Torque and Temperature Calculator user guide

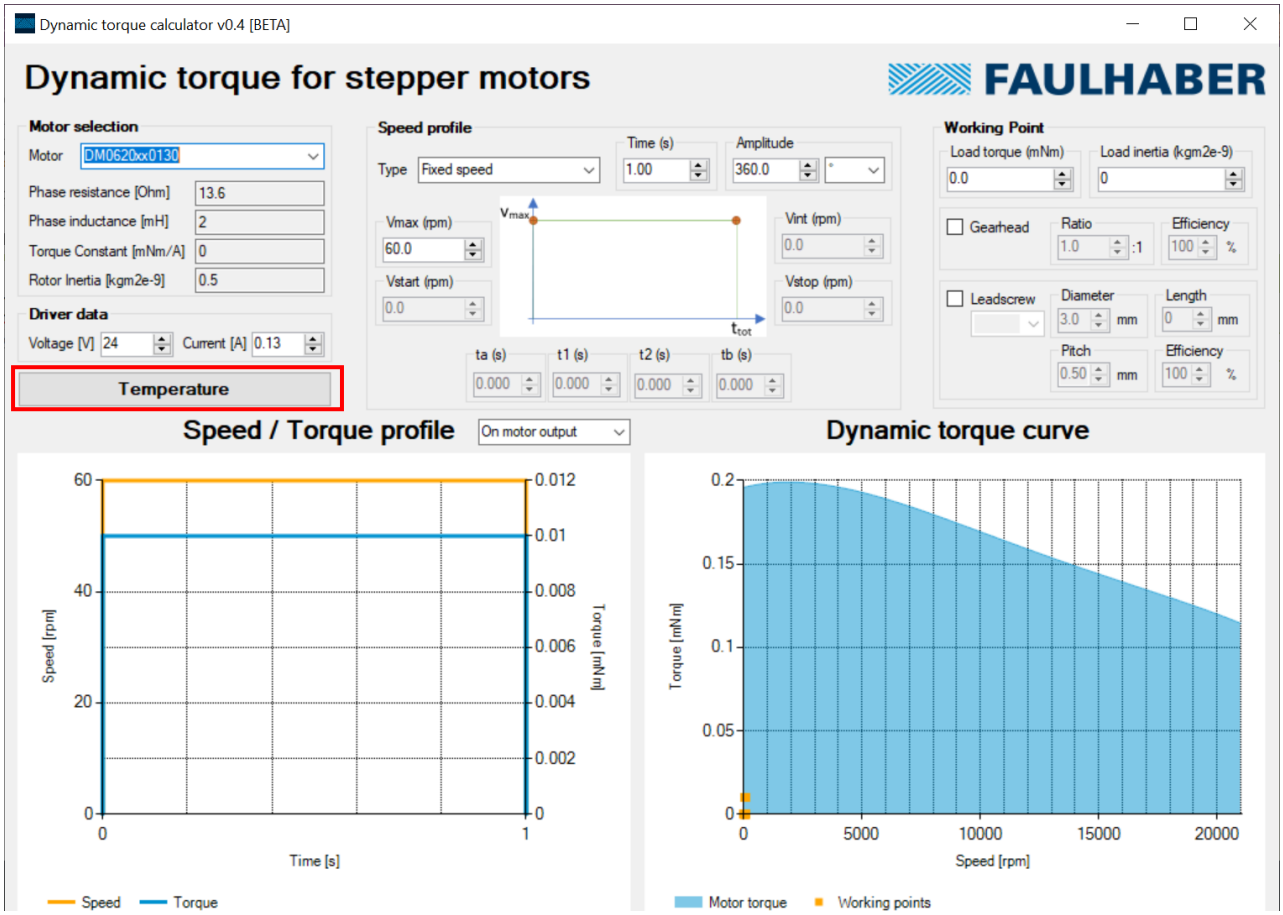
Introduction

The present document presents the main features of the stepper motor calculator and explains to users how to use them. The main goal of the software is to verify that a selected stepper motor is suitable to a defined working point. All the stepper motors from the FAULHABER portfolio are stored in the software database, and the GUI allows to setup the working point by defining the speed profile parameters as well as the torque requirement, including the possibility to add a gearhead or a leadscrew on the actuator. Finally, a temperature calculation tool allows to estimate the temperature evolution with time under specific working conditions.

