Power Supply Selection
for Advanced Motion Controls Amplifiers and Drives

There are several factors to consider when selecting a power supply for Advanced Motion Controls servo amplifiers.

1. Power requirements
2. Isolation
3. Regeneration
4. Voltage ripple

Power requirements refers to how much voltage and current will be required by the amplifier(s) in the system. *Isolation* refers to whether the power supply needs an isolation transformer. *Regeneration* is the energy the power supply needs to absorb during deceleration. *Voltage ripple* is the voltage fluctuation inherent in unregulated supplies.

Each consideration is discussed in detail in the following pages.

I. Power Requirements

A system will need a certain amount of voltage and current to operate properly. If the power supply has too little voltage/current the system will not perform adequately. If the power supply has too much voltage the amplifier may shut down because of over voltage or worse, the amplifier may be damaged. The processes of calculating the voltage and current requirements are described below.

1) Selecting the Supply Voltage

The ideal voltage is defined by the following constraints:

- Upper Constraints
  - Amplifier over voltage limit
  - Shunt regulator voltage
- Lower Constraints
  - System voltage requirements
  - Amplifier under voltage limit

The figure below illustrates the constraints when selecting a power supply voltage for the B25A20 amplifier to be used with a system that requires 100V to operate.

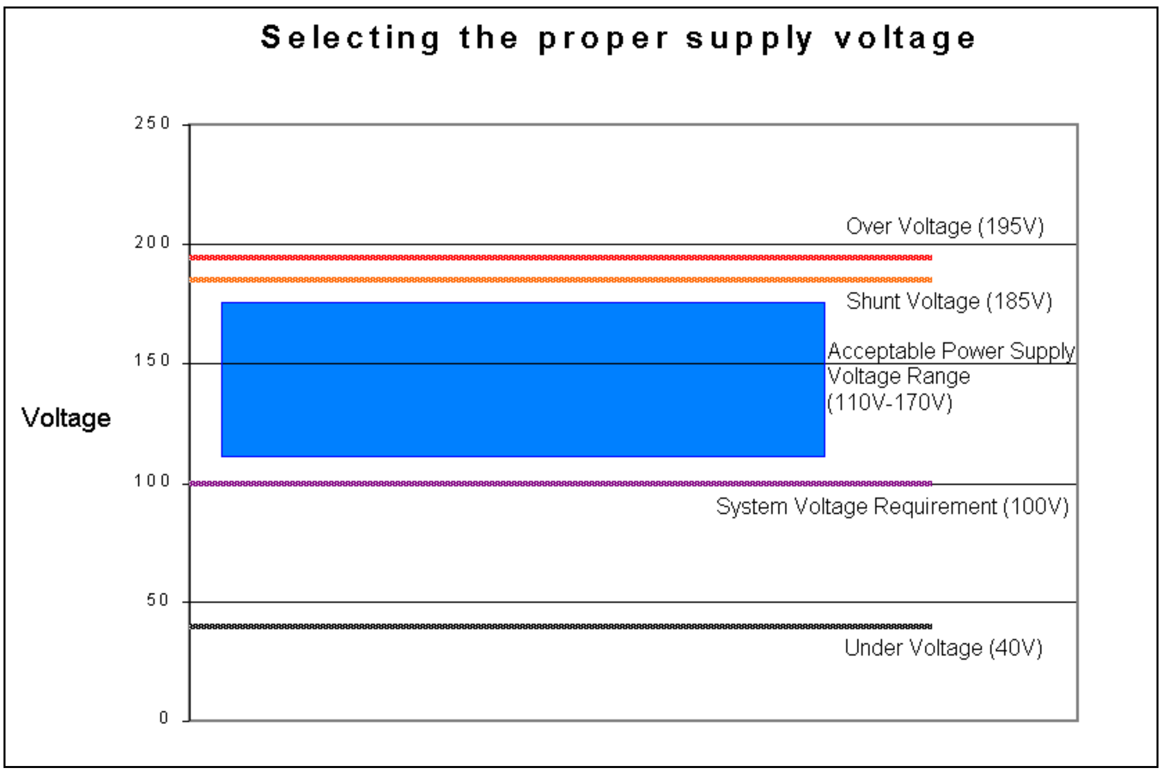


Figure 1.1. In this case the acceptable power supply voltage is between 110V and 170V.

Calculations

Over Voltage – The over voltage level on Advanced Motion Controls amplifiers can be found in the amplifier data sheet. In the example from Figure 1.1. the data sheet for the B25A20 amplifier states that the over voltage shut down point is 195V.

