Low voltage AC drives

ABB micro drives
Drive dimensioning guide

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Need help with dimensioning a drive?

Selecting the right drive brings long-term benefits

There might be different external and internal conditions that need to be considered when selecting the drive to run a machine or process. When aiming for longterm reliability, these conditions might affect the rating of the drive. A drive which is correctly dimensioned will work properly throughout its lifetime.

Dimensioning the drive correctly involves a process of derating the continuous drive output current (motor current) or by selecting auxiliary devices such as chokes or RFI filters. Derating must be taken into account when using the drive in conditions as those shown in this guide. Conditions that are often forgotten are the application cyclicity and switching frequency. Ambient temperature or other environmental conditions such as dust or humidity might also be unknown, especially when a drive is not installed by the end-user but the machine manufacturer.

It is very important to identify all derating factors in order to reach a reliable solution. Correctly dimensioning a drive saves you time and costs.

Conditions that require special consideration

- Ambient temperature
- Altitude
- Application duty cycle
- Motor cabling
- Multi-motor systems
- Drive's switching frequency
- Supply network quality

Motor control adjustments

Correctly tuned motor control will work better in applications and ensure correct operation in abnormal situations.

Operation condition	Description	Outcome
Ambient temperature	Refers to the cabinet temperature in IP20 drives and the room temperature in wall-mounted drives.	Derating needed above 40 °C (104 °F).
Switching frequency	The higher the switching frequency of the drive is, the more the power semiconductors heat up.	When using a higher switching frequency, a drive's output current needs to be derated.
Altitude	Low air pressure decreases the cooling capability of air and air insulation.	Derating above 1000 m and PELV above 2000 m to be considered.
Duty cycle and application cyclicity	Primary target of micro drives are quadratic torque and simple constant torque applications, so attention needs to be paid when using them in cyclic applications.	When used in demanding constant torque applications, the drive should be oversized in order to maintain lifetime expectation.
Motor cabling	Long motor cabling requires special consideration because high frequency common mode current causes drives to overheat.	Drive derating, external output choke or EMC need to be considered.
Multi-motor systems	When several motors are powered by one drive, the common mode current increases and therefore current also increases (because of parallel connection of motor windings).	The same dimensioning criteria as for single motor drives doesn't apply anymore.
Supply network quality	The drive usually has a limited amount of input reactance and therefore unstable power supply causes stress for the drive's input bridge.	Input choke enhances the reliability of the drive.
Harsh environment	The drive is constantly or occasionally exposed to dust and/or humidity or even splashing or spraying water.	IP66/67 variant needs to be selected. Also, proper filtering and preventing hot air circulation inside the cabinet are useful methods.

Temperature and switching frequency

Basic principles of temperature and electrical components

– The higher the temperature, the lower the lifetime expectation of each electrical component
– High cyclic temperature dT (=T_{max} - T_{min}) causes high stress for all electronics, especially for solder joints of components

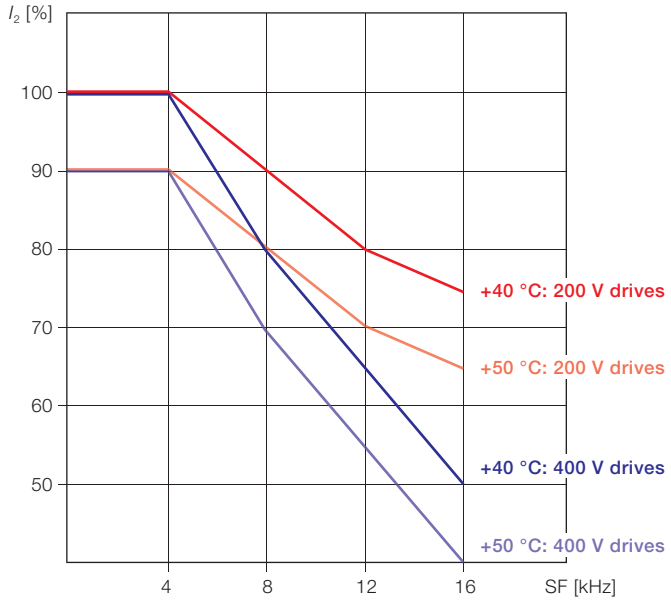
Above the drive designed ambient temperature, drives can usually operate when the maximum output current is derated according to the user's manual.

