOUR RATING (A): 225.

Output torque calculation:

$$P = (2 * \pi * N * T) / 60.$$

P: Motor Output power(rated)=20 HP.

T: Output torque.

N: Operating speed of motor.

Re-arranging:

$$T = (60 * P) / (2 * \pi * N).$$

$$T = (60 * 20 * 765) / (2 * 3.1415 * 3000).$$

$$T = 50 \text{ NM (approx.)}$$

Gear torque = motor torque * (input speed / output speed) * gear efficiency

Input speed = 3000 rpm

Output speed = 1000 rpm

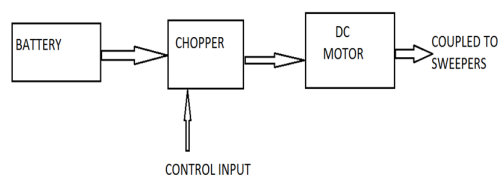
Gear efficiency = 0.85

Gear torque = $50 * (3000 / 1000) * 0.85$

$$= 127.5 \text{ Nm}$$

IV. SWEEPER SYSTEM

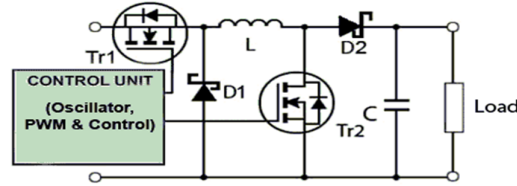
The sweeping system is a set of four rubber sweepers that act to push the dust inwards to the vacuum system. The sweepers are actuated by two motors and are connected via a gear so as to ensure that enough torque can be produced for the operation. The motors are rated at 0.5HP and have can run over a range of input voltages with the preferred one being 24V.



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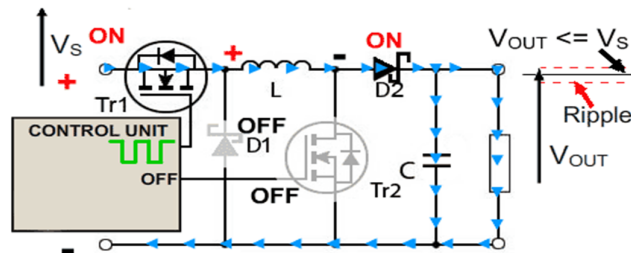
The above shows the block diagram of the sweeping system, the control input dictates the output speed of the DC motor thereby controlling the speed of the sweepers as needed.

A. Chopper Circuit



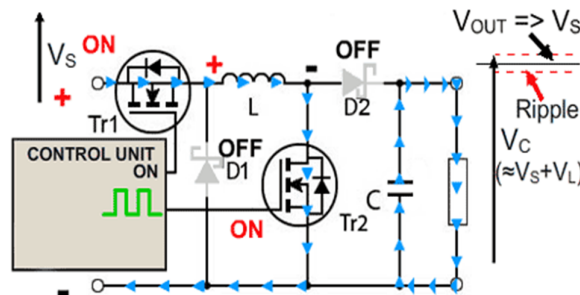
The chopper circuit is a buck-boost converter that is used to vary the output voltage in accordance with the inputs from the main control panel. By selecting the appropriate option, the control unit can be used to operate the chopper in buck/boost mode thereby varying the output speed of the motor.

1) Operation As A Buck Converter



In this mode Tr2 is turned off, and Tr1 is switched on and off by a high frequency square wave from the control unit. When the gate of Tr1 is high, current flows through L, charging its magnetic field, charging C and supplying the load. The Schottky diode D1 is turned off due to the positive voltage on its cathode.

