

## D.C. Motor Speed Control using the ZTX450

### Introduction

The function of the following circuit is to improve the load/speed regulation of a d.c. machine. One of the main reasons why the speed of a permanent magnet field d.c. motor varies with load, is that a voltage drop is current and hence load dependent. The circuit given in Figure 1 stabilises the speed of the motor by cancelling out the effect of the motor rotor resistance using a bridge circuit.

### Theory

If the bridge and variable resistor are analysed on their own (Figure 2), a proof can be derived which shows that the control voltage (i.e. the speed) is not directly dependent on the motor current. (Please refer to Appendix).

The value of  $r_a$  varies from motor to motor, so the bridge must be balanced to suit the motor employed.

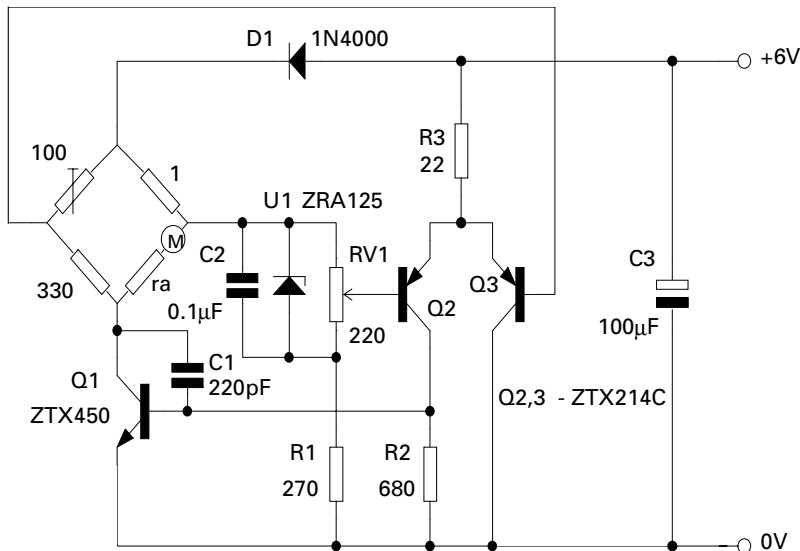
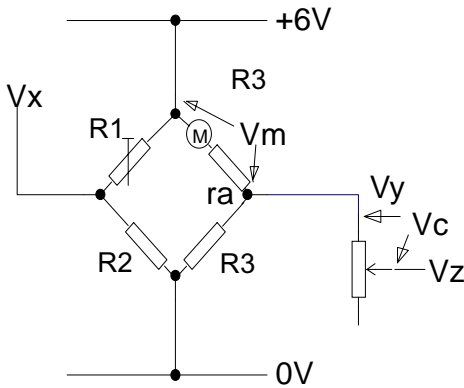


Figure 1  
DC Motor Speed Control Circuit.

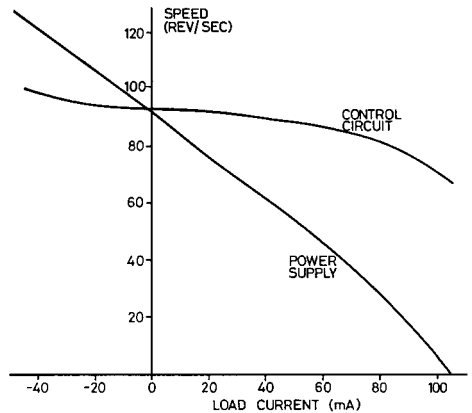


**Figure 2**  
**Bridge Circuit.**

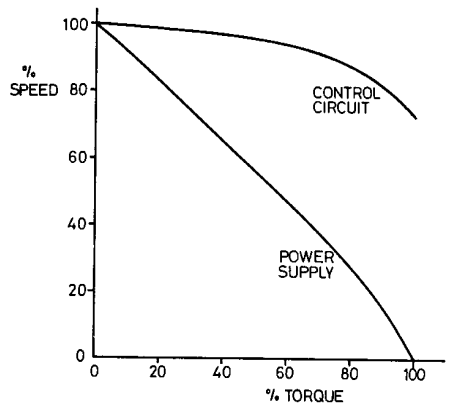
This can be done by calculation and measurement of the motor resistance, or by adjusting the value of the  $100\Omega$  preset resistor until the motor speed just becomes unstable and then backing off a fraction.

The current/speed and torque/speed characteristics of a test motor have been plotted in Figures 3 and 4, with and without the control circuit, to show the improvement in speed stability. Variations in motor speed due to supply changes are also greatly reduced by the circuit. On the test motor a speed change of  $\pm 2\%$  was recorded for a supply change of  $\pm 20\%$ .

Larger motors can be accommodated by using higher current capable transistors, such as the ZTX689B - a high gain, 2A DC rated device, or the ZTX869 - a high gain 5A DC rated transistor.



**Figure 3**  
**Current/Speed Characteristics of a Test Motor.**



**Figure 4**  
**Torque/speed Characteristics of a Test Motor.**

## Appendix

### Derived Proof

$$V_x = [V_m + I_m R_3] \times \frac{R_2}{R_1 + R_2} \quad \dots 1$$

$$V_y = I_m R_3 \quad \dots 2a$$

$$V_z = V_y + V_c = I_m R_3 + V_c \quad \dots 2b$$

$$\text{but } V_m = V_a + I_m r_a$$

substituting in 1.

$$V_x = [V_a + I_m r_a + I_m R_3] \times \frac{R_2}{R_1 + R_2} = [V_a + I_m(r_a + R_3)] \times \frac{R_2}{R_1 + R_2} = \frac{V_a R_2}{R_1 + R_2} + I_m R_2 \frac{(r_a + R_3)}{R_1 + R_2}$$

now  $V_x = V_z$  (1st assumption)

$$\text{so } V_z = \frac{V_a R_2}{R_1 + R_2} + I_m R_2 \frac{(r_a + R_3)}{R_1 + R_2}$$

$$\text{from 2b } V_z = I_m R_3 + V_c$$

$$V_c + I_m R_3 = \frac{V_a R_2}{R_1 + R_2} + I_m R_2 \times \frac{r_a + R_3}{R_1 + R_2}$$

Dividing by  $R_3$  gives

$$\frac{V_c}{R_3} + I_m = \frac{V_a R_2}{R_3(R_1 + R_2)} + I_m R_2 \frac{r_a + R_3}{R_3(R_1 + R_2)}$$

$$\frac{V_c}{R_3} + I_m = \frac{V_a R_2}{R_3(R_1 + R_2)} + I_m \left[ \frac{R_2 r_a + R_2 R_3}{R_1 R_3 + R_2 R_3} \right]$$

now  $R_1 R_3 = r_a R_2$  (2nd assumption)

$$\frac{V_c}{R_3} + I_m = \frac{V_a R_2}{R_3(R_1 + R_2)} + I_m$$

$$V_c = \frac{V_a R_2}{R_1 + R_2}$$