Note: When a drive is installed in too full of a cabinet, the drive heats up the cabinet. Also, other devices inside the cabinet affect the temperature.

The standard dimension is done based on the default switching frequency, which is 4 kHz for ABB micro drives (5 kHz for ACS55). The switching frequency can be set up to 16 kHz. The higher the switching frequency of the drive is, the more the power semiconductors generate heat losses. Thus, the drive output current is derated when increasing the switching frequency. This applies to nominal current, overload current and maximum instantaneous current.

Drive's operating temperature

ACS150/355/310
Derate I_{2N} 1% for every 1 °C above 40 °C (104 °F)
Operation: -10 to +50 °C (14 to 122 °F)
Operation with limitations*: +50 to +55 °C



* Limitations when the drive is used above +50 °C:

– Drive lifetime is limited to 15.000 operating hours (recommended fan replacement every year)
– I/O loading of the drive is limited to 100 mA
– External fieldbus options are not allowed (only the drive's embedded fieldbus or FMBA-01 possible)
– Only 4 kHz switching frequency allowed

Altitude

The cooling capability of air is decreased in high altitudes at low air pressure. Above an altitude of 1000 m, the ambient temperature or the maximum output current should be decreased. Decrease the output by 1% per 100 m altitude above 1000 m or reduce the max. ambient temperature by 1 degree per 200 m.

Low air pressure also decreases air insulation capability. The drives' creepage and clearance distances are designed to withstand certain altitudes. ACS150 and ACS355/310 design limits (PELV = Protected extra low voltage, meaning IO and user's panel interface has reinforced isolation from mains voltage):

– 1~200 V and 3~400 V drives the design limit is 2000 m
– 3~200 V drives the design limit is 3000 m

Clarification

Safety isolation clearances: To meet CE requirements for drives, ABB drives are designed according standard IEC/EN-61800-5-1: Adjustable speed electrical power drive systems – Safety requirements – Electrical, thermal and energy.

According to this standard, the drive does not fulfill the safety clearance requirement between main circuit and IO when:

– the altitude is above the design limit and
– the drive is assembled in an industrial supply network

In altitudes from 2000 m to 3000 m, 1~200 V and 3~400 V drive's IO still fulfill safety isolation circuitry requirements in non-industrial supply networks.

The difference between industrial and non-industrial supply networks is allowed maximum impulse voltage in type testing:

– industrial supply network 4 kV
– non-industrial supply network 2.5 kV

These values are defined in the standard IEC 60664-1.

Application duty cycle

Drive dimensioning is easy for quadratic torque and simple constant torque applications. Cyclic operation of the drive causes more stress on power semiconductor components of the drive, and thus larger dimensioning of the drive is recommended.

Quadratic torque applications, typically pumps and fans, are operated with constant speed or inside narrow speed band around rated speed. Running times are typically long and drive might be always turned on, but the motor is loaded below nominal power.

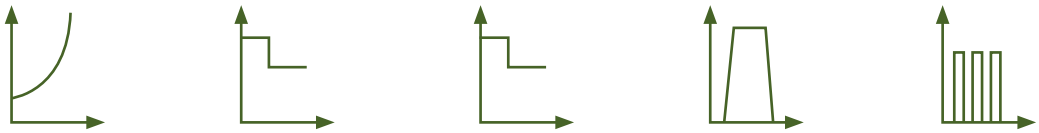
Simple constant torque applications, typically conveyors and mixers, are operated with constant speed. Motor loading is typically low during steady operation, but short time overloading may be required occasionaly, eg. during start and stop of the application.

Demanding constant torque applications are operated with constant speed or torque reference. Overloading conditions are typical and the frequency of start-stop cycles or loading cycles is high also during the normal operation, and therefore also the expected number of cycles per machine lifetime is high.

Standard dimensioning bases for micro drives

ACS55/ACS310/ACS320 ACS150/ACS355

	Quadratic torque	Constant torque/ simple	Constant torque/de-manding	Constant torque/ cyclic	Motion
Typical applications	Centrifugal pumps and fans	Mixers, conveyors	Cranes, extruders, compressors	Lifts	Motion control
Number cycles per lifetime *)	30,000	60,000	600,000	6,000,000	60,000,000



Typical operation	Few cycles/day	Few cycles/hour	Several cycles/hour	Few cycles/minute	Several cycles/minute

In the event that the application duty cycle demand is more challenging than indicated by the standard design criteria of the drive, derating the drive will extend the lifetime expectation.