Shunt Regulator Voltage – From figure 1.1 an SRST185 was chosen with a 185V shunt voltage. The purpose of a shunt regulator is to clamp the power supply voltage so it doesn't exceed the amplifier over voltage levels during regeneration. See section 3 (Regeneration) to determine if a shunt regulator is required and how to select the correct voltage.

System Voltage Requirement – The system voltage requirement is based on the motor properties and how fast and hard the motor is driven. The system voltage requirement is equal to the motor voltage required to achieve the move profile.

V_M Motor Voltage:

$$V_M = \left(K_E \cdot S_M\right) + \left(I_M \cdot R_M\right) \qquad (1.1)$$

Where:

V_M Motor Voltage (V)
I_M Motor Current (A) (use the maximum current expected for the application)
K_E Motor Back EMF Constant
R_M Motor Line to Line Resistance (Ω)
S_M Motor Speed (use the maximum speed expected for the application)

If I_M is not known you can use the maximum current rating of the motor or amplifier or you can calculate it:

I_M Motor Current:

$$I_M = \frac{\text{Torque}}{K_T} \qquad (1.2)$$

Where K_T is the motor torque constant.

Keep in mind the calculated value for V_M is the minimum voltage required to complete moves at the desired speed and torque. There should be at least 10% head room between the calculated value and the actual power supply voltage to allow for machine changes such as increased friction due to wear, change in load, increased operating speed and other changes.

Under Voltage Limit – The under voltage level on Advanced Motion Controls amplifiers can be found in the amplifier data sheet. In the example from Figure 1.1. the data sheet for the B25A20 amplifier states that the under voltage shut down point is 40V.

Acceptable Power Supply Voltage – The power supply voltage needs to be at least 10% above the *system voltage requirement* and at least 10% below the lowest value of the following:

- Shunt regulator voltage
- Amplifier over voltage
- Power supply over voltage

If possible 15% or more headroom should be used.

2) Selecting the Supply Current

The power supply current rating is based on the maximum current that will be required by the system. If the power supply powers more than one amplifier then the current requirements for each amplifier should be added together. Due to the nature of PWM amplifiers the current into the amplifier does not always equal the current out of the amplifier, but the *power in* is equal to the *power out*. Use the following equation to calculate the amplifier current requirements based on the motor current requirements.

I_{PS} Power Supply Output Current:

$$I_{PS} = \frac{V_M \cdot I_M}{V_{PS} \cdot (.98)} \qquad (1.3)$$

Where:

V_{PS}	Nominal Power Supply Voltage (V)	
I_M	Motor Current (A)	eq(1.2)
V_M	Motor Voltage (V)	eq(1.1)

Use values of V_M and I_M at the point of maximum power in the move profile (when $V_M \cdot I_M$ = max). This will usually be at the end of a hard acceleration when both the torque and speed of the motor is high. (See figure 1.2 below)

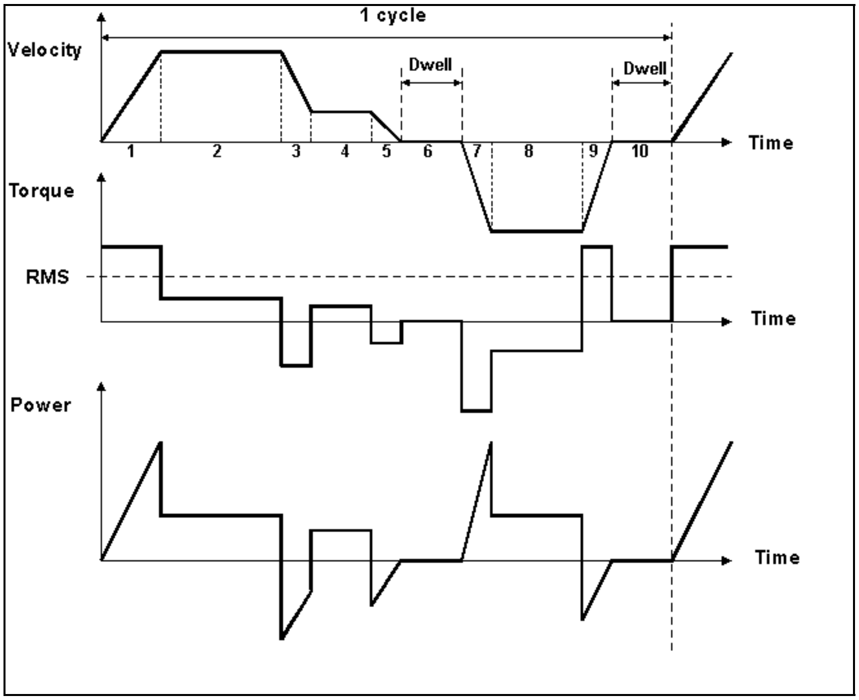


Figure 1.2. Power is equal to Torque x Velocity. V_M and I_M should be chosen where power is at the maximum.

