Wireless DC Motor Speed Control

Senior Design Proposal

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Introduction

The title of our project is High-performance low-cost low-loss wireless DC motor speed control unit. Nowadays, there are lots of good-quality motor speed controls on the market. However, their costs are relatively high. A speed control with both low cost and good performance will be highly marketable, especially for small mobility applications. On the other hand, the wireless connectivity has a nature of low cost and less environmental limitations. Combining these ideas together, we came up with this project.

Objectives

The wireless remote controller is simple: start, stop, accelerate and decelerate. The source of the speed control is a 12 V battery and control currents over a range of 0 to 50 A. The controller has a high efficiency for motor loads in the range of 50 to 150 W. It should deliver the nominal power continuously and be able to tolerate slight overloading for a short period of time. For strong overloading, it should protect the motor from being damaged for a few seconds, then shut down the motor and request a reset from the user simultaneously. Finally, the total parts cost of the converter does not to exceed $12.

Benefits

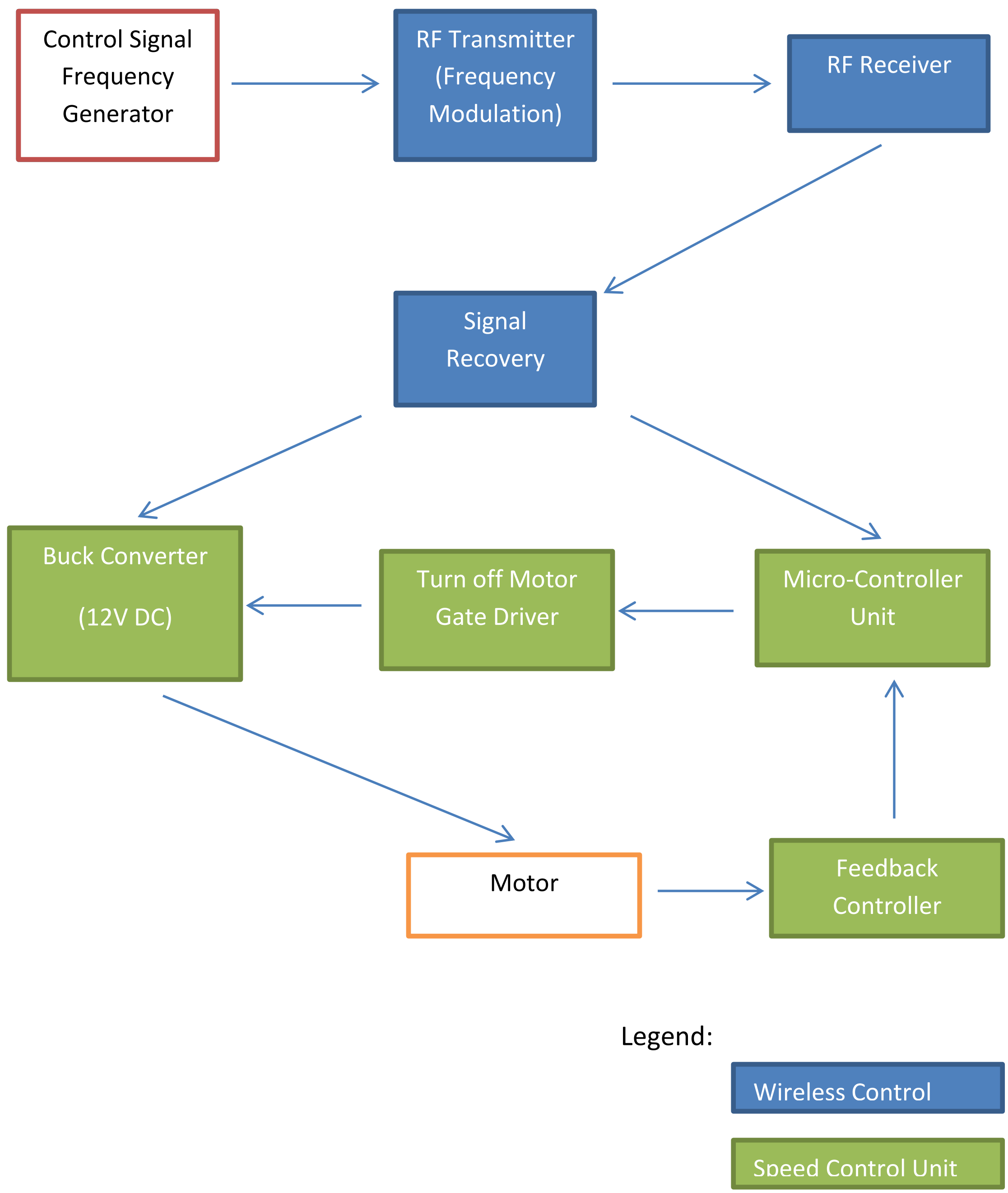
1. Low cost: each speed control unit costs no more than $12.
2. High performance: In standard input range, the motor has over 90% efficiency.
3. Self-protection: automatically shut down the motor when overloading is detected.
4. Less setup limitations: the wireless controller provides a high degree of freedom in terms of various range
5. Multiple unit control: one remote controller can control multiple motors if they are tuned to the same frequency channel.

