

Appendix G

Regeneration

The APEX615n can dissipate regenerated energy in its internal *regeneration resistor*. If an APEX615n system regenerates more energy than the internal resistor can dissipate, you can connect an external resistor between two terminals labeled **V Bus+** and **Regen Resistor**, located on the motor connector. The external resistor will double the dissipation capabilities of the APEX6151 and APEX6154. To increase the APEX6152's dissipation capabilities, you can add a resistor network, as explained later in this appendix..

The APEX6151's regeneration circuit works automatically—there are no adjustments to make. The circuit monitors the voltage on the power bus. If regenerated energy from the motor causes the bus voltage to rise above a threshold value, the circuit closes a switch, thus connecting the regeneration resistor between the positive and negative sides of the power bus, **V Bus+** and **V Bus-**. The energy is then dissipated in the resistor. During the regeneration event, the red LED labeled **Regen Active**, located on the APEX615n's front panel, will be illuminated.

The next drawing shows a schematic that includes the internal regeneration resistor, terminals for

When Do You Need an External Regeneration Resistor?

The APEX6151's regeneration control circuit was designed to automatically deal with regenerated power from almost all applications. Occasionally, however, an application situation arises in which regeneration will cause more power dissipation than the internal resistor can safely tolerate. In this situation, you can connect an external regeneration resistor to double the power that the system can dissipate.

To determine whether or not you need an external resistor, you can use one of two methods:

- Empirical Method
- Calculation Method

Empirical Method

The empirical method uses a trial procedure to determine whether excess regeneration will cause a regen or overvoltage fault. Operate your system (or a prototype of your system) and observe the results of regeneration. When your system decelerates, the *Regen Active* LED will be illuminated whenever regeneration turns on the internal resistor.

If the system's regeneration levels are too high, eventually either a regen fault or an overvoltage fault will shut down the APEX6151. (Be sure to let your system run for a long enough time to see if the regen fault will be triggered.) At this point, you have two options:

- Modify the system's move profile
- Install an external regeneration resistor

By changing the move profile—less torque, slower velocities, or a longer time between moves, for example—you may be able reduce the regeneration to a lower level, so that the fault no longer occurs.

By installing an external resistor, you can double the regeneration circuit’s power dissipation capabilities. With the resistor installed, the circuit’s specifications become:

	Continuous Power Dissipation Rating	Peak Power Dissipation Rating
APEX6151	100 watts	2 KW
APEX6152	N/A	N/A
APEX6154	180 watts	12 KW

After you alter the move profile, or install the external resistor, run the system again to verify that regeneration no longer causes a fault.

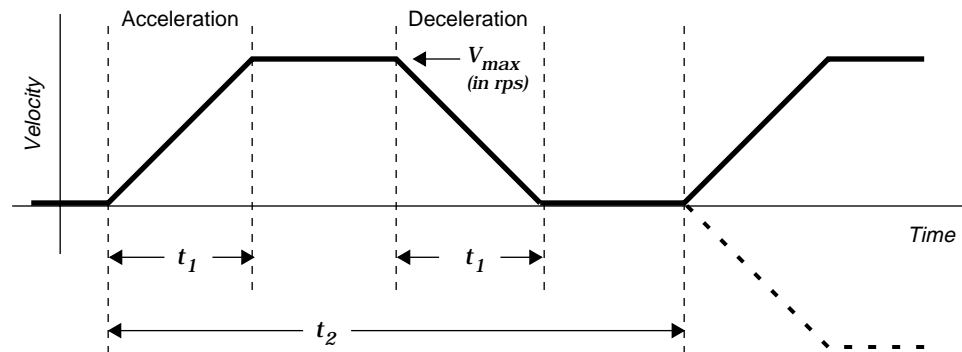
Calculation Methods

You can use the calculation method to predict peak power dissipation and average power dissipation. If peak power is greater than one kilowatt, or average power is greater than 50W, you should install an external regeneration resistor.

A NOTE ABOUT UNITS: We want a solution for power that is express in *watts*. To be consistent, we will use SI (metric) units in the following equations. If you want to use other units, apply conversion factors in the appropriate places.

Calculating Peak Power

A typical trapezoidal move profile is shown below.



Move Profile for Regeneration Calculations

Regeneration only occurs during the deceleration portion of the move. At any moment during deceleration, the amount of power regeneration is equal to the shaft power:

$$P_{shaft} = \omega T = 2\pi vT$$

where

T = torque, in newton meters (Nm)

ω = shaft velocity, in radians per second

v = shaft velocity, in revolutions per second (rps)

Peak power regeneration occurs at the moment deceleration begins, when the velocity is highest.

$$P_{shaft(peak)} = 2\pi v_{max} T$$

Not all of this peak power must be dissipated in the power resistor. Some of it will be dissipated in the copper windings of the motor—these power losses are known as *copper losses*.

$$P_{copper} = I^2 R = \frac{3}{2} \left(\frac{|T|}{k_T} \right)^2 R$$

where

I = motor current, in amps (A)

R = line – to – line motor resistance, in ohms (