Note: The only time the power supply current needs to be as high as the amplifier output current is if the move profile requires maximum current at maximum velocity. In many cases however maximum current is only required at start up and lower currents are required at higher speeds.

II. Isolation

There needs to be isolation between the AC line and the signal pins on the amplifier. If there is no isolation, the amplifier will immediately fail when the amplifier signal ground is pulled to earth ground. There are two options for isolation:

1. The amplifier can have built in optical isolation
2. The power supply can provide the isolation via an isolation transformer

The system must have at least one of these options to operate safely.

1) Amplifier With Isolation

Some Advanced Motion Controls amplifiers come with standard optical isolation, others have isolation as an option, and some do not have isolation at all. To determine if an Advanced Motion Controls amplifier has optical isolation look at the data sheet. The isolation will be indicated by a dashed line through the functional block diagram and labeled as optical isolation. If the line is labeled "*optional* optical isolation" then the part number determines if the amplifier has isolation. An amplifier has the optional optical isolation if the letter "I" is between the base part number and the revision letter. Example: B30A8Q (no isolation), B30A8IQ (isolation). If there is no dashed line through the block diagram the amplifier does not have isolation.

The following are *some* of the Advanced Motion Controls amplifiers that come standard with optical isolation:

- Products that are rated to 400VDC
- Amplifiers that take AC line voltage for power
- Digital amplifiers

2) Power Supply With Isolation

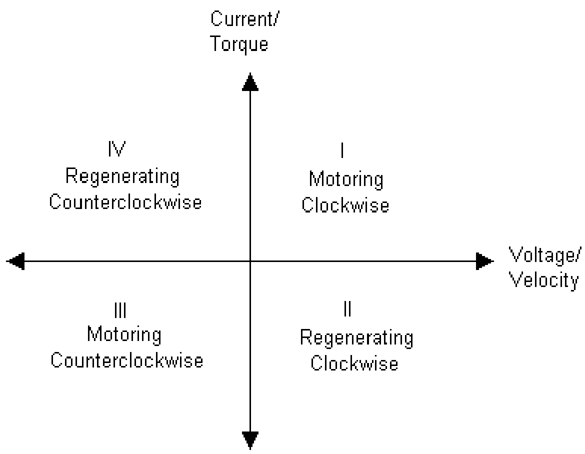
An isolated power supply uses a transformer to isolate the AC line voltage from the power supply ground. This allows both the power ground on an isolated power supply and the signal ground on a non-isolated amplifier to be safely pulled to earth ground. Always use an isolated power supply if there is no isolation on the amplifier.

III. Regeneration

From Advanced Motion Controls Engineering and Installation notes:

During motor deceleration or a downward motion of the motor load, conversion of the system's mechanical energy (kinetic and potential) will be regenerated via the servo amplifier back onto the supply in the form of electrical energy.

This regenerative process can charge the capacitors in the power supply to potentially dangerous voltages or voltages that may cause an amplifier over-voltage shutdown. Consequently, power supplies should have sufficient capacitance to absorb this energy without causing an over-voltage fault. If it is not practical to supply enough capacitance, use of a "shunt regulator" may be necessary to dissipate the kinetic and potential energy of the load. The shunt regulator is connected to the DC power supply to monitor the voltage. When a preset trip voltage is reached, a power resistor R is connected across the DC power supply by the shunt regulator circuit to discharge the power supply capacitor. The electric energy, stored in the capacitor, is thereby transformed into heat (I^2R).



I	Torque +	Velocity +	No Regen
II	Torque -	Veolcity +	Regen
III	Torque -	Velocity -	No Regen
IV	Torque +	Velocity -	Regen

Figure 3.1. Four quadrant operation. Regeneration occurs when the polarity of the Torque and Velocity are opposite.

Calculations

Voltage rise on power supply capacitors (no shunt regulator) – The amount of energy transferred to the power supply can be determined through a simple energy balance equation.

$$E_O = E_f \qquad (3.1)$$

These energy terms can be broken down into the approximate mechanical and electrical terms. Note: use the metric (kg-m-s) system of units for calculation.

