# SPEED CONTROL OF DC MOTORS WITH THE L292 SWITCHMODE DRIVER

*Power dissipation in DC motor drive systems can be reduced considerably with an L292 switchmode driver. This application guide describes two speed control systems based on this device; one voltage controlled and one controlled by a 6-bit binary word. Both examples are designed for 60W motors equipped with tacho dynamos.*

The L292 is a monolithic power IC which functions effectively as a power transconductance amplifier. It delivers a load current proportional to an input voltage, handling up to 2A at 18-36V with a bridge output stage. Completely self-contained, it incorporates internal switchmode circuitry and all the active components to form a current feedback loop.

The L292 is designed primarily for use with an L290 and L291 in DC motor servopositioning applications. However, the L292 can be useful in a wide range of applications as the two examples here show. The first is a simple tachometer feedback circuit, the speed of which is controlled by a DC voltage; direction is controlled by the polarity of this voltage. The second circuit is controlled digitally and includes an L291 D/A converter.

## SYSTEM WITH DC CONTROL

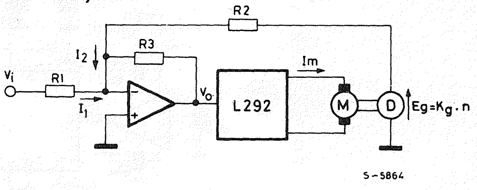
In this system the control quantity is a dc voltage variable between

$$+V_{iM} \text{ and } -V_{iM}$$

Since the quantity under control is the speed of the motor, it is required that it varies linearly in function of the control voltage.
A simplified circuit diagram of the system is shown in fig. 1.

The current $I_1$, proportional to the set voltage $V_i$, and the current $I_2$, proportional to the speed of the motor, are fed to the sum point of the error amplifier. Assuming that the motor does not drain current, the system is in a steady-state condition whenever $I_1 = -I_2$; as a matter of fact, in this case the output from the error amplifier $V_o$ is 0V. During transients, the voltage $V_o$ will assume a value $V_o = -R3\,(I_1 + I_2)$ and consequently, since the L292 integrated circuit operates as a transconductance ($G_m$), a mean current $I_m = G_m \cdot V_o$ will flow in the motor determining an acceleration proportional to it.

*Fig. 1 - Simplified circuit diagram of DC control system*



**Calculation of R1, R2, R3**

Let us call:

| | |
|---|---|
| $V_{iM}$ | the maximum control voltage value |
| $n_M$ | the maximum speed allowed for the motor |
| $K_g$ | voltage constant of the dynamo |

By imposing that the balance condition be met in correspondance to the maximum rotation speed the following equation is obtained:

$$I_1 = -I_2 ; \quad \frac{V_{iM}}{R1} = -\frac{K_g \cdot n_M}{R2}$$

Since R2 is the impedance which the tachometer dynamo is loaded on to and its value is recommended by the manufacturer, it is possible from the previous relationship to determine the value of R1.
Resistor R3 determines the system gain. It's best to keep the gain as high as possible (and consequently R3 as high as possible) to obtain a high response speed of the system, even for small variations in the control voltage. On the other hand, an excessive gain would cause excessive overshoot around the balance conditions at the end of transients. Consequently, a trade-off must be made between the two opposing requirements in select-

ing the final gain. The value for R3 should be theoretically determined by studying the transfer function, by knowing the electrical and mechanical constants of the motor as well as the load applied to it.

A complete diagram of the circuit actually realized is shown in fig. 2, while fig. 3, shows the characteristic $n = f(V_i)$ obtained.

Resistor R2 drawn in the simplified circuit diagram has been split here in two parts and, in addition, a capacitor has been interposed to ground to filter the signal coming from the tachometer dynamo.