Software GUI presentation

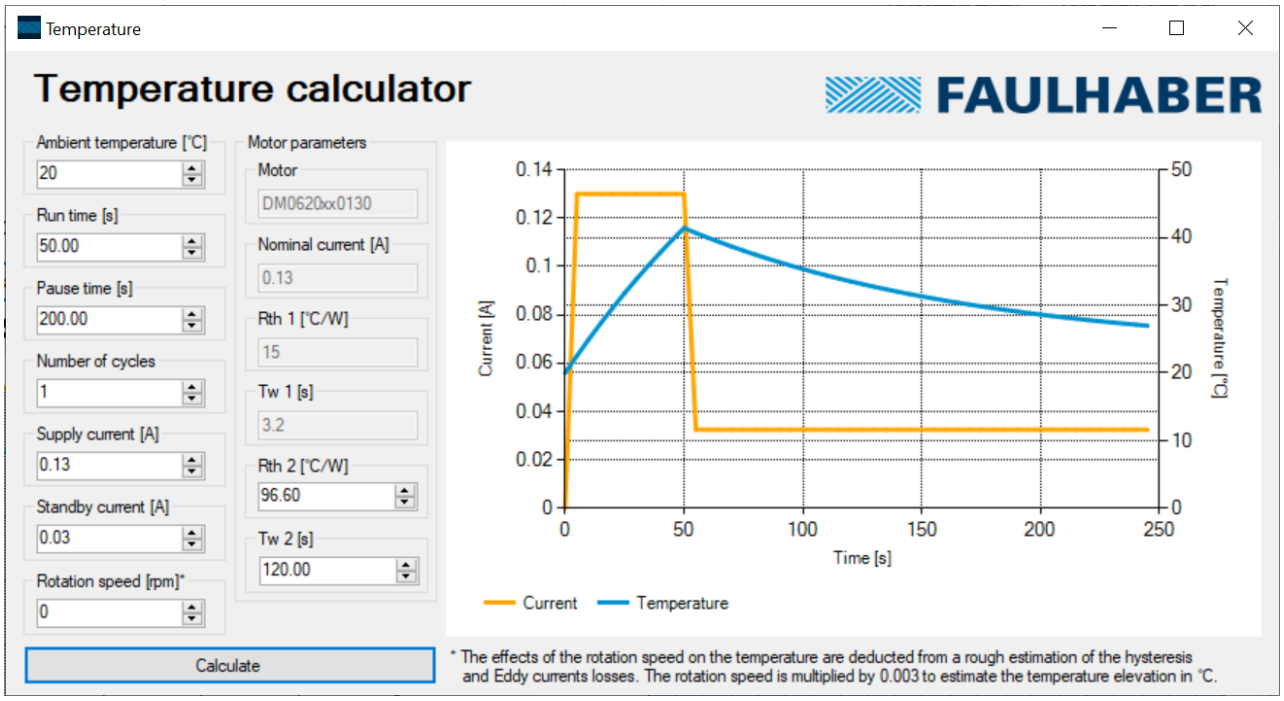
The graphical user interface is composed of two different windows:

- **Main window**: Main form, showing the motor selection and driver setup panes, the speed profile and the working point definition:



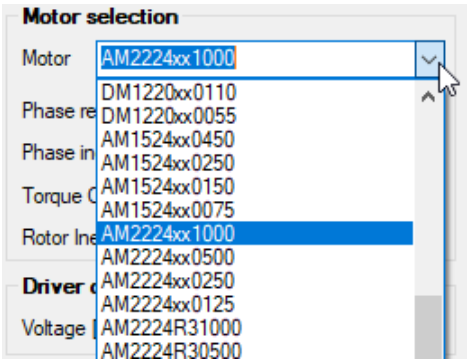
From the main window, a temperature calculation tool can be accessed through the “Temperature” button.

- **Temperature**: This form is used to compute the motor temperature evolution with time, depending on the motor working cycles (current):



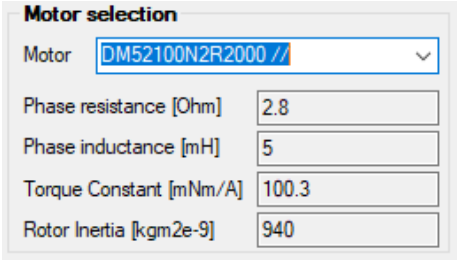
Motors selection

All the stepper motors from the FAULHABER portfolio are listed in a drop list on the top left of the main panel. The first action is usually to select a motor from this list according to the first estimations/feeling:



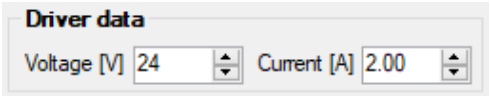
The motors are sorted out sizewise. For each diameter, several winding options are available (defined by the 4 last digits of the designation).