Features

1. Able to control the speed of motor such as: small motorized shopping cart, luggage cart, electric golf bag cart
2. Wireless connectivity
3. Protection on potentially overloading motor
4. Simple turning knob for speed control

Design

Block Diagram



Block Descriptions

Control Frequency Signal Generator:

This circuit generates a square wave whose frequency and duty ratio are controlled by two variable resistors.

RF transmitter:

The transceiver chip will take the output from the function generator (square wave) and frequency modulates it with the carrier signal. The modulated signal is then sent through an antenna. The chip we plan to use is CC1120, a high performance low power RF transceiver made by TI.

RF receiver:

The same transceiver chip on the receiving end will pick up the desired signal, demodulate it and pass it to the signal recovery unit. This block might contain additional filters depending on the actual quality of the received signal.

Signal recovery:

This block contains Op-amps, CMOS inverters and linear amplifiers. The first stage Op-amp amplifies the demodulated signal to drive the CMOS inverters. The CMOS inverters then sort the signal to a rail-to –rail square wave. Finally, the linear amplifier amplifies the signal to the appropriate level to drive the speed control unit.

Buck Convertor:

The Buck Convertor takes a 12 V DC source as its input and output the DC voltage less than 12 V which controlled by the gate driver signal. The higher output voltage causes the higher speed on the motor. The Buck Convertor has two transistors; one is call “driver transistor” whose gate is controlled by the signal from the signal recovery, the other call “load control transistor” whose gate control by the output from the turn off motor gate driver. The load control transistor is always on except the motor has been overloading for 70 second.

Feedback Controller:

The feedback controller takes the voltage between a 0.1Ω current sense resistor which connect in series with the motor as its input. Since the overload power is defined as 200W, the overload voltage between the current sense resistor is 2 V. Therefore, a comparator is needed. Comparing the input of the feedback controller and 2 V, if the input is bigger than 2V, the feedback controller would output “1”, else output “0”.

Micro Controller:

We use the micro controller 16F887 to detect if the motor has been overload for a longer period such as 70 seconds. The Micro controller takes the two inputs from the output of the feedback controller and the signal from the signal recovery and generates a clock signal with frequency at 0.1 Hz. Moreover, the micro controller creates two set of states. The first set of states contains 8 states. If the input is “1”, it goes to the next state. If the input is “0”, it would go back to the first state. When it is on the last state, it outputs “1”, else it output “0”. The set of states contains two states. The initial state called “open”. When it read the signal from the signal recovery is “1”, the state move to the second state called “close” and the micro controller output “0” if the previous output is “1”. When it read the signal is “0”, a counter would increase by one. Whenever it read “1”, the counter would reset to zero. When the counter reaches twenty, the state moves back to “open” state.

Turn off Motor Gate Driver:

This driver takes the output of the micro controller as its input. When input is “1”, output “0”. Otherwise, it output high voltage to driver the load control transistor in buck convertor.

Performance Requirement:

1. Wireless controller should be able to perform: start, stop, accelerate and decelerate commands.
2. The speed control has at least 90% efficiency for motor loads in the range of 50 to 150 W.
3. It should deliver 150 W continuously, 250 W for at least one minute, and up to 50 A at 10 V or more for at least 5 seconds without damage.
4. If it is overloaded for a longer period, it should shut off automatically and require a reset by the user.

Special Circuit

No special circuit is required.