The curve n. 1 in fig. 3 refers to the operation of the motor in no-load condition, with a current drain of 200 mA; the curve n. 2 refers to a motor loaded so as to drain a current of 1A. By disregarding the discontinuity around the origin, it can be noted that the characteristics are linear over the whole control voltage range.
By analyzing the curves around the origin, it can be noted that the motor stands still as long as the input signal does not exceed a certain threshold level, which is as much higher as the current drained by the motor is higher.

Let us call $G_m$ the transconductance of L292, and I the starting current of the motor; the voltage which must be available at the input of L292 in order that the motor starts turning is:

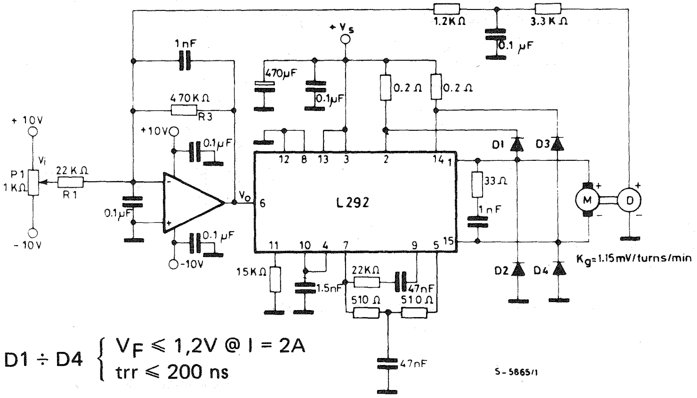
$$V_o = \frac{I}{G_m} \text{ with } G_m = 220 \frac{mA}{V} \text{ (typical value)}$$

The corresponding control voltage will be:

$$V_i = V_o \cdot \frac{R1}{R3} = \frac{I}{G_m} \cdot \frac{R1}{R3}$$

and it is as much lower as the gain of the error amplifier is higher.
The presence of a control voltage interval in which the motor stands still, can be useful when it is required that, for a certain position of potentiometer P1 (see fig. 2), the motor speed be zero. An other method to hold the motor still is to use the inhibits of L292, for instance by grounding pin 13.

*Fig. 2 - Complete circuit diagram*



$$D1 \div D4 \left\{ \begin{array}{l} V_F \leqslant 1{,}2V \text{ @ } I = 2A \\ trr \leqslant 200 \text{ ns} \end{array} \right.$$

It can be noted from fig. 3 that, by keeping the control voltage $V_i$ constant, the speed varies according to the motor current drain.
Let us call $\Delta I$ the current variation; the voltage variation required at the input of L292 is

$$\Delta V_o = \frac{\Delta I}{G_m}$$

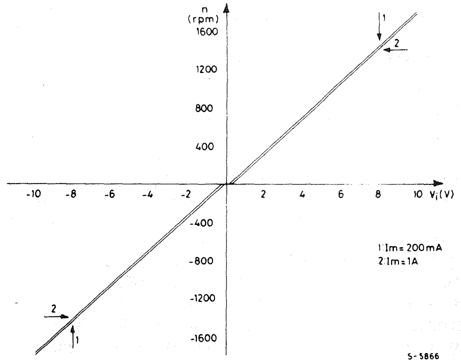
since the control voltage is constant, to generate this $\Delta V_o$ it is necessary that the rotation speed be varied by a quantity $\Delta n$ such as to have:

$$K_g \cdot \Delta n \cdot \frac{R3}{R2} = \Delta V_o = \frac{\Delta I}{G_m}$$

$$\Delta n = \frac{\Delta I}{G_m \; K_g} \cdot \frac{R2}{R3}$$

($\Delta I$ shall be taken with its sign)

