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Regenerative Braking System Using a DC/DC Buck-Boost Converter

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Abstract

In a battery-powered electric vehicle, regenerative braking is the conversion of the vehicle's kinetic energy into chemical energy stored in the battery, where it can be used later to drive the vehicle. It is braking because it also serves to slow the vehicle. It is regenerative because the energy is recaptured in the battery where it can be used again. The conservation of this energy is very important, as it allows us to drive further distances in electric-powered vehicles, and be more efficient overall. In this project, we wish to use a DC/DC buck-boost converter, connected to a wheel. This wheel will produce kinetic energy that is sent to the DC/DC converter, which is then sent to a battery that supplies it back to the vehicle in question. The most common power processing converter used for the battery converter in hybrid/electric vehicles is a buck and boost converter. When recovering the kinetic energy from the vehicle, the device operates in buck mode, where the voltage level is decreased to a level that is within the safe voltage range of the battery. When propelling the vehicle, the device operates in boost mode, and the DC voltage is regulated to output a higher voltage level for the electric motor drive and motor. In this case, when regenerative braking is activated, we allow the motor to stop completely, and the dynamo takes over in this case. The momentum of the wheel when it's braked is sent over to the dynamo. It will generate a voltage which is boosted by the buck-boost converter to

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supply energy to the battery, rather than allowing it to go to waste. This is a more practical demonstration as a solitary motor acting as both a motor and generator would be overly pricy.

Keywords: regenerative braking, conservation of energy, buck-boost converter, dynamo, motor, generator.

1.1 Introduction

The invention of the Electrical Vehicle is nothing short of a miracle. Electrical and Hybrid vehicles are shown to be emission free, which is extremely necessary in this heavy pollution ridden climate. Fuel based modes of transport dependent on petrol cause major harm to the environment, as well as diminishes at a rate that is impossible to replenish, therefore the slow shift of dependency onto Electrical and Hybrid vehicles over the conventional sort, is a needed change. Every year, the government is pushing for more and more electrical vehicles to be built in an attempt to stop the damage being done to the ozone layer, and to reduce the usage of fossil fuels overall. In India, automobiles are one of the key forms of economic growth, and they are a booming source of revenue, only growing year by year. This however does mean that they are one of the largest sources of pollution. Due to this, the Indian government is in a frenzy to switch to a complete focus on electrical vehicles by 2030. Electrical cars are hardly a new invention, rather the roots were found all the way back in the 1900s. However the electrical vehicular mania did not last long, as electrical cars in that time were restricted by their top speed and mileage. There were a number of issues other than that, which made it difficult to adopt the technology in the past. The first attempts of regenerative braking were found back then, as even primitive regenerative braking could improve a car's range by 10-25%. Traditional braking systems use up and waste quite a lot of energy in the form of heat. They use mechanical braking to dissipate the kinetic energy gathered, into wasteful heat energy using a frictional method to bring the car to a stop. Studies show, that about a third to a half of the energy used for the operation of a car, is consumed during breaking, especially within urban areas where braking constantly is necessary. The energy we waste away as heat can be converted into something far more useful. In this case, Regenerative Braking. Regenerative Braking is present only in electrical and hybrid vehicles and is implemented to recapture the wasted heat energy. This heat energy can be converted into electrical and stored in batteries, as to improve the overall health of the car, and the driving range of said vehicle.Some of the main benefits of regenerative braking include:

- Reduces wastage of fuel
- Extends the charge of the battery by recharging it with the converted heat energy the strain upon the breaks and keeps it healthier and working longer energy

1.2 Regenerative Braking System

The block diagram Figure 1.2 shows the general schematic of the proposed circuit. This regenerative braking system focuses on feasibility, by using a dynamo alongside a DC/DC buck-boost converter and a 12V battery, forthe main operation of the circuit. The battery is also connected to a 5V output which is sent to make the Arduino ESP32 function, producing results onto the devices connected via Bluetooth [1, 2, 3]. During forward movement, the 12V battery supplies energy to the motor, giving it enough electricity to propel itself forward. This is motoring mode, and works in a rather straightforward fashion. The battery sends this voltage to the motor through the DC/DC converter, allowing it to supply the motor with the needed amount of voltage to function. This is done in boost mode. During regenerative braking, the momentum of the wheel is taken up by the dynamo, allowing the motor to be stopped. The dynamo acts as a generator and supplies energy to the battery. If the generated voltage by the dynamo is higher than the battery voltage, the converter operates in buck mode, otherwise it operates in boost mode to reach 12V. The battery being charged can be supplied to the relevant vehicle to save both fuel and energy[4, 5, 6]. The Arduino ESP32 is necessary for Bluetooth support, requiring 5V to function which it is supplied by from the 12V battery. The 5V can be gained using a zener diode, to convert the 12V into a usable 5V. The Arduino ESP32 is only used for the Bluetooth functionality, programmed to function and produce results to external Bluetooth devices. It uses hotspot functionality, by using the Network name and Password, so when the hotspot is active, the user can gain clear voltage readings of the circuit, whenever it is used, alongside a history of previous usage. The LED shows the voltage reading of the generated voltage and the battery voltage[10]. The DC/DC Buck-Boost converter is the proposed converter for this system. A buck-boost converter is necessary to raise or lower the voltage when being sent towards the battery or the motor. This circuit is made up of a DC source (Motor), MOSFET, 2 capacitors, 2 inductors, 1 load, and a PI controller that is fed the