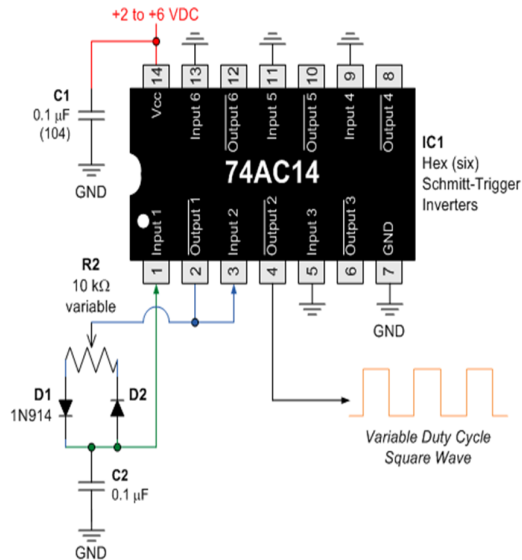
2) Operation As A Boost Converter



In Boost Converter mode, Tr1 is turned on continually and the high frequency square wave applied to Tr2 gate. During the on periods when Tr2 is conducting, the input current flows through the inductor L and via Tr2, directly back to the supply negative terminal charging up the magnetic field around L. Whilst this is happening D2 cannot conduct as its anode is being held at ground potential by the heavily conducting Tr2. For the duration of the on period, the load is being supplied entirely by the charge on the capacitor C, built up on previous oscillator cycles. The gradual discharge of C during the on period (and its subsequent recharging) accounts for the amount of high frequency ripple on the output voltage, which is at a potential of approximately $V_s + V_L$.

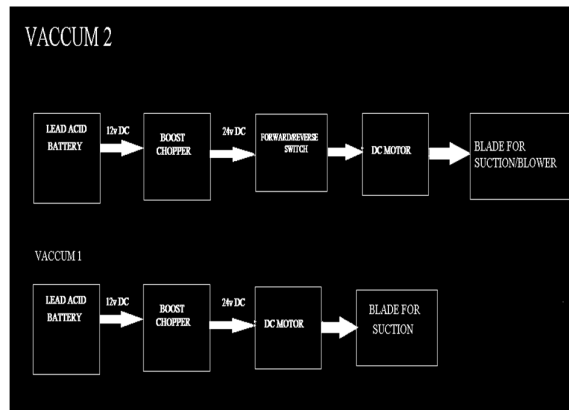
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B. Control Circuit



The PWM wave is a square wave with varying duty cycles, the IC is six Schmitt trigger inverter circuit that produces high frequency variably duty cycle square output. This acts as the gate signal to the switches aiding in the conduction.

V. VACUUM SYSTEM



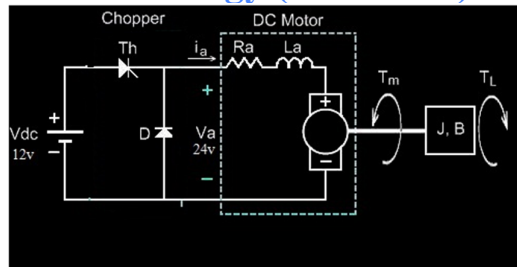
The vacuum system is used to suck in the dust present on the road that is swept toward it by the sweeping system. The vacuum system comprises of two different vacuum pumps each of which operate individually. The above diagram shows the block diagram of the two individual vacuum systems.

Vacuum-1:

This a universal motor driven vacuum creator used to suck in the dust irrespective of the season and road conditions. The universal motor is coupled to the fan and is driven by a chopper which is fed from a lead acid battery source. The chopper used is a BOOST chopper.