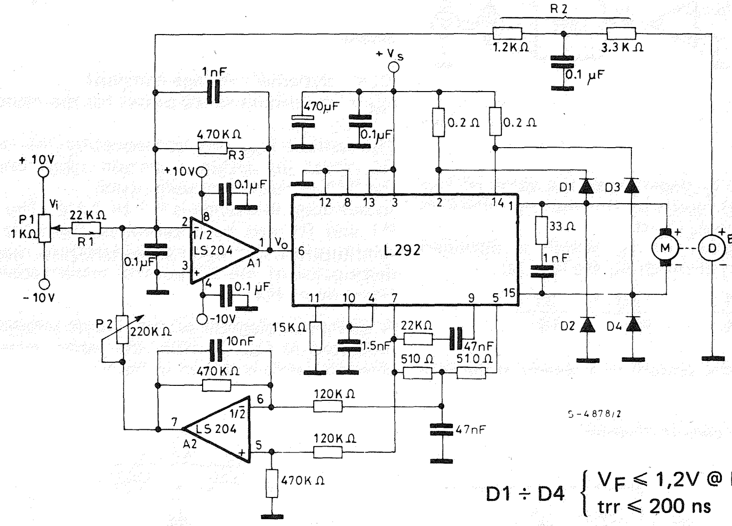
*Fig. 3 - Output characteristics of the circuit in fig. 2*



In this case too, the variation Δ n is as much lower as the error amplifier gain is higher. With the circuit shown in fig. 2 Δ n is approximately 30 turns/min. with Δ I = 800 mA, Δ n = 0.037 turns/mA.min approx.

It is possible to adopt a circuit which prevents the variation in the number of turns in function of motor current. The problem is to "sense" the current flowing through the motor and to send a current proportional to it to the sum point of the error amplifier. The complete circuit which includes, beside the voltage feed-back loop, also a current feed-back loop, is illustrated in fig. 4.

*Fig. 4 - Complete circuit with current feedback*



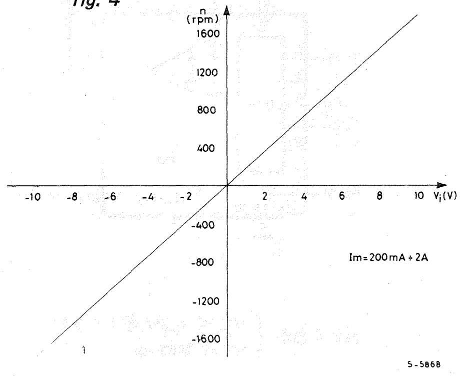
$$D1 \div D4 \begin{cases} V_F \leqslant 1{,}2V @ I = 2A \\ trr \leqslant 200 \text{ ns} \end{cases}$$

In the integrated circuit L292, a current proportional to the mean current drained by the motor flows between pin 5 and pin 7.
An operational amplifier amplifies the voltage drop provoked by this current across a 510 Ω resistor and sends a current to the sum point which is consequently proportional to the mean current in the motor, the value of which can be made vary by acting on potentiometer P2. By properly adjusting P2, a condition can be achieved in which the speed does not change when the current drained by the motor varies.

The discontinuity around the origin, which was present in the previous circuit (fig. 2), is practically negligible in the circuit shown in fig. 4.

The characteristic n = f ($V_i$) relevant to the circuit of fig. 4 is shown in fig. 5, and this characteristic does not substantially change over the whole range of currents allowed by the L292 (up to 2A).
In the circuit described above if the motor stall condition is requested. it is preferable to act on the inhibits of the integrated circuit L292, for instance by grounding pin 13, instead of adjusting potentiometer P1: as a matter of fact, the exact position of this potentiometer is difficult to obtain, since the characteristic crosses the axis $V_i$ in one only point (this means that n is only 0 for a very narrow interval of $V_i$).