*) Number of cycles is not definite. Installation conditions and electrical conditions have a high impact on the end result.

Motor cabling

Long motor cabling requires special consideration because it causes:

- Higher common mode current, and thus decrease the loadability of the drive
- More radio frequency or low frequency interference
- Inaccuracy of the control performance

Table of cable lengths of ACS150/ACS310/ACS320/ACS355

Motor cable limits

R1-R4			Shielded cable [m]			Non-shielded cable [m]
EMC compatibility and motor cable length (m)			EMC			Operational
RFI filtering	Output choke	Drive derating	C1	C2	C3	
Internal filter	–	–	10	30	30	50
External filter	–	–			50	
Internal filter	External output choke	–			60	100
External filter	External output choke	–	20	60	100	
Internal filter	–	Derating (next frame size)			30	75
Internal filter	External output choke	Derating (next frame size)			60	150

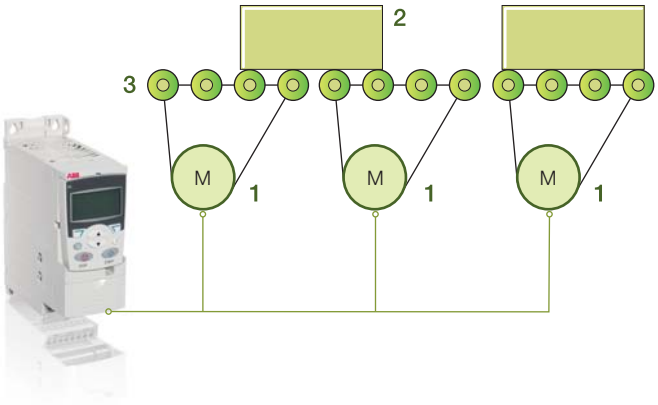
* These values apply with switching frequency 4 kHz.

Selecting derated (next frame size) drive

1-phase 230 V drives		Derated drives
ACSXXX-01X-02A4-2	→	ACSXXX-01X-04A7-2
ACSXXX-01X-04A7-2	→	ACSXXX-01X-07A5-2
ACSXXX-01X-06A7-2	→	ACSXXX-01X-07A5-2
ACSXXX-01X-07A5-2	→	–
ACSXXX-01X-09A8-2	→	–
3-phase 230 V drives		**Derated drives**
ACSXXX-01X-02A4-2	→	ACSXXX-01X-04A7-2
ACSXXX-03X-03A5-2	→	ACSXXX-01X-04A7-2
ACSXXX-03X-04A7-2	→	ACSXXX-03X-07A5-2
ACSXXX-03X-06A7-2	→	ACSXXX-03X-07A5-2
ACSXXX-03X-07A5-2	→	ACSXXX-03X-13A3-2
ACSXXX-03X-09A8-2	→	ACSXXX-03X-13A3-2
ACSXXX-03X-13A3-2	→	ACSXXX-03X-24A4-2
ACSXXX-03X-17A6-2	→	ACSXXX-03X-24A4-2
ACSXXX-03X-24A4-2	→	ACSXXX-03X-31A0-2
ACSXXX-03X-31A0-2	→	ACSXXX-03X-46A2-2
ACSXXX-03X-46A2-2	→	–
3-phase 400 V drives		**Derated drives**
ACSXXX-03X-01A2-4	→	ACSXXX-03X-07A3-4
ACSXXX-03X-01A9-4	→	ACSXXX-03X-07A3-4
ACSXXX-03X-02A4-4	→	ACSXXX-03X-07A3-4
ACSXXX-03X-03A3-4	→	ACSXXX-03X-07A3-4
ACSXXX-03X-04A1-4	→	ACSXXX-03X-07A3-4
ACSXXX-03X-05A6-4	→	ACSXXX-03X-07A3-4
ACSXXX-03X-07A3-4	→	ACSXXX-03X-12A5-4
ACSXXX-03X-08A8-4	→	ACSXXX-03X-12A5-4
ACSXXX-03X-12A5-4	→	ACSXXX-03X-23A1-4
ACSXXX-03X-15A6-4	→	ACSXXX-03X-23A1-4
ACSXXX-03X-23A1-4	→	ACSXXX-03X-31A0-4
ACSXXX-03X-31A0-4	→	ACSXXX-03X-44A0-4
ACSXXX-03X-38A0-4	→	ACSXXX-03X-44A0-4
ACSXXX-03X-44A0-4	→	–

Multi-motor application setup

There are several ways to build the multi-motor application; master-slave control, parallel control of motors and combinations of these two ways. The most typical multi-motor application for compact drives is the parallel control, which means that several motors are powered by one inverter (parallel connection of motor windings). The benefits of such approach are that there is only one inverter to startup, and that less time and effort is needed for the installation work. Multi-motor application is possible only with asynchronous motors.



