Problem: When braking the energy of the moving system flows back to the drive. In some application the DC-bus capacitors (if present) are able to take only a small amount of this energy, the rest of it has to be converted to heat by a resistor.

Solution: ♦ **Drive** : Technosoft Intelligent Servo Drive **ISCM4805**
ISCM8005
ISCM4805-DIN
ISCM8005-DIN
IDM240-xx
IDM640-xx
IPS110

Description: This application note is meant to help the user selecting the braking resistor. Since the applications that require dissipative braking can be very different, you'll find here some guide lines that are generally applicable.

1. How to determine the energy from the system:

$$E_M = (E_K + E_P) - (E_{Co} + E_F)$$

E_M - is the total energy of the motor+load, minus the system losses [J]
E_K - is the kinetic energy of the motor+load [J]
E_P - is the gravitational potential energy of the motor+load [J]
E_{Co} - is the energy lost in the motor coils (copper – ohm losses) [J]
E_F - is the energy lost by friction [J]

For a standard torque motor, here is the formula to compute the total energy from the system:

$$E_M = \underbrace{\frac{1}{2}(J_M + J_L)\varpi_M}_{\text{Kinetic energy}} + \underbrace{(m_M + m_L)g(h_{initial} - h_{final})}_{\text{Potential energy}} - \underbrace{3I_M^2 R_{Ph} t_d}_{\text{Copper losses}} - \underbrace{\frac{t_d \varpi_M}{2} T_F}_{\text{Friction losses}}$$

J_M - is the total rotor inertia [kgm^2]
J_L - is the total load inertia [kgm^2]
ϖ_M - is the motor speed before deceleration [rad/s]
m_M - is the motor mass [kg] – supposing the motor is moving in a non-horizontal plane
m_L - is the load mass [kg] – supposing the load is moving in a non-horizontal plane
g - is the gravitational acceleration [m/s^2]
$h_{initial}$ - is the initial system altitude [m]
h_{final} - is the final system altitude [m]
I_M - is the motor current during deceleration [A_{RMS}/phase]
R_{Ph} - is the motor phase resistance [Ω] (as detected by IPM Motion Studio)
t_D - is the time to decelerate [s]
T_F - is the friction torque [Nm]

Note that usually a torque motor system has the gravitational potential energy zero, but the system may have any other form of energy, which must be added to the above formula.

2. How to determine when a resistor is needed for braking:

Since all the system energy (E_M) will be flowing back to the drive during braking, we need to know whether the drive can withstand this amount of energy or not.

$$E_M > \frac{1}{2}C(U_{MAX}^2 - U_{NOM}^2)$$

C - is the total capacitance seen from the DC bus [F]
U_{MAX} - is the maximum voltage allowed on the DC bus [V]
U_{NOM} - is the nominal voltage of the DC bus [V] (supposing the drive is supplied with U_{NOM})

If the above relation is true, then it means that the braking energy will be higher than the energy that the drive can store during braking, and therefore a braking resistor is needed. Depending on the braking type and regime, in some cases, you can only connect an additional bigger capacitor on the DC-bus to increase the energy that can be stored in the drive. You can even add both a capacitor and a resistor if needed, but in most of the cases this proves to be a more expensive solution. When adding only a capacitor you must choose it's capacitance so that the above relation becomes false and determine its voltage according to the U_{MAX} value.

3. How to determine the resistor to be used:

The minimal resistance value is computed using formula:

$$R_{min} = \frac{U_{MAX}}{I_{peak}}$$

U_{brake} - is the braking voltage [V]
I_{peak} - is the peak current of the braking transistor (the peak current of the drive) [A]

There are some rules regarding U_{brake} :

- U_{brake} is selected from the drive dialogue, when you activate the “Use external brake resistor” check-box
- U_{brake} must be higher than the U_{NOM} + tolerance (assuming the drive is supplied with U_{NOM}), otherwise the brake resistor will be activated continuously
- U_{brake} must be lower than the U_{MAX}

The value of the braking resistor R must be selected based on the following rules:

- $R > R_{MIN}$
- The braking current (computed as $\sqrt{\frac{P_{BR}}{R}}$) must be lower than the I_{NOM}
- $\frac{U_{brake}^2}{2R} \geq P_{BR}$

I_{NOM} - is the nominal current of the drive [A]
P_{BR} - is the braking power dissipated on the resistor [W]

$$P_{BR} = \frac{E_M - \frac{1}{2}C(U_{MAX}^2 - U_{brake}^2)}{t_d}$$

When choosing the resistor, you must also know the average power that will be dissipated on the resistor, and also the peak power that can be dissipated:

$$P_{AV} = \frac{E_M - \frac{1}{2}C(U_{MAX}^2 - U_{brake}^2)}{t_{cycle}}$$

$$P_{PK} = \frac{U_{MAX}^2}{R}$$

P_{AV} - is the average power dissipated on the resistor [W]
P_{PK} - is the peak power dissipated on the resistor [W]
t_{cycle} - is the smallest time between two consecutive decelerations [s]

In the table below, you'll find all the drive related parameters that you need for computations:

	ISCM4805	ISCM8005	ISCM4805-DIN	ISCM8005-DIN	IDM240	IDM640	IPS110
U_{NOM} [V]	48	80	48	80	48	80	42
U_{MAX} [V]	54	95	54	95	63	100	48
C [µF]	100[1]@100V	100[1]@100V	100@100V	100@100V	200@100V	200@100V	200[2]@63V
I_{NOM} [A]	5	5	5	5	5	8	0.5
I_{PEAK} [A]	16.5	16.5	16.5	16.5	16.5	16.5	1

[1] Present only on IO ISCM board

[2] Present only on IO IPS110 board

The following table contains moments of inertia for various common bodies. The 'M' in each case is the total mass of the object.

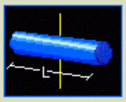
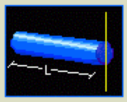
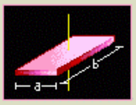
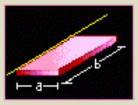
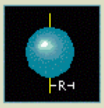
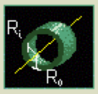
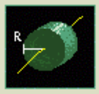
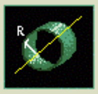
slender rod:	axis through center	$I=\frac{1}{12}\cdot M\cdot L^2$		axis through end	$I=\frac{1}{3}\cdot M\cdot L^2$	
rectangular plane:	axis through center	$I=\frac{1}{12}\cdot M\cdot\left(a^2+b^2\right)$		axis along edge	$I=\frac{1}{3}\cdot M\cdot a^2$	
sphere	thin-walled hollow	$I=\frac{2}{3}\cdot M\cdot R^2$		solid	$I=\frac{2}{5}\cdot M\cdot R^2$	
cylinder	hollow	$I=\frac{1}{2}\cdot M\cdot\left(R_i^2+R_o^2\right)$		solid	$I=\frac{1}{2}\cdot M\cdot R^2$	
	thin-walled hollow	$I=M\cdot R^2$				

Figure 1. *Appendix with the total inertia formula for various common bodies.*