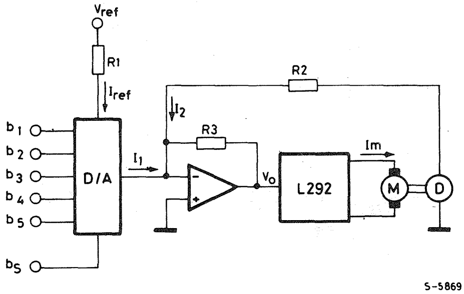
*Fig. 5 - Output characteristic of the circuit in fig. 4*



## SYSTEM WITH DIGITAL CONTROL

In this system the speed information is given to the circuit by a binary code made up of 5 information bits plus one sign bit, which determines whether the movement shall be clockwise or counterclockwise. For the circuit implementation, the integrated circuits L291 (which includes a D/A converter and two operational amplifiers) and L292 are used.
A simplified circuit diagram is shown in fig. 6.

*Fig. 6 - Simplified circuit diagram (digital control)*



The current value $I_1$ depends on the value of $I_{ref}$ and on the value of inputs $b_1$ through $b_5$, where its sign depends on the $b_S$ input.
The maximum value for $I_1$, which is obtained whenever inputs $b_1$ through $b_5$ are low, is:

$$I_{1\,max} = I_{ref}\frac{31}{16} = \frac{V_{ref}}{R1}\cdot\frac{31}{16}$$

In order to have the system in a steady state condition (no current drained by the motor), it must be:

$$I_1 = -I_2$$

By imposing the balance condition at the maximum speed, one obtains: $I_{1\,max} = -I_{2\,max}$

$$\frac{V_{ref}}{R1}\cdot\frac{31}{16} = -\frac{K_g\,n_M}{R2}$$

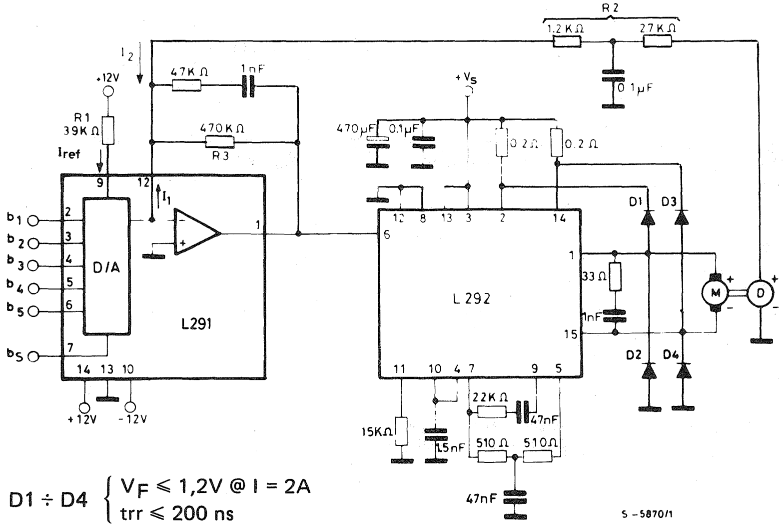
where

$K_g$ = dynamo's voltage constant
$n_M$ = maximum speed preset for the motor.

The current $I_{ref}$, and consequently the ratio $V_{ref}/R1$, must lie within a certain range imposed by the D/A converter actually used.
In our case, this range is 0.3 to 1 mA. The values of R1 and R2 can be determined from the previous relationship. The same considerations made in the description of the DC control system apply for the selection of R3.

A complete diagram of the circuit implemented is indicated in fig. 7, while the input versus output characteristics is shown in fig. 8.

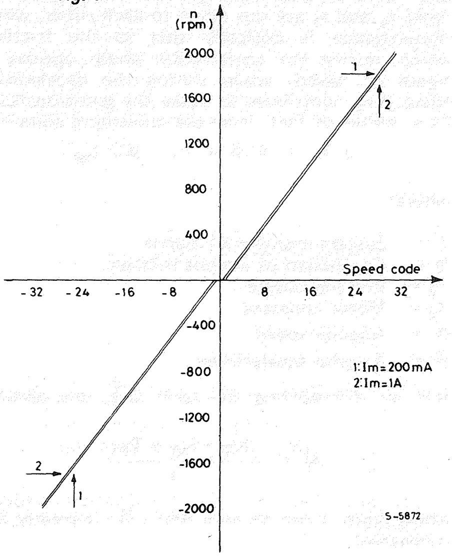
*Fig. 7 - Complete circuit diagram*



$$D1 \div D4 \begin{cases} V_F \leqslant 1{,}2V\ @\ I = 2A \\ trr \leqslant 200\ ns \end{cases}$$