1 Motors (3 × 1.5 kW)
2 Load
3 Rollers

Correct selection of drive is critical with this kind of setup. This is due to the fact that increased amount of common mode current will reduce the loading current capability of the drive.

Factors that affect drive loadability and the amount of common mode current:

- Total length of motor cabling
- Total amount of parallel motors (motor size)
- Amount of parallel motor cables
- Motor cable type (shielded cable has higher capacitance than un-shielded)
- Common output choke for all motors (thermal current must be 1.2 times total sum of motor currents)

The drive is selected based on the sum of the connected motor powers. See the table below to indicate the drive type depending the total motor power. Typically, also the use of external output chokes is recommended and the maximum motor cable length is more limited than with a single motor connection.

When one drive controls several motors, only scalar control should be used. Motor parameters (P_N, I_{2N}) are given as the sum of the nominal values of the motors. Nominal speed is given as an average of the motor rated speeds. It is recommended to limit the maximum current according to the actual need and it should not exceed 1.1 × I_{2N} (parameter 2003 MAX CURRENT). Only 4 kHz switching frequency is allowed to be used.

When multiple motors are connected, the sum of the output cable lengths must not exceed the maximum allowed cable length (see table below). Cables should be separated as close to the drive as possible. If motor contactors are used, switching the contactors during operation is not recommended.

			Total length sum of all motor cables	
ACS150, ACS310, ACS320 and ACS355 selection for multi-motor application	Sum of motor current [A]	Recommended drive (3~400 V) I_{2N} or P_N [kW]	Shielded [m]	Non-shielded/shielded with common output choke [m]
3 to 6 motors	…3.5	4A1-4/1.5	20	30
	3.5 to 5.5	7A3-4/3	20	30
	5.5 to 7.0	8A8-4/4	20	30
	7.0 to 10.5	12A5-4/5.5	30	50
	10.5 to 18	23A1-4/11	30	50
	18 to 27	31A0-4/15	40	60
	27 to 33	38A0-4/18.5	40	60
	33 to 38	44A0-4/22	40	60
7 to 16 motors	…4.5	07A3-4/3	15	30
	4.5 to 8.0	12A5-4/5.5	20	30
	8.0 to 23	31A0-4/5	30	50
	23 to 35	44A0-4/22	30	50

* EMC with external filter only

Supply network quality

Drives are designed for stable supply network conditions.

Typical problems of unstable and weak supply networks:

- Voltage spikes stress for drive's input bridge
- Instantaneous voltage drops (high current spikes after power recuperation cause stress for the drive's input bridge)
- Unbalanced phase voltages (some diodes on the input bridge are carrying more load)
- Missing phase (when load demand is low, drive protection might be unable to see the missing phase, overheating the other two phases)

Typical problems of supply networks that are too strong:

- Commutation of the diode bridge is too fast (causing the bridge to overheat when running at full load)

Input choke is a useful and simple remedy both for voltage spikes and commutation overheating. Input choke also decreases the input current by lowering harmonics, allowing use of smaller fuses and smaller cable diameter.

Input choke does not need to be placed right next to the drive. Installation in the beginning of the cable protects also the drive cabling.