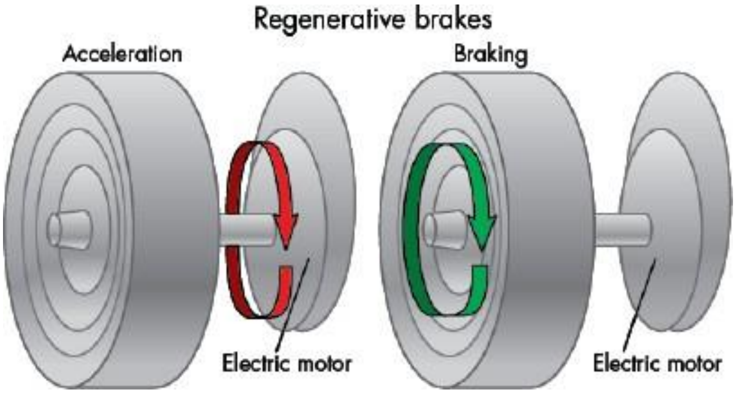

Figure 1.1 Basic diagram representing Regenerative braking.

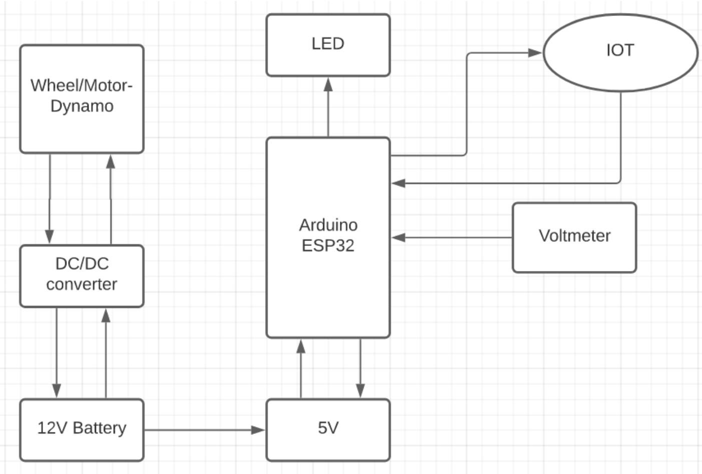

Figure 1.2 Block diagram of Proposed Regenerative braking system.

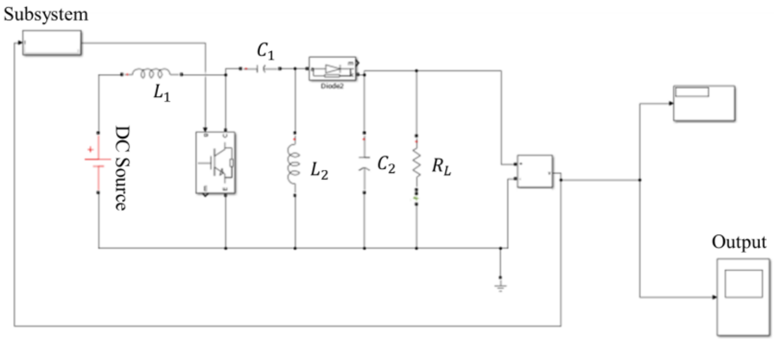

Figure 1.3 Simulink Circuit diagram of proposed converter.