The main electrical parameters of the selected motor are shown on the information panel just below:



Driver parameter definition

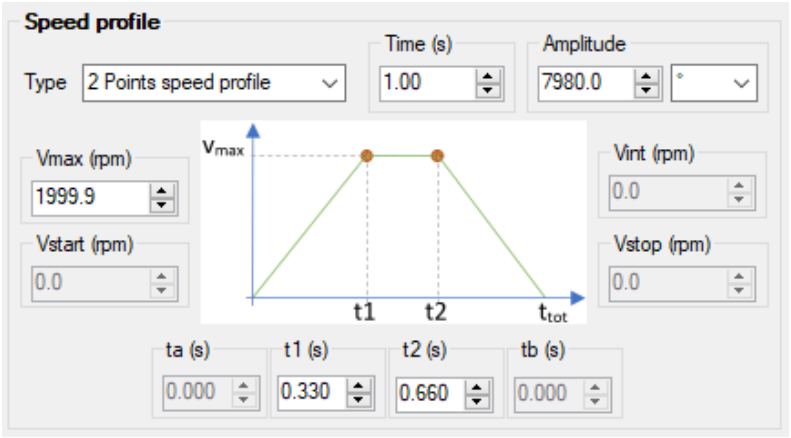
Two parameters are used to define the driver: Supply voltage and current limit:



The software considers a current mode driver and microstep driving.

Speed profile definition

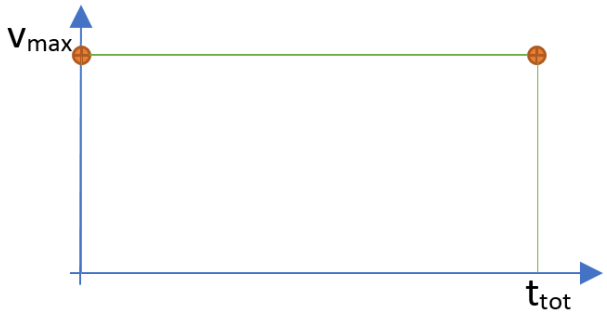
The speed profile can be setup in the following panel:



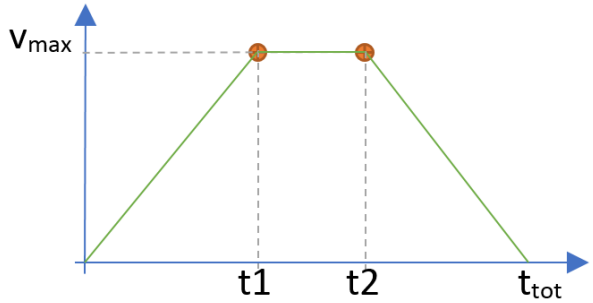
The main parameters defining the movement are the time and amplitude. In some cases, the speed is the most important parameter. In such situation, it can be directly set in the Vmax field. Then the amplitude would be calculated by the software.

Four scenarios are proposed for the speed profile definition:

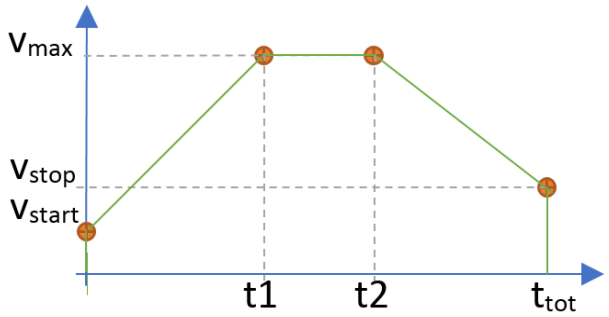
- Fixed speed (no acceleration)



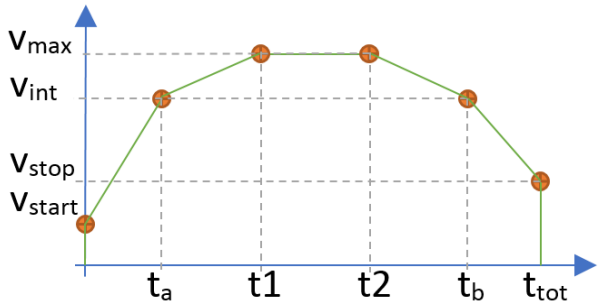
- 2 points speed profile (acceleration and deceleration)



- 4 points speed profile (acceleration, deceleration and start/stop speeds)



