

ELECTRONIC DIFFERENTIAL MOTOR CONTROLLER (EDMC)

FOR ELECTRIC VEHICLES WITH TWO INDEPENDENTLY DRIVEN WHEELS

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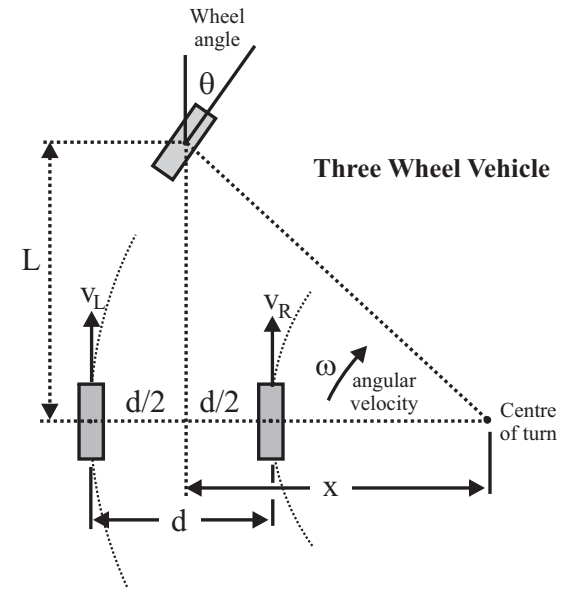
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Electronic Differential Introduction

In an electric vehicle where two or more motors are used to provide the driving force, some means needs to be provided to take into consideration that the two motors need to be driven at different speeds when turning. Such a situation is shown on the right for the case where the two rear wheels have two independently driven motors and the steering is accomplished by a free single wheel. This situation is commonly known as the trike configuration.

The question is, what should be the different speeds of the two wheels and hence the speeds of the two motors when turning? This depends on the geometry of the wheel arrangement and the angle at which the steering wheel is turned. The diagram shows the various distances involved. When turning, all wheels should follow a circular path with the same centre of rotation. The mathematics involved are as follows where V_L and V_R are the speeds of the two driven wheels.



$$V_L = \omega \left(x + \frac{d}{2} \right) \dots\dots\dots(1)$$

$$V_R = \omega \left(x - \frac{d}{2} \right) \dots\dots\dots(2)$$

$$x = \frac{L}{\tan\theta} \dots\dots\dots(3)$$

Substituting equation (3) into (1) and (2),

$$V_L = \omega \left(\frac{L}{\tan\theta} + \frac{d}{2} \right) \dots\dots\dots(4)$$

$$V_R = \omega \left(\frac{L}{\tan\theta} - \frac{d}{2} \right) \dots\dots\dots(5)$$

The ratio of,

$$\boxed{V_L / V_R = \left(\frac{L}{\tan\theta} + \frac{d}{2} \right) / \left(\frac{L}{\tan\theta} - \frac{d}{2} \right) \dots\dots\dots(6)}$$

As an example, if $d = 1.0$ m, $L = 2.0$ m and $\theta = 45^\circ$, then using equation (6),

$$V_L / V_R = \left(\frac{2}{\tan(45)} + 0.5 \right) / \left(\frac{2}{\tan(45)} - 0.5 \right) = 1.7$$

This means that if the front steering wheel is turned by an angle of 45° to the right, then the speed of the left driven wheel should be 1.7 times greater than the right driven wheel. The same situation exists when turning left but it is the right wheel whose speed should be greater by the calculated ratio.