Table 1.1 Caption

S.No	Components	Values
1.	DC source	10V
2.	L1	100H
3.	L2	100H
4.	C1	100F
5.	C2	100F
6.	Load1	204
7.	Gain in subsystem	1/12

Output, which is essentially fed back to the MOSFET. The values of each circuit element are:

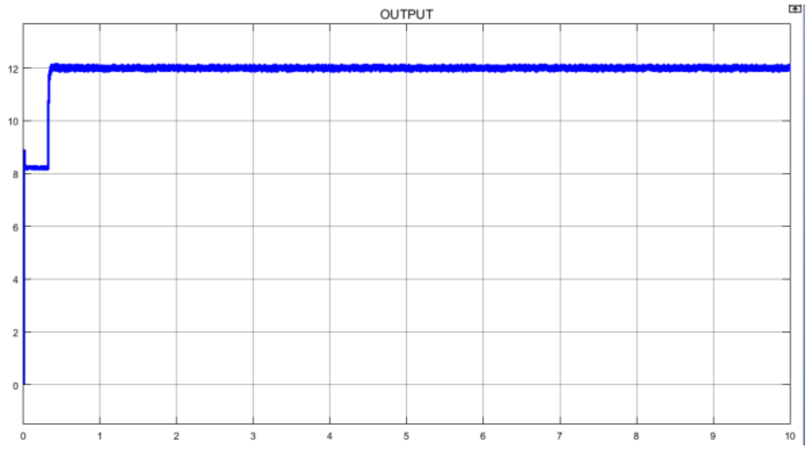

Figure 1.4 Regenerative braking Output from simulation.

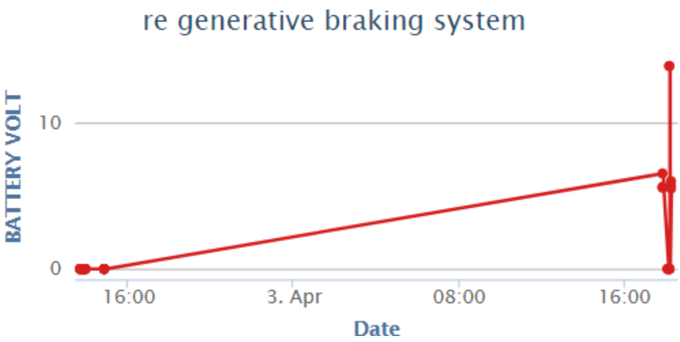

Figure 1.5 Graphical representation of Output of IOT.

The PI controller receives constant feedback from the o/p, which it feeds to the gain channel in the MOSFET. In the actual circuit, the PI controller subsystem is replaced with the Arduino ESP32. It acts in the same manner, as the same way the PI controller operates in the simulation circuit[7, 8, 9]. When we run this circuit, our goal is to produce a 12V at the output, for the battery as to charge it in regenerative braking mode. As our motor in this specification runs at 10V, the boost mode of this converter is used to bring it to 12V. The diode in this circuit is to keep the signal DC, converting any stray AC signals into pure DC, as the battery can only use DC. The following graph Figure 1.4, is the operation of the converter for a time period of 10s, giving it enough sample time to show that it can maintain 12V with some margin of error in the simulation.

1.3 IoT Simulations

The simulation consists of the DC/DC buck-boost converter mainly, the DC source input acting as a stand in for the motor, the output being 12V meaning to be fed to the battery. The feedback of said output is sent to the PI controller, which sends it to the MOSFET appropriately, rather than the Arduino for the simulation. The IOT can show the graphical results of testing the generated voltage that was to be sent to the battery, shown in Figure 1.5 The final produced voltage in the IOT device, is 12V as it should be (other values were produced while testing the output)

1.4 Conclusion and future work

While working on this project, we found ourselves understanding the importance of energy conservation in general, and with that the importance of Regenerative braking. The percentage of energy saved using this method may seem underwhelming, but in the age of electrical cars, and eco friendly methods of transport, we can see that every bit of energy that we can retain, can be essential in the future. Regenerative braking, and other similar methods of energy conservation, have only improved over the years. Initially the downsides to such heavy emphasis on conservation were considerable, such as lowering the life of the vehicle considerably, reducing the range, and taxing the speed greatly, but technological advances, alongside the boom of electrical and hybrid vehicles, we are entering the age where regenerative braking will soon be common place in most cars, rather than an experimental luxury.

The Buck-Boost method of Regenerative braking is relatively simple, and not as complex or expensive as other methods, such as using ultra capacitors for storage, however using a dynamo during regenerative breaking, allows us to simulate and conceptualize how exactly basic regenerative braking can function. As Electrical vehicles become more commercial, as regenerative braking works with it, hand in hand, it is only a matter of time, before regenerative braking is implemented just about everywhere having another benefit of IOT being implemented and becoming more commonly used in both daily life appliances, and more complex tasks. Being implemented to show a basic rundown of the energy being spent in our own vehicles can give us some much needed perspective and understanding of our own usage, which will only become more relevant the further ahead we move with our technology.

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