- 6 points speed profile (2 phases acceleration and deceleration, start/stop speeds)

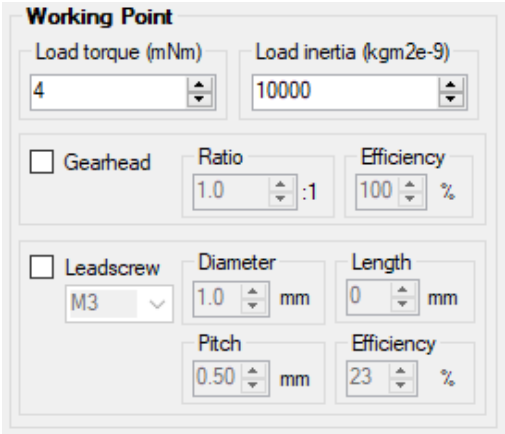


Depending on the selected profile, all the parameters related to the profile have then to be selected:

- Movement time and amplitude (in °, turns or mm if a leadscrew is used)
- Times when the acceleration stops and the deceleration starts (if not fixed speed)
- Start/Stop frequency for 4 and 6 points speed profiles
- Intermediate speed for 6 points speed profile, and timings to reach the intermediate speed

Working point definition

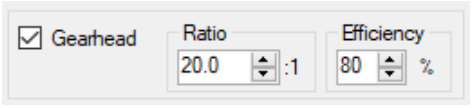
The user can define the working conditions of the motor through the “Working point” panel and define the speed profile through the “Speed profile” panel.
The working point can be calculated considering a gearhead or/and a leadscrew assembled. The load torque/force and inertia can also be defined:



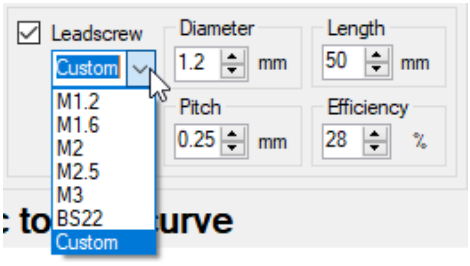
In case of a motor alone, two paramers only must be set:

- The load torque
- The load inertia

If a gearhead is assembled on the motor, for example to increase the torque capability, two additional parameters must be set: The gearhead ratio and efficiency:

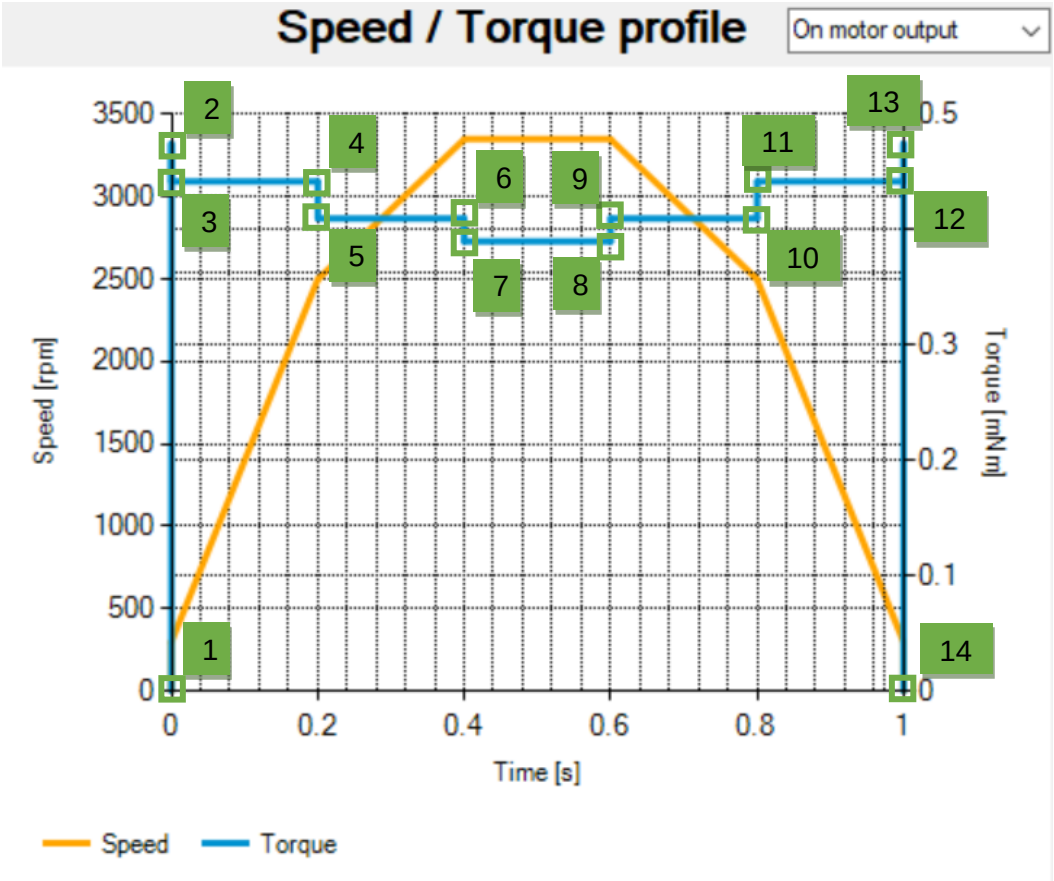


For linear application, a leadscrew can also be added on the actuator. The latter is defined by 4 parameters: Diameter, length, pitch and efficiency. Standard leadscrews from the FAULHABER portfolio can be selected. In this case, the leadscrew parameters are stored in the database and only the length can be modified by the user. In case of a custom leadscrew, this option can be selected in the dropdown list and the user can modify all the leadscrew parameters:



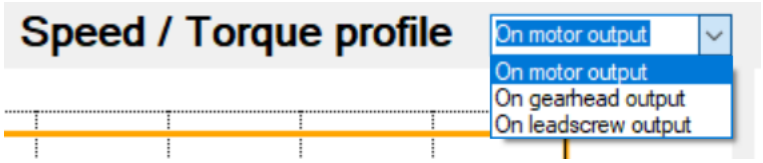
Speed / Torque profile calculation

From the user inputs, the software will automatically calculate the different working point along the defined speed profile. Two curves are used to represent these points : Speed curve and torque curve. Depending on the selected speed profile mode, up to 14 points are calculated:



Point	Time	Speed	Torque	Comment
1	0	0	0	
2	0	SpeedStart	StartTorque	
3	0	SpeedStart	AccelerationTorque 1	
4	ta	SpeedIntermediate	AccelerationTorque 1	Only for 6 points profile
5	ta	SpeedIntermediate	AccelerationTorque 2	Only for 6 points profile
6	t1	SpeedMax	AccelerationTorque 2	
7	t1	SpeedMax	FrictionTorque	
8	t2	SpeedMax	FrictionTorque	
9	t2	SpeedMax	DecelerationTorque 1	
10	tb	SpeedIntermediate	DecelerationTorque 1	Only for 6 points profile
11	tb	SpeedIntermediate	DecelerationTorque 2	Only for 6 points profile
12	t_{tot}	SpeedStop	DecelerationTorque 2	
13	t_{tot}	SpeedStop	StopTorque	
14	t_{tot}	0	0	

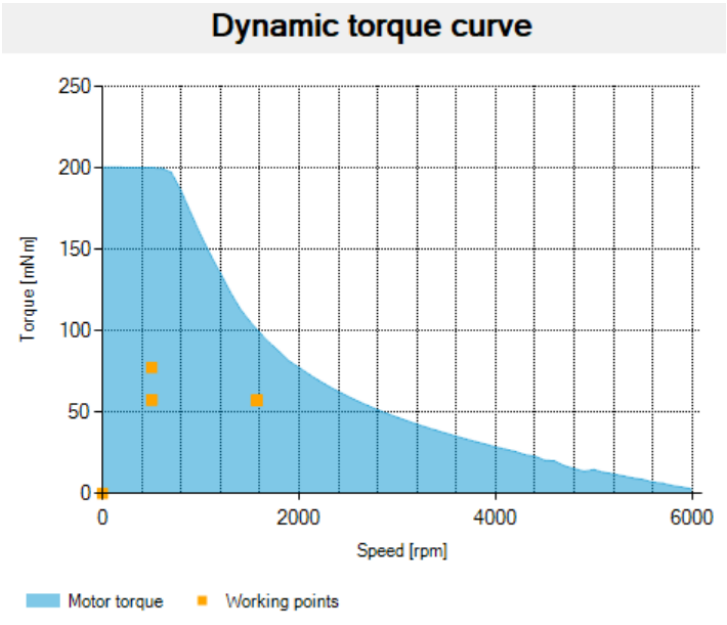
The user can select if the speed and torque parameters shown on the graph are to be calculated on the motor, gearhead, or leadscrew side:



Dynamic torque curve

Two types of information are shown on the dynamic torque curve graph:

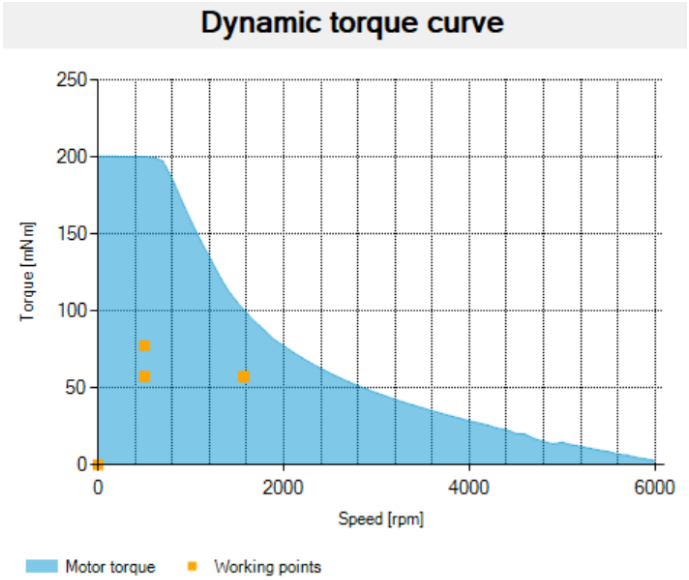
- The calculated torque vs. speed capability of the selected motor (blue curve)
- The calculated working points (up to 14 orange points)



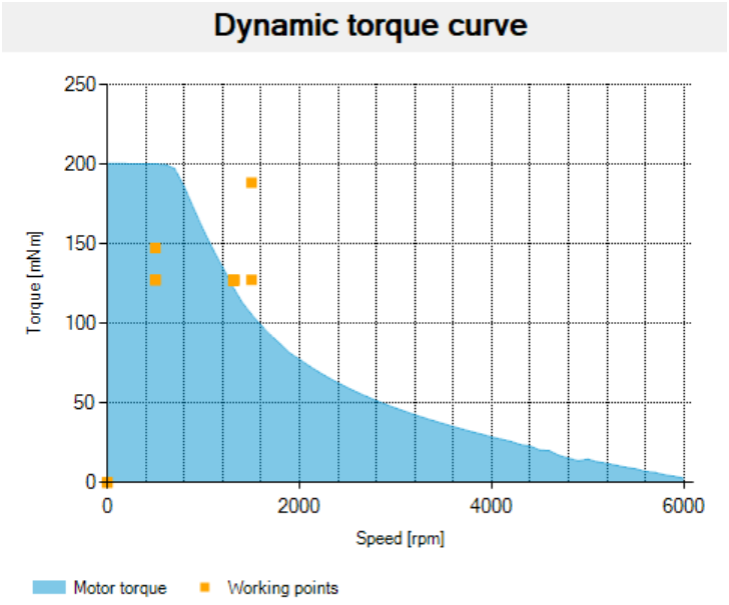
The motor torque capability is calculated from the motor and driver information:

- Torque capability of the selected motor
- Limitation from the driver setup (voltage and current limitation)

The final verification if a drive system (actuator + driver) matches speed and torque requirements can be done from this graph. If the drive system can fulfil the speed/torque requirements, all the working points (in yellow) will be situated below the motor torque capability (blue curve):



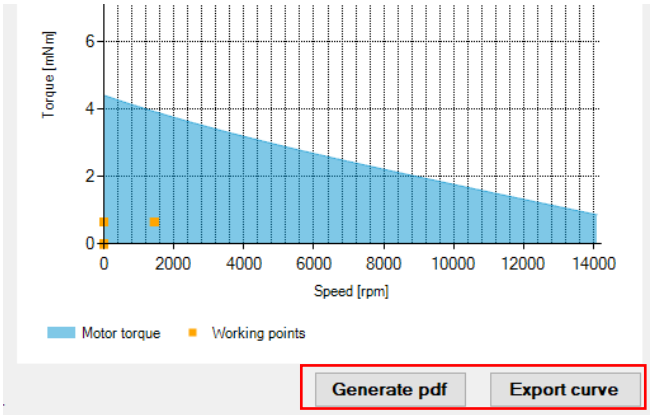
If some of the working points are situated above the motor torque capability curve, the motor will not be able to fulfil the torque requirement under the specified conditions. Either a more powerful combination must be selected, or the conditions must be changed / tuned:



If the above situation occurs, where the motor is unable to provide the requested torque in the specified conditions, it is worth trying to tune the driver parameters and work on the speed profile optimization before rejecting a pre-selected actuator. In any case, contacting the nearest point of sale for technical support is highly recommended.