Electronic Differential Introduction continued

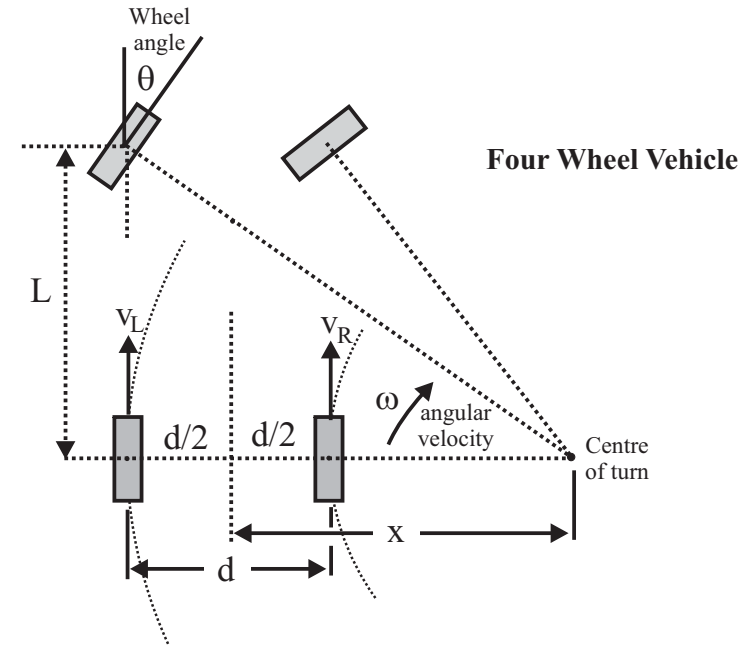
Following a similar approach to that used earlier, the ratio of the speeds in the case of four wheels (two rear wheels driven independently and two front steering wheels), the ratio of the two speeds is given by,

$$\frac{V_L}{V_R} = \frac{L}{L - d \tan(\theta)}$$

As an example, if $d = 1.0$ m, $L = 2.0$ m and $\theta = 45^\circ$, then using the above equation,

$$V_L/V_R = 2.0$$

In this situation therefore, the speed of the left wheel should be 2.0 times greater than that of the right wheel. The same situation exists when turning left but it is the right wheel whose speed should be greater by the calculated ratio.



Electronic differential implementation in the case of a Trike Configuration

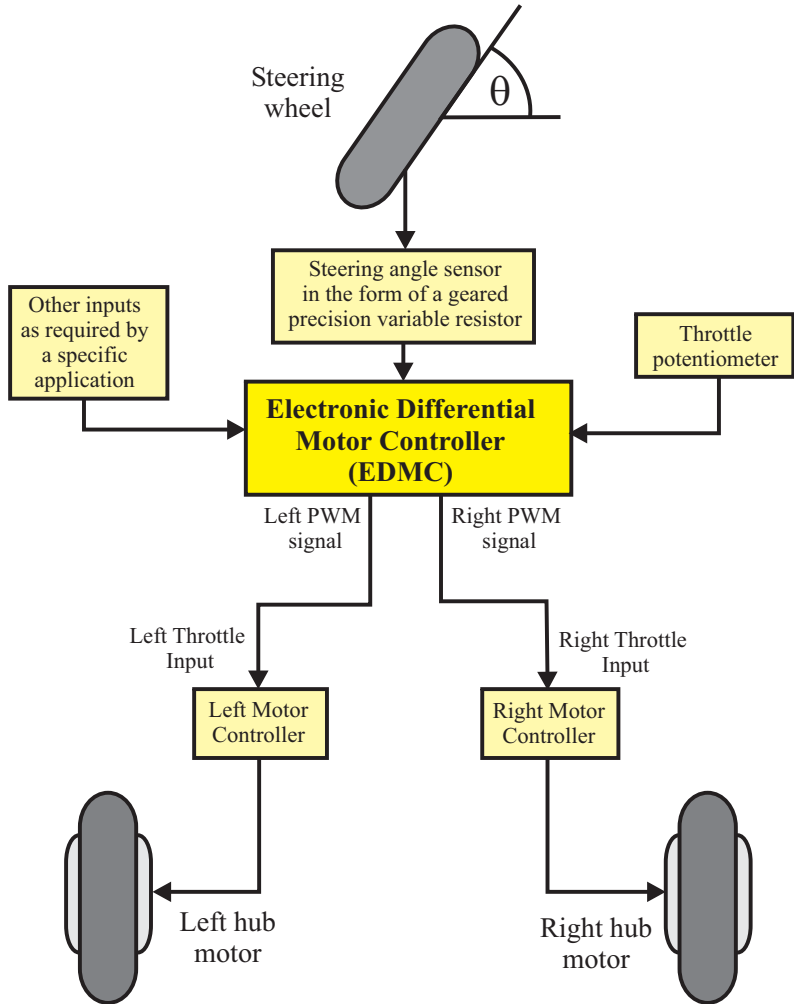
The diagram on the following page shows the general principles involved in implementing an electronic differential system in the case of a trike configuration where two DC permanent magnet hub motors are used. The Electronic Differential Motor Controller (EDMC) carries out the following basic tasks:

- Reads the calibrated steering angle potentiometer voltage and based on this it then calculates the steering angle and also determines whether the vehicle is moving straight, turning left or right.
- Reads the throttle potentiometer voltage so that the desired vehicle speed is known.
- Based on the above information, the ratio of the two speeds V_L/V_R is calculated using the appropriate equation such as Equation (6) shown earlier (previous page).
- A separate Pulse Width Modulated (PWM) signal is then applied to each of the two motors in accordance with the required speed ratio.
- The above sequence is repeated at an extremely fast rate so that the EDMC continues to make adjustments on a continuous basis.

The EDC can also be programmed to incorporate the following:

1. Stability control such that when the speed is too high for a particular steering angle, the motors are automatically driven at some lower safe speed.
2. Cruise control.

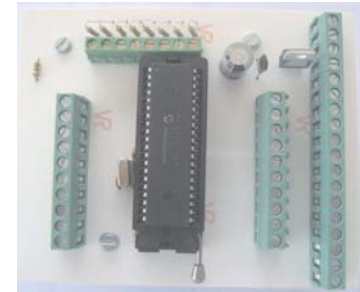
General principles involved in implementing an electronic differential system



Steering Angle Sensor



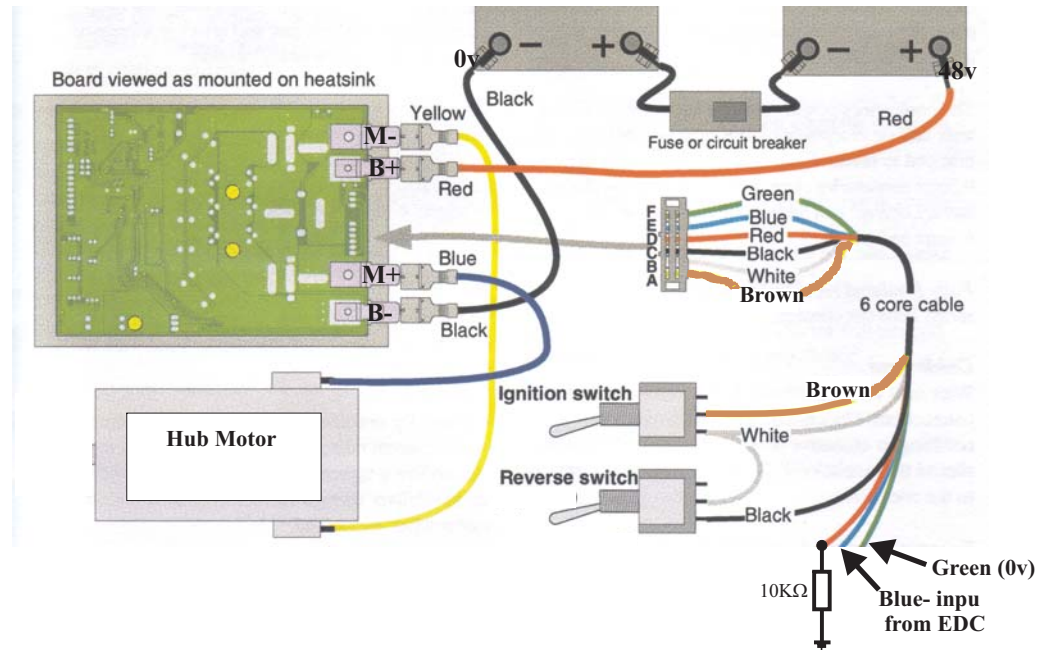
Electronic Differential Controller (EDC) PCB



Hub Motor



4QD Pro-150 Digital Motor Controller



Practical Examples in the use of an Electronic Differential System

The pictures below show a solar car which is under development . The EDMC previously described is in the process of being incorporated.