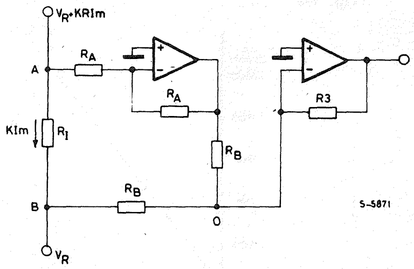
In the graph of fig. 8 the rotation speed of the motor is represented on ordinates, while the decimal speed code, corresponding to the binary code applied to inputs $b_1$ through $b_5$, is represented on abscissae.
The abscissa 1 corresponds to the minimum speed code, i.e. input $b_1$ low and remaining inputs high, since the least significant input is $b_1$ and the active status of inputs is low. The abscissa 31 corresponds to the maximum speed code, i.e. all inputs $b_1$ through $b_5$ low. The negative abscissae have been obtained by changing the status of the $b_S$ input. The graph in fig. 8 should have been made up of a number of dots; these dots have been joined together with an ininterrupted line for convenience. This graph has the same features as the graph in fig. 3, i.e. the curve features a discontinuity around the origin, and it lowers as long as the motor current drain increases. In this case too, the circuit in fig. 7 can be modified in order to

*Fig. 8 - Output characteristic of the circuit in fig. 7*



prevent that the speed vary in function of the motor load, by adding a current loop in the control circuit, by using the remaining operational amplifier available in the integrated circuit L291.
Since this amplifier has only the inverting input available, while the non-inverting input is grounded, a circuit arrangement as schematically shown in fig. 9 has been adopted in order to have an output signal referred to ground, given an input signal referred to a reference voltage (in L292) of approximately 8V.

*Fig. 9 - Translator circuit*

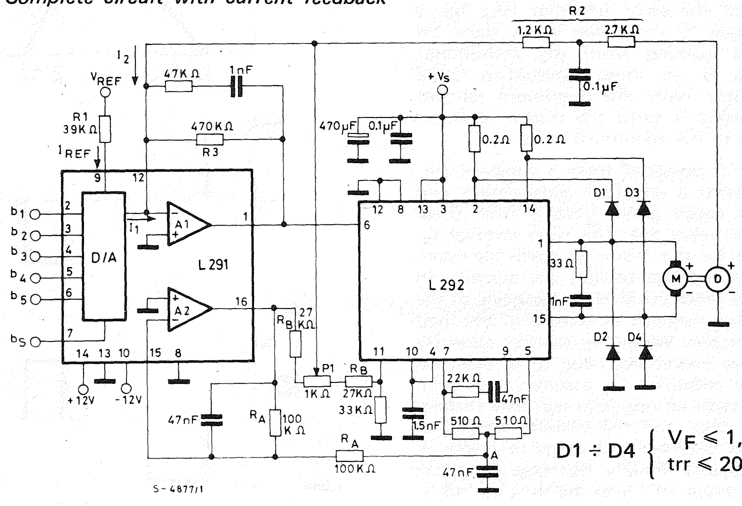


Resistors $R_A$ and $R_B$ must be high-precision resistors in order to have output 0 with no $I_m$ current present. In the practical implementation, resistors with an accuracy of 5% are used and the ends of a potentiometer are interposed between resistors $R_B$ and the output to the sum point of the error amplifier is made through the cursor. The gain of this current loop is proportional to the ratio $R3/R_B$. A complete circuit diagram is shown in fig. 10.