Dynamic torque curve

In the bottom right corner of the main page are two buttons, that allow to export the speed profile, torque profile and dynamic torque curve as either a .PDF file, or as a .CSV file in excel. This allows to easily share the information and to integrate the curves of this calculator in other documents.



Temperature calculation

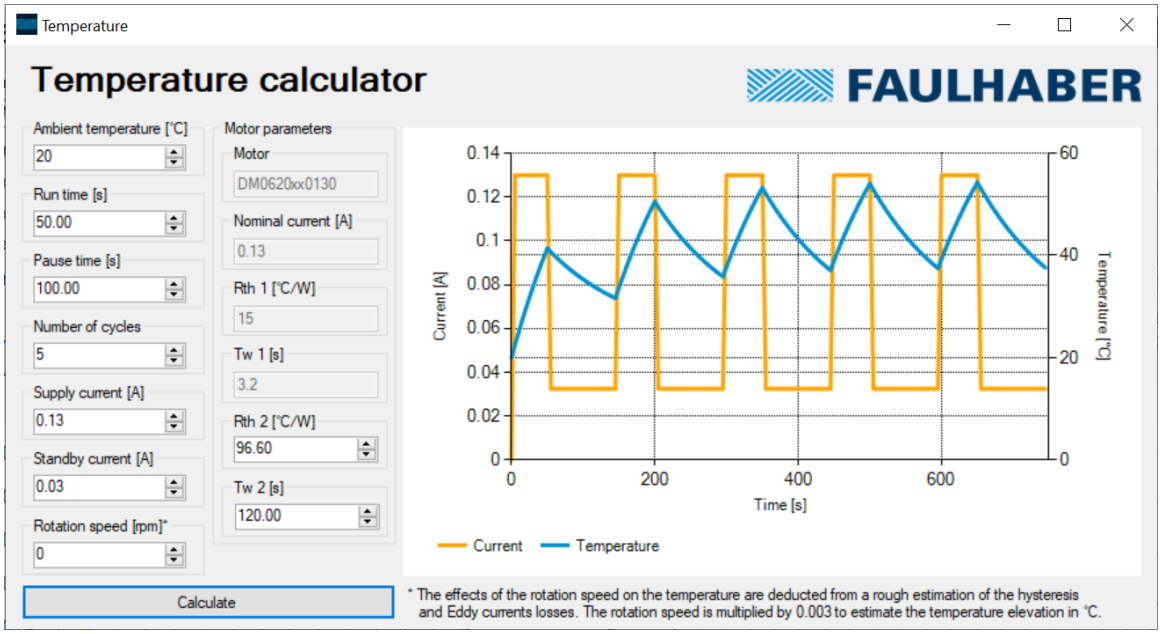
The temperature calculation tool is mainly useful to evaluate the temperature evolution of the motor under special conditions, like:

- Overdrive mode: Motor drive current higher than nominal
- Higher ambient temperature (70° or more)

The temperature is plotted according to the motor driving information:

- Motor rotation time (deducted from speed profile)
- Pause time (standby)
- Supply current (motor ON)
- Standby current
- Number of cycles (1 cycle = Motor rotation + pause time)
- Ambient temperature
- Rotation speed (approximation)

The results are shown on the current and temperature graph, as in the example below. The temperature is considered inside of the motor.



As long as the peak value of the calculated temperature remains below 130°C, the motor will support the working conditions.

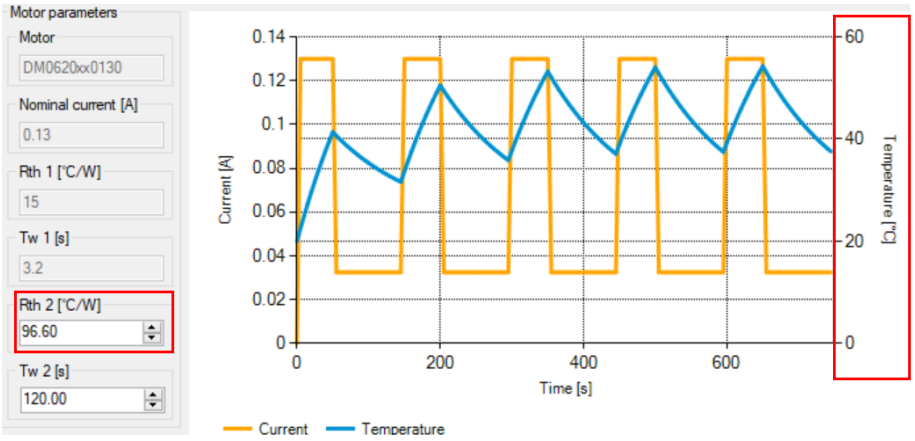
The thermal model of the motor considers the Joule effects but is neglecting the Eddy currents losses. The calculator however includes a “rotation speed” field, which allows the software to perform a rough approximation of the temperature elevation with the speed increase. The model just considers a temperature increase of 10° per 3000 rpm for any type of motor. This does not reflect perfectly the reality but allows a better temperature approximation than by just considering Joule effects.