Energy stored in a capacitor:

$$E_c = \frac{1}{2}CV^2 \qquad (3.2a)$$

Rotational mechanical energy (kinetic):

$$E_r = \frac{1}{2} J\omega^2 \qquad (3.2b)$$

Potential mechanical energy (gravity):

$$E_p = mgh \qquad (3.2c)$$

During regeneration the kinetic and potential energy will be stored in the power supply's capacitor. To determine the final power supply voltage following a regenerative event, the following equation may be used for most requirements (see below for variable definitions):

$$\left(E_c + E_r + E_p\right)_0 = \left(E_c + E_r + E_p\right)_f \qquad (3.3)$$

$$\frac{1}{2} C V_{nom}{}^2 + \frac{1}{2} J \varpi_0{}^2 + mgh_0 = \frac{1}{2} C V_f{}^2 + \frac{1}{2} J \varpi_f{}^2 + mgh_f \qquad (3.4)$$

Which simplifies to:

$$V_f = \sqrt{V_{nom}{}^2 + \frac{J}{C}\left(\varpi_0{}^2 - \varpi_f{}^2\right) + \frac{2mg\left(h_0 - h_f\right)}{C}} \qquad (3.5)$$

The V_f calculated must be below the power supply capacitance voltage rating and the amplifier over-voltage limit. If this is not the case, a ***shunt regulator*** is necessary. A shunt regulator is sized in the same way as a motor or amplifier i.e. continuous and RMS power dissipation must be determined. The power dissipation requirements can be calculated from the application move profile (see figure 1.2).

Where:

E	Energy (joules)
C	Capacitance (F)
V	Voltage (V)
L	Inductance (H)
I	Current (A)
J	Inertia (kg-m^2)
ω	Angular Velocity (rad/sec)
m	Mass (kg)
v	Linear velocity (m/s)
g	Gravitational Acceleration (9.81m/s^2)
h	Vertical height (m)
t	time (sec)

Subscripts:

0	Initial state
f	Final state
nom	Nominal

Special Case

Continuous regeneration – If the application requires continuous regeneration (more than a few seconds) then the shunt regulator may not be sufficient to dissipate the regenerative energy. Please contact Advanced Motion Controls for possible solutions to solve this kind of application. Some examples:

Web tensioning device
Electric vehicle rolling down a long hill
Spinning mass with a very large inertia (grinding wheel, flywheel, centrifuge)
Heavy lift gantry

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IV. Voltage Ripple

For the most part Advanced Motion Controls amplifiers are unaffected by voltage ripple from the power supply. The current loop is usually fast enough to compensate for 60Hz fluctuations in the bus voltage, and the components on the amplifier are robust enough to withstand all but the most extreme cases. Peak to peak voltage ripple as high as 25V is acceptable.

There are some applications where the voltage ripple can cause unacceptable performance. This can become apparent where constant torque or force is critical or when the bus voltage is pulled low during high speed and high current applications. If necessary, the voltage ripple from the power supply can be reduced, either by switching from single phase AC to three phase AC, or by increasing the capacitance on the power supply.

Calculations

The voltage ripple for a system can be estimated using the following equation:

V_R Voltage Ripple:

$$V_R = \frac{I_{PS}}{C_{PS}} F_f \qquad (4.1)$$

The power supply capacitance can be estimated by rearranging the above equation to solve for the capacitance and entering the target voltage ripple for V_R.

C_{PS} Power Supply Capacitance:

$$C_{PS} = \frac{I_{PS}}{V_R} F_f \qquad (4.2)$$

The variables for these equations are defined below.

F_f Frequency Factor:

Single Phase AC

$$F_f = \frac{0.42}{f} \qquad (4.3)$$

f = AC Line Frequency (Hz)
Note: For half wave rectified power supplies use $f = f/2$.

I_{PS} Power Supply Output Current:

If this value is not known the current can be estimated by using information from the output side of the servo amplifier:

$$I_{PS} = \frac{V_M \cdot I_M}{V_{PS} \cdot (.98)} \qquad (1.3)$$

V_M Motor Voltage:

$$V_M = (K_E \cdot S_M) + (I_M \cdot R_M) \qquad (1.1)$$

I_M Motor Current:

$$I_M = \frac{Torque}{K_T} \qquad (1.2)$$

Variables

C_{PS} Power Supply Capacitance (F)
I_{PS} Power Supply Current (A)
V_{PS} Nominal Power Supply Voltage (V)
V_R Voltage Ripple (V)
F_f Frequency Factor (s)
f AC Line Frequency (Hz)
I_M Motor Current (A)
V_M Motor Voltage (V)
K_E Motor Back EMF Constant
K_T Motor Torque Constant
R_M Motor Line to Line Resistance (□)
S_M Motor Speed