Boost Chopper:

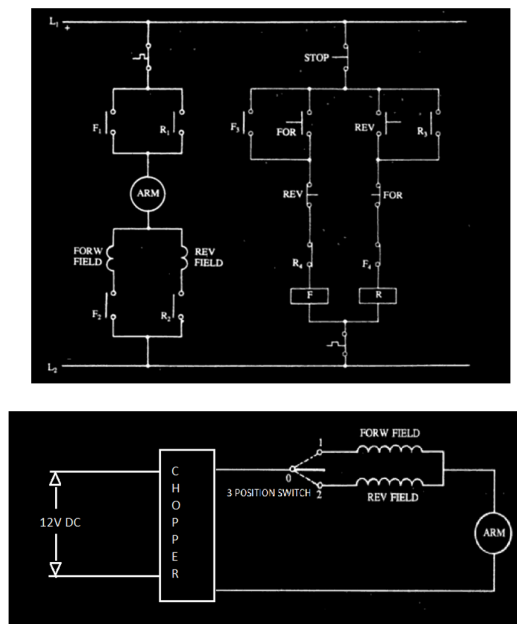
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The above diagram is the boost chopper used; by varying the firing pulse of the thyristor switch we can control the output voltage and thus the speed of the motor.

Vaccum-2:

The second vacuum system acts as a suction/blower device based on the season. In summer when the moisture on the roads is minimal the setup is used as a vacuum device. During rainy seasons, the setup funnels hot air from the main motor toward the ground thus drying up moisture and enabling easier vacuuming and preventing sand from sticking to the ground. This is also a universal motor coupled to the fan controlled by a chopper and the field has a reversal circuit used to control the direction of rotation.



The above shows the block diagram of the reversal system. The motor has two windings one for forward operation and the other for reverse operation, by using a DPDT switch to switch between the windings, the direction of operation of the universal motor can be reversed.

Universal motor:

Universal motors can rotate at a speed of up to 20000 rpm. It is used for low torque applications. The motor used in the vacuum system is a 1400W 12v DC motor.

Calculation of the radius of the impeller:

Suction Pressure = $(1/2) \cdot \rho \cdot V^2$.
 ρ - Density of air = 1.225.
 Suction Pressure: 30 KPA.

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V-Velocity of the fan blade.

Re-arranging:

$$V = \sqrt{(2 * \text{Suction Pressure}) / \rho}$$

$$V = \sqrt{(2 * 30 * 10^3) / 1.225}$$

$$V = \sqrt{48,979.592}$$

$$V = 221.31 \text{ M/SEC.}$$

$$V = (R * W * 2 * \pi) / 60$$

Where,

R-Radius of fan blade.

W-Speed in RPM.

Re-arranging:

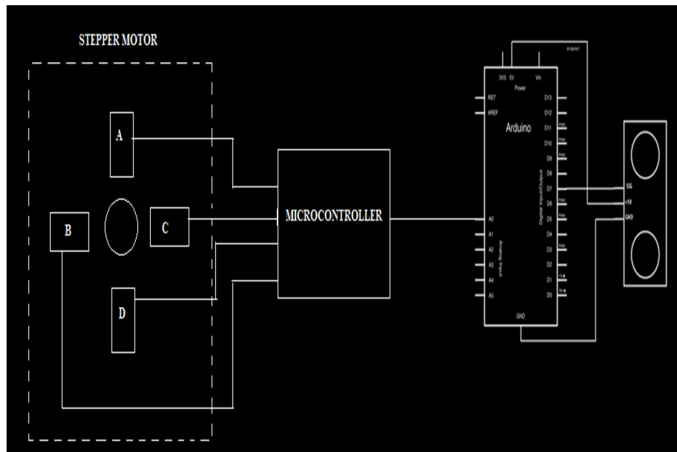
$$R = (60 * V) / (W * 2 * \pi)$$

$$R = (221.31 * 60) / (10000 * 2 * 3.1415)$$

$$R = 13278.6 / 62830$$

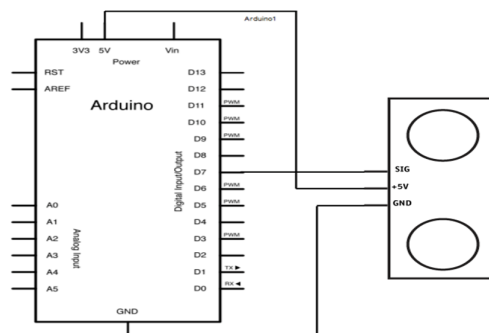
$$R = 0.211 \text{ M.}$$

VI. SWEEPER PROTECTION SYSTEM



A. Ping Sensor

The ping sensor is an ultrasonic sensor which measures the distance from the vehicle and any obstacle. If the distance is lesser than 2m, the sweeper system will be raised by the stepper motor