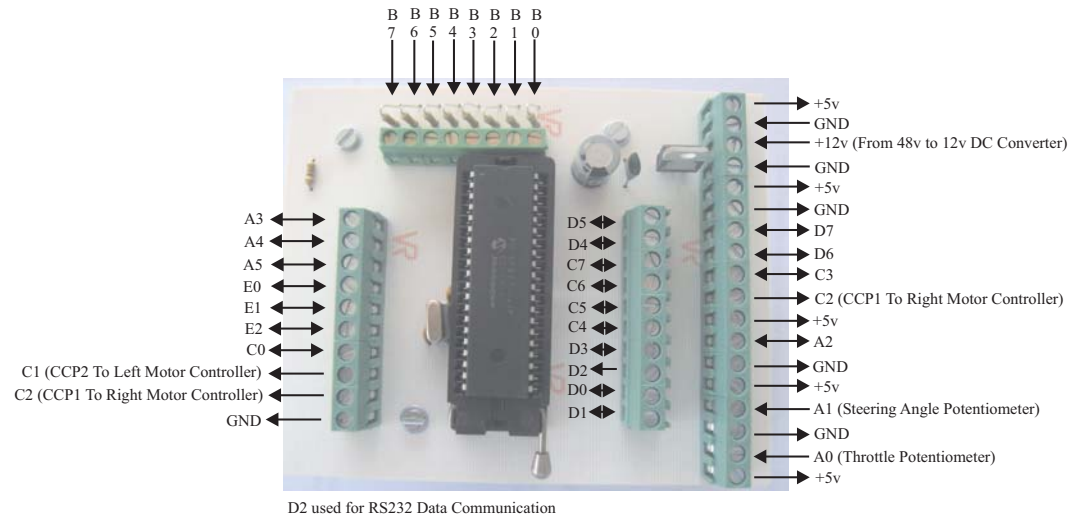


The EVT 345 Trike, shown on the left, is claimed by some suppliers (not the manufacturer) as having an electronic differential system. In actual fact, all it has is a speed limiter when turning and not the sort of system described here. If it did use the system described here, a significant performance improvement would be expected.

As a matter of interest, the same hub motors used on the EVT trike have been used on the solar car shown above.

Present Status and Availability of the Electronic Differential Motor Controller (EDMC)

Currently the EDC is in its prototype form as shown below.



Bench testing has been successfully completed and extensive tests under full load conditions are in progress. It is expected that the product will be available to customers within the next three weeks. It is anticipated that the product will be offered to customers in two possible versions:

EDMC1 version

This version will consist of the Electronic Differential Motor Controller preprogrammed in accordance with the information provided by the customer. The information to be provided will be the distances L and d and whether the application involves a three or four wheel configuration. The EDMC1 package will include the gears and the precision potentiometer which are to be used to form the steering angle sensor. It is the customer's responsibility to mount this appropriately and in accordance with the information which is to be given in the EDMC1 User Manual.

EDMC2 version

This version will include, in addition to the above an LCD and a Keypad mounted onto the EDMC such that the customer can enter the required data through a menu-driven software. This would allow the customer to experiment with different dimensions if so desired. In addition, the LCD display will continuously display the appropriate calculated speed ratio and the PWM signal levels being applied to the two motor controllers. This version will also allow minor speed adjustments to be made to compensate for minor differences in the speed characteristics of the two motors.

Other versions

Other customized versions could be made available for volume customers.

Prices

The price of the two versions is under review but would be expected to be around £70.00 for the EDMC1 and around £99.00 for the EDMC2.