Type designation ACS355-	Frame size	Input choke	I_{1N} without choke [A]	I_{1N} with choke [A]	I_{TH} [A]	L [mH]
1-phase AC supply, 200 to 240 V						
01X-02A4-2	R0	CHK-A1	6.1	4.5	5	8.0
01X-04A7-2	R1	CHK-B1	11.4	8.1	10	2.8
01X-06A7-2	R1	CHK-C1	16.1	11	16	1.2
01X-07A5-2	R2	CHK-C1	16.8	12	16	1.2
01X-09A8-2	R2	CHK-D1	21	15	25	1.0
3-phase AC supply, 200 to 240 V						
03X-02A4-2	R0	CHK-01	4.3	2.2	4.2	6.4
03X-03A5-2	R0	CHK-02	6.1	3.6	7.6	4.6
03X-04A7-2	R1	CHK-03	7.6	4.8	13	2.7
03X-06A7-2	R1	CHK-03	11.8	7.2	13	2.7
03X-07A5-2	R1	CHK-04	12	8.2	22	1.5
03X-09A8-2	R2	CHK-04	14.3	11	22	1.5
03X-13A3-2	R2	CHK-04	21.7	14	22	1.5
03X-17A6-2	R2	CHK-04	24.8	18	22	1.5
03X-24A4-2	R3	CHK-06	41	27	47	0.7
03X-31A0-2	R4	CHK-06	50	34	47	0.7
03X-46A2-2	R4	CHK-06	69	47	47	0.7
3-phase AC supply, 380 to 480 V						
03X-01A2-4	R0	CHK-01	2.2	1.1	4.2	6.4
03X-01A9-4	R0	CHK-01	3.6	1.8	4.2	6.4
03X-02A4-4	R1	CHK-01	4.1	2.3	4.2	6.4
03X-03A3-4	R1	CHK-01	6	3.1	4.2	6.4
03X-04A1-4	R1	CHK-02	6.9	3.5	7.6	4.6
03X-05A6-4	R1	CHK-02	9.6	4.8	7.6	4.6
03X-07A3-4	R1	CHK-02	11.6	6.1	7.6	4.6
03X-08A8-4	R1	CHK-03	13.6	7.7	13	2.7
03X-12A5-4	R3	CHK-03	18.8	11.4	13	2.7
03X-15A6-4	R3	CHK-04	22.1	11.8	22	1.5
03X-23A1-4	R3	CHK-04	30.9	17.5	22	1.5
03X-31A0-4	R4	CHK-05	52	24.5	33	1.1
03X-38A0-4	R4	CHK-06	61	31.7	47	0.7
03X-44A0-4	R4	CHK-06	67	37.8	47	0.7

I_{1N} = Nominal input current. When used in 480 V network I_{1N} is 20% lower with rated power.
I_{TH} = Nominal choke thermal current
L = Choke inductance

Input choke offering from ABB central stock in Europe. Local offering may be different since 5% choke with similar current dimensioning will do the work.

Motor control adjustments

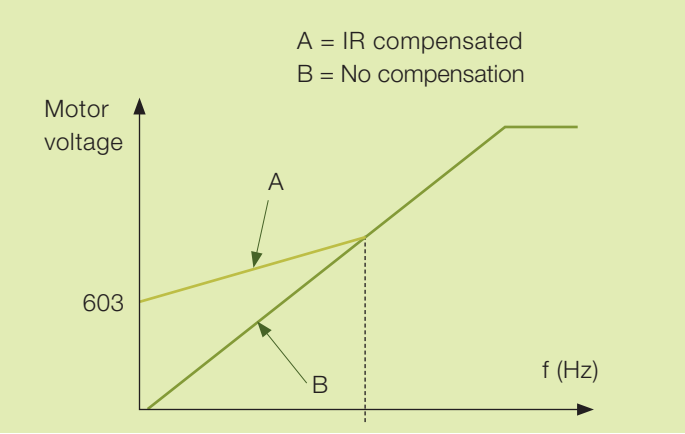
Scalar control adjustments

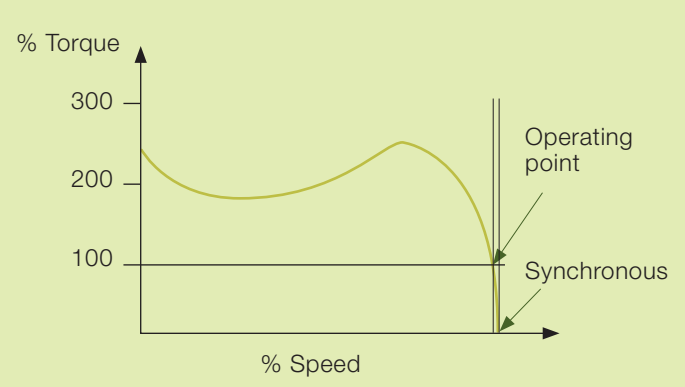
Scalar control is the default control mode for ABB micro drives. The motor speed reference is displayed in Hz and is proportional to the motor rated frequency.

IR compensation – Voltage boost

Defines motor voltage at zero speed. Overcomes the resistive losses in motors at low speeds. This is useful in applications where you need high break-away torque.