Thermal resistance usage

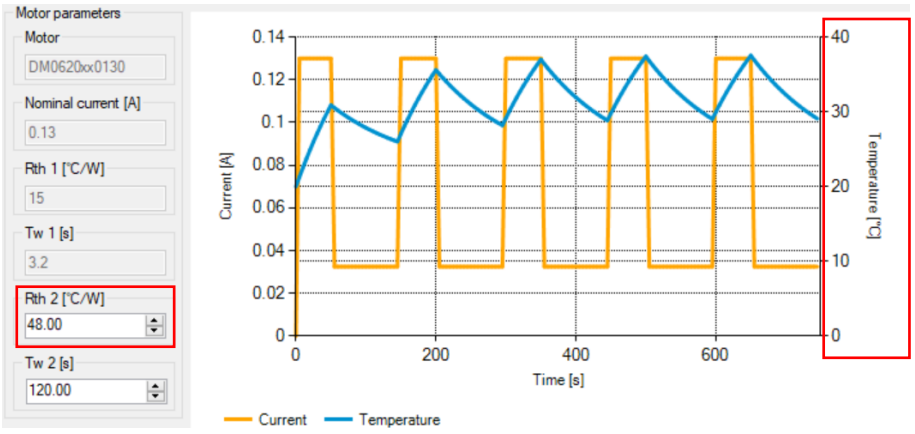
Most of the time, the motor is assembled on an external frame or power dissipative component. This will influence the thermal resistance between the housing of the motor and the ambient air (R_{th2}) and change the temperature evolution[1]. Usually, if the motor is connected to another metal part, R_{th2} can be considered half of the catalogue value. On the opposite, if the motor is working under vacuum conditions, R_{th2} must be increased to reflect the reality.

Below an example (50s run time, 100s pause time, 5 cycles) with the default R_{th2} values from the datasheet:

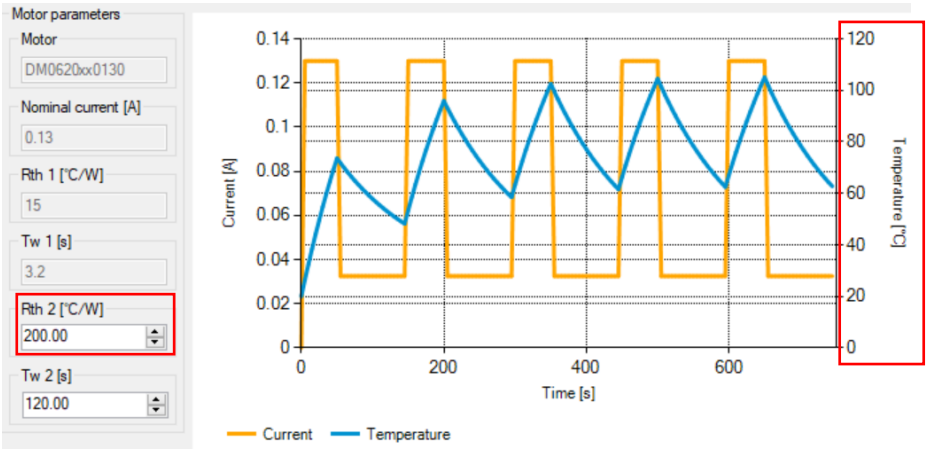
[1] For more information about the about the thermal behaviour of stepper motors please refer to our application note AN008 “*Thermal behaviour of a stepper motor*”.



Same example but considering that the motor is fixed by the front flange (R_{th2} can be divided by 2). Note how the temperature decreased:



Same example under vacuum conditions. Note how the maximum temperature increased:



For large DM motors (DM40 and DM52), the values of R_{th1} and R_{th2} have not been measured separately. Therefore, only $R_{th\ Total}$ and $T_{w\ Total}$ are given in the datasheets and can be modified in the software.