

## How to Select a DC Micromotor

Selecting a DC motor for a particular application can be a rather involved process and should be done in close consultation with MicroMo's applications engineers. However, it is often useful to be able to "ballpark" a motor selection on one's own. A few rules relating to the physics and the practical application of motors should be kept in mind:

The major constraint on motor operation is thermal in nature. The heat a motor must dissipate can always be calculated as follows:

$$P_{dis} = I^2 \times R$$

Heat dissipated= current through the motor squared, multiplied by the terminal resistance.

The current through a motor is solely determined by the torque the motor produces. Current and torque are related by the torque constant of the motor.

$$I = \frac{M_o}{k_M}$$

Current through motor = torque produced divided by the torque constant

### Further Considerations:

- The constant current operation of a DC motor produces constant output torque regardless of speed.
- Given a constant load (i.e. torque) the speed of a motor is solely dependent on the voltage applied to the motor.
- Power is the product of speed and torque. The maximum power of a DC motor is produced at the operating point that is defined by operation at half the no-load speed and half the stall torque. Seldom will a motor be operated at maximum output due to thermal considerations.
- The general rule of thumb for operation of a DC micromotor is to operate the motor at approximately 90% of its no-load speed and from 10% to 30% of its stall torque. This is also the motor's most efficient area of operation.
- For use with gearing, the motor should be selected for the minimum speed practical by choosing a motor with higher voltage ratings than the available voltage supply. This will result in lower noise generation and better life characteristics.
- For DC motors operated at a constant voltage, the speed and torque produced are inversely related. The higher the torque produced, the lower the speed of the motor will be.
- Other factors, of course, enter into the selection of an appropriate motor. Such factors may include size, environmental conditions, weight, required life, etc. As an example, assume the following application parameters:

### Initial Motor Choice Parameters:

- Available voltage (V) = 20 Volts DC
- Output torque required (M) = .425 oz-in
- Output speed required (n) = 5,000 rpm
- Minimum physical size is desirable
- Ambient Temperature= 22°C

Given these parameters, it is unlikely that a standard catalog motor will fulfill all parameters simultaneously since they are not independent. The selection process consists of finding the best fit.

As a first step, determine the required output power as follows:

$$P_o = \frac{n \times M}{1350}$$

\*1350 is a units conversion factor

$$P_o = \frac{5000 \times .425}{1350}$$

$$P = 1.57 \text{ Watts}$$

The motor should be rated at least 1.5 to 2 times the desired output power in relation to its maximum output power (at nominal voltage). A motor with approximately 2.4 to 3.2 Watts maximum output power should suffice. Referring to the MicroMo catalog, the smallest motor to achieve this power rating is the 1331 series (13mm diameter x 31mm long). The 24 Volt version is closest to the desired operating voltage (20 volts). To find the no-load speed, a good first approximation is simply to ratio the voltages and speeds.

$$n_{20} \cong \frac{20}{24} \times n_0$$

Then:

$$n_{20} \cong \frac{20}{24} \times 11,400 \cong 9500 \text{ rpm}$$

Since our desired speed is 5,000 rpm, this represents only 53% of the no-load speed (at 20 Volts). Unless size is of paramount importance, this motor (1331T024S) is not a great choice even though it can provide the power required. The next selection from the catalog which meets the power requirements is the series 2230 motor (22mm diameter and 30mm long) and the selection would again be the 24 Volt version (2230T024S). The pertinent data for this motor is as follows:

- $n_0 = 9,000$  rpm (at 24 Volts)
- $I_0 = 0.005$  A
- $R = 50$  Ohms
- $K_M = 3.59$  oz-in/A
- $P_0 = 2.88$  Watts

The approximate no-load speed at 20 Volts would be:

$$n_{20} \cong \frac{20}{24} \times 9000 \cong 7500 \text{ rpm}$$

The desired speed is 67% of the no-load speed, and even though its not quite 70%, it is worth continuing the selection process.

The current through the motor will be the sum of the load current and the no-load current, where:

- $I_m =$  current through the motor
- $I =$  current due to load
- $M =$  desired torque
- $I_0 =$  no-load current
- $k_m =$  torque constant

$$I_m = I + I_0$$

Since  $I = M/k_m$

$$I_m = \frac{M}{k_m} + I_0$$

Then:

$$I_m = \frac{.425}{3.59} + 0.005 = .123A$$

To calculate the speed at the desired load torque, the following formula applies:

$$n = n_0(@ 20Volts) - 1350 \times \frac{I_m \times R}{k_m}$$

Then:

$$n = 7500 - 1350 \times \frac{.123 \times 50}{3.59} \cong 5187rpm$$

As this speed value is very close to the desired value, the selection of this motor appears reasonable. A check of the thermal heat rise of the motor is in order to confirm the selection. The power dissipated by the motor is given by:

$$P_{dis} = I^2 \times R$$

where  $P_{dis}$  is the power dissipated by the motor

$$P_{dis} = (.123)^2 \times 50 = .76Watts$$

The heat rise under steady state conditions is given by the following equation:

$$\Delta T = P_{dis} \times (R_{th1} + R_{th2})$$

where:

$R_{th1}$  = the thermal resistance from rotor to case in °C/W

$R_{th2}$  = the thermal resistance from case to ambient in °C/W

(delta) T = the motor temperature rise in °C

$$\Delta T = .76 \times (4 + 28) = 24.3^\circ C$$

The motor temperature under steady state is then:

$$T_M = T_{amb} + \Delta T$$

Where:

- $T_M$  = Operating temperature in °C
- $T_{amb}$  = Ambient temperature in °C
- (delta) T = the motor temperature rise in °C

Then:

$$T_M = 22 + 24.3 = 46.3^\circ C$$

This value is satisfactory because it is well below the maximum operating temperature for this type of motor.

To summarize the desired values versus the selected values for the 2230T024S motor:

Parameter	Desired Value	Selected Value
Voltage	20 VDC	20 VDC
Torque	.425 oz-in	.425 oz-in
Speed	5,000 rpm	5,187 rpm

Usually a motor selection involves many more factors than are presented here. This method, however, provides the designer with a starting point for the selection of motors for a particular set of application parameters. Please contact MicroMo Electronics for further assistance.