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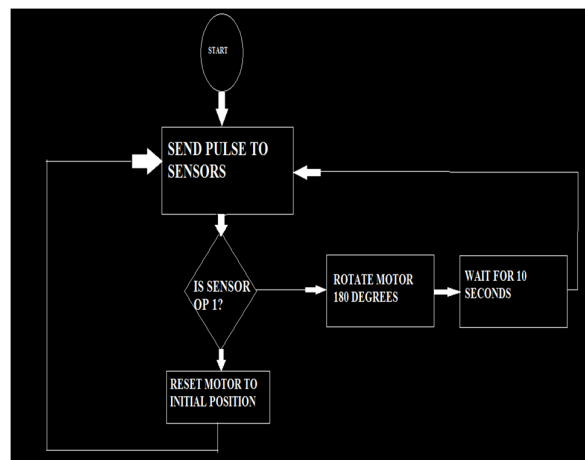
The ultrasonic ping sensor provides an easy method of distance measurement. Interfacing to a microcontroller is a snap. A single I/O pin is used to trigger an ultrasonic burst (well above human hearing) and then "listen" for the echo return pulse. The sensor measures the time required for the echo return, and returns this value to the microcontroller as a variable-width pulse via the same I/O pin.

The sensor provides precise, non-contact distance measurements within a 2 cm to 3 m range. Ultrasonic measurements work in any lighting condition, making this a good choice to supplement infrared object detectors. Simple pulse in/pulse out communication requires just one I/O pin. Burst indicator LED shows measurement in progress.

The 5V pin of the PING is connected to the 5V pin on the Arduino, the GND pin is connected to the GND pin, and the SIG (signal) pin is connected to digital pin 7 on the Arduino.

The sensor output pin is connected to an arduino board which converts the analog signals from the sensor to digital values which act as input to the microcontroller. The microcontroller reads the output of the arduino and rotates the stepper motor according to the same. If the distance measured by the sensor is lesser than or equal to 2m, the input to the controller will '1' otherwise the input will be '0'.

B. Flow Chart For Stepper Motor Control



C. Algorithm

- Step 1: start the process
- Step 2: send trigger signals to the microcontroller
- Step 3: read the output of the sensor
- Step 4(A) : if the output of the sensor is 0, goto step 4(B): Else goto step 5.
- Step 5: initialize the data pointer
- Step 6: push data 0C to the higher byte of data pointer and 00 to lower byte.
- Step 7: move the data to R0.
- Step 8: initialize the out port and enable it.
- Step 9: move the data in R0 to out port C0.
- Step 10: give a delay of 5 seconds.

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Step 11: goto step 1.

VII. ADVANTAGES

The principal advantages of this system involve its large adaptability and relative cost efficiency. Absence of regular fuelling reduces fuel costs and the design of the system with only a electric energy source means that there is no need for a separate oil fuel for the vehicle and additional electricity for the other systems.

VIII. CONCLUSION

The proposed paper deals with the use of a electric vehicle for sweeping and vacuuming purposes. An electric vehicle has the dual advantage of both being relatively eco-friendly as well as much more cost efficient. Instead of individual systems for the sweeper and cleaner using electric systems and operating the vehicle on combustion engine, the system's use of pure electric propulsion means the unit can be designed as a whole. The entire vehicle can be modified and redesigned as needed for operation. The vehicle can save costs on fuel in the long run as well as the fact that electricity remains the only future resource for mankind. This vehicle can also reduce road pollution and thereby help reduce the amount of accidents that occur due to improper road maintenance.

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