Verification

Testing procedure

1. Test the control signal frequency generator through an oscilloscope; observe if the output is a perfect square wave. Check if the duty cycle and frequency can be controlled by varying the variable resistor.
2. Check the waveform of the modulated signal with an antenna directly connected to the channel 1 of the oscilloscope. Connect the channel 2 to the receiving RF transceiver and see if the received waveform is the same. Also, perform this test in a hotter environment and see the noise is affecting the received signal quality. Since a running motor can produce additional thermal noise.
3. Check the processed signal waveform at each level of the signal recovery stage. The amplitude of the output at each stage should be large enough to drive the next stage. Most importantly, the final output signal strength should be amplified to two different levels in order to drive the microcontroller unit and the Buck converter respectively.
4. Setup a basic Buck converter, feed in a square wave from a function generator and see it reaches 90% power efficiency. Also check the overload requirements. If the requirements are not met, change to different resistors and capacitors until the requirements are fulfilled.
5. Connect the load controlled transistor to the buck converter in series with the motor. Check if it is able to shut down the motor.
6. Check the feedback control and see if we can output a digital 1 when the input is higher than 2V and a digital 0 otherwise.
7. Test the microcontroller unit, see if can detect the “open” state and “close” state.
8. Input a digital 1 as the output of the feedback controller to the microcontroller and see if it will output a digital 1 after 70 seconds.
9. Connect the Buck converter, motor, feedback controller, microcontroller and the turn off motor gate driver and check if the converter can meet all the specifications.
10. Assemble the entire project and see everything is working properly.
11. If all tests are passed, the product may still not meet the performance requirement perfectly because the circuit is very sensitive to temperature. However, due to the $12 budget as required, we cannot replace our circuit with less sensitive components because they are relatively expensive.

Tolerance Analysis

Since we have to deal with two overload cases which may damage our components. We have to setup up a specific testing plan for it. First, connect a thermometer on transistors in the Buck converter. Then, start on the 150W loading and run it for 5 minutes and record the temperature. Calculate the power lost on the transistors. Gradually increase the input power, record the temperature and calculate the power lost on the transistor for every 10W power increase. If the temperature rises too quickly, shut down the circuit immediately and modify components to achieve higher overloading tolerance. By testing the 500W case, replace the motor by power resistor and see if the circuit meets the requirement because in this case, there will be 50A of current going through the load which may damage the motor.

Cost and Schedule

Cost Analysis

1. Labor

   Jing Y. Guo: ($30/hr) x (15hr/week) x (9weeks) = $4050

   Yu Qiao: ($30/hr) x (15hr/week) x (9weeks) = $4050

2. Parts

Parts	Quantity	Total
CC1121	2	$3.30
UC3843	1	$1.32
16F887	1	$2.69
LF347	4	$1.24
2N6508	2	$3.32
LME49990	1	$1.75
1N4001	6	$0.12
Total		$13.74

3. Grand Total

   Grand Total = $4050 * 2 + $13.74 = $9134.74

Date	Tasks		Person in Charge
2/6	Prepare for proposal	Yu Qiao	Yu Qiao
	Prepare for proposal	Jing Guo	
2/13	Design schematics and research on transceiver implementation	Yu Qiao	Jing Guo
	Calculate the value of component	Jing Guo	
2/20	Complete all the initial design and prepare for design review	Yu Qiao	Yu Qiao
	Order parts	Jing Guo	
2/27	Implementing transceiver chip for TX	Yu Qiao	Jing Guo
	Built the control frequency circuit	Jing Guo	
3/5	Implementing transceiver chip for RX and design additional filter if necessary	Yu Qiao	Yu Qiao
	Built the buck convertor	Jing Guo	
3/12	Testing the quality of the TX and RX signal and make adjustments	Yu Qiao	Jing Guo
	Built the feedback control circuit	Jing Guo	
3/19	Spring Break and assist Jing if needed	Yu Qiao	Yu Qiao
	Combine the convertor with feedback control and control frequency	Jing Guo	
3/26	Sign up for Mock presentation Tweak the amplifier configuration	Yu Qiao	Jing Guo
	Program the micro controller	Jing Guo	
4/2	Continue signal recovery	Yu Qiao	Yu Qiao
	Connect the micro controller to the circuit and check if the function is working or not	Jing Guo	
4/9	Testing and improving	Yu Qiao	Jing Guo
	Combine the top level circuit	Jing Guo	
4/16	Assemble the product	Yu Qiao	Yu Qiao
	Test the requirements, and change part if necessary	Jing Guo	
4/23	Demo and prepare for presentation	Yu Qiao	Jing Guo
	Create presentation	Jing Guo	