Since, for reasons of gain, resistor $R_B$ must be 27 kΩ and, if connected to pin 7 of L292, should have subtracted too much current by thus affecting the correct operation of L292, it has been connected to pin 11, having the same potential as pin 7. Consequently, the resistance value between pin 11 and ground has been modified, in order to maintain the switching frequency of L292 unchanged. In order to have a correct adjustment of potentiometer P1, it is enough to set the 0 speed code ($b_1$ through $b_5$ high) and turn the cursor until the motor stops.

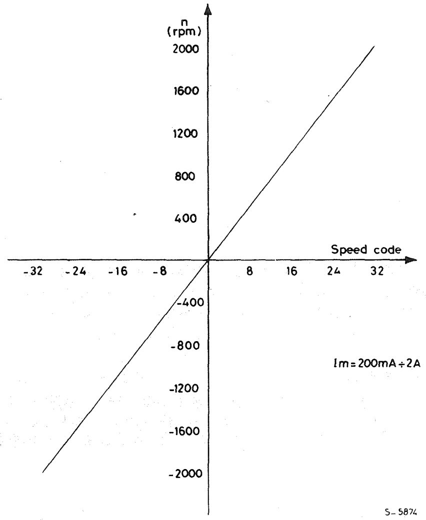
The input versus output characteristic obtained with the circuit of fig. 10 is indicated in fig. 11.

*Fig. 10 - Complete circuit with current feedback*



D1 ÷ D4 { $V_F \leqslant 1{,}2V$ @ I = 2A
trr ⩽ 200 ns

*Fig. 11 - Output characteristic of the circuit in fig. 10*



## RESPONSE TO INPUT STEP

Measurements have been taken on the circuits described in the previous paragraphs, in order to analyze how the motor speed varies when a step variation is imposed to the input.

For the system DC control, the control voltage has been changed from 0 to the maximum value $V_{iM}$ and down to 0 again. For the digital system the speed code has been changed from 0 ($b_1$ through $b_5$ high) to the maximum value ($b_1$ through $b_5$ low) and down to 0 again. When the control quantity changes from 0 to the maximum value, the output voltage of the error amplifier ($V_o$, fig. 1 and fig. 6) assumes its maximum value, since the feed-back signal coming from the tachometer dynamo initially 0. In these conditions, L292 supplies the motor with the maximum current (2A) and maintains it until the motor speed is sufficiently close to the maximum value.

Since the motor is powered from a constant current, it moves with a constant acceleration and consequently its speed grows linearly from 0 up to the maximum value over the time interval $t_a$. The time needed for the motor to reach the maximum speed also depends, besides the current, on the electrical and mechanical characteristics of the motor and on the moment of inertia of the load applied to the motor. When the control quantity changes from the maximum value to 0, the output of the error amplifier $V_o$ assumes the maximum value, but with an opposite sign with respect to the previous case, and the current flowing in the motor is also reversed and tends to brake it, by making the speed linearly decrease from the maximum value down to 0 over the time period $t_f$.

The no-load characteristics, relevant to the motor used for the previous tests, are shown in fig. 12. The times $t_a$ and $t_f$ are not equal to each other, which circumstance is basically due to the frictions which, during the acceleration phase, oppose increase of speed, while during the deceleration phase they contribute to make the speed decrease. As a matter of fact, from the movement equation:

$$J\ddot{\Theta} + D\dot{\Theta} + T_f = K_T I_M$$

where:

$J$ = System moment of inertia
$D$ = Coefficient of viscous friction
$T_f$ = Braking couple
$K_t$ = Motor constant
$\dot{\Theta}$ = Angular speed
$\ddot{\Theta}$ = Angular acceleration

and by disregarding the term $D\ddot{\Theta}$, one obtains:

$$\ddot{\Theta} = \frac{K_T \cdot I_M - T_f}{J}$$

where from it can be seen that $|\ddot{\Theta}|$ is greater if $I_M$ is negative.

*Fig. 12 - Pulse response*