Parameters: 2603 IR COMP VOLT and 2604 IR COMP FREQ





Slip compensation

Defines additional frequency to overcome increased slip of the motor due to loading. In other words, static removal of speed error caused by load on the shaft.

Parameters: 2608 SLIP COMP RATIO

Generic motor control settings

Acceleration time

Defines the time to accelerate from zero speed to maximum frequency. Scalar control tries to keep the current below the maximum by limiting the acceleration rate.

Parameters: 2202 ACCELER TIME 1 and 2205 ACCELER TIME 2

Deceleration time

Defines the time to decelerate from maximum frequency to zero speed. Fast deceleration of high inertia loads can cause the DC voltage to rise to the overvoltage control limit. To prevent DC voltage from exceeding the limit, an overvoltage controller automatically decreases braking torque extending deceleration time.

Parameters: 2203 DECELER TIME 1 and 2206 DECELER TIME 2

Maximum current

Defines maximum allowed motor current. Typically 180% times rated drive current for 2 seconds but should be set to a lower value depending on the application. Reducing maximum current will impact acceleration rate.

Parameters: 2003 MAX CURRENT

Vector control adjustments

Vector control mode (9904 MOTOR CONTROL MODE = 1, VECTOR: SPEED or 2, VECTOR: TORQ) is only available on ACS355 products. Vector control enables higher control dynamics and more stable performance when reference needs to be followed precisely. Speed controller values have no impact on scalar control mode. Motor speed reference is given in rpm and torque reference is given in % of motor rated torque.

Speed controller gain and integration time

Defines drive response to the estimated motor speed vs. given reference i.e. speed error. Higher gain increases the response but too high gain can cause speed oscillation. Integration time defines the time how fast the speed error is removed. Too short integration time can make the control unstable. Automatic tuning can be enabled on stable systems allowing a continuous steady state of operation. Automatic tuning keeps the system stable by giving conservative speed controller tuning.

Parameters: 2301 PROP GAIN, 2302 INTEGRATION TIME and 2305 AUTOTUNE RUN

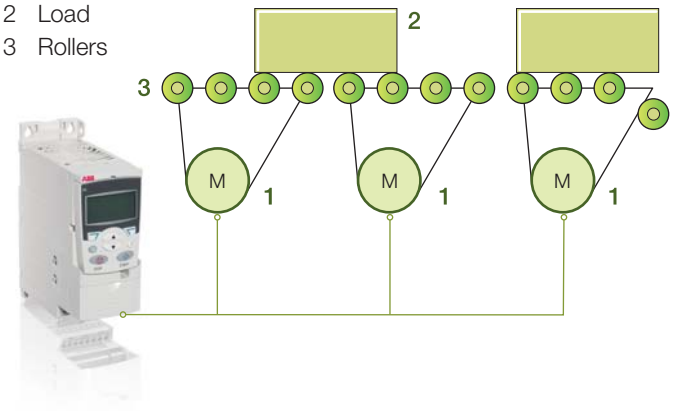
Speed controller tuning highly depends on the application.

1) ACS355 default values results in a quite traditional control with stabile acceleration for different load conditions: 2301=5, 2302=0.5, 2303=0
2) for applications where more responsive control and higher torque response is desired, controller values can be tuned. Eg: 2301=15 to 30, 2302=0,4 to 0,8

Derating example cases

This example shows when drive is installed in 50 °C ambient temperature, controlling multi-motor application

1 Motors (3 × 1.5 kW)
2 Load
3 Rollers



Dimensioning criteria of the drive:

- Motor based rating: 1.5 kW motor rated current 3.2 A
  3 × 3.2 A = 9.6 A
- Add temperature derating (10%):
  9.6 A × 1.1 = 10.6 A
- Select the drive from selection table (3-6 motors):
  => ACS355-03E-23A6-4
- Additionally use external output choke, if possible

This example shows when drive is installed in high performance application with 12 kHz sf and power cycling

High speed motor
- 15 kW
- Speed range 0 to 600 Hz
- Cyclic loading

Dimensioning criteria of the drive:

- Motor based rating: 15 kW
- Add switching frequency derating (35% for 12 kHz):
  15 kW × 1.35 = 20 kW
- Consider over sizing the drive due to cyclic loading of the application (10%): 20 kW × 1.1 = 22 kW

Notes

Contact us

For more information please contact your local ABB representative or visit:

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3AUA0000149377 REV A EN 22.8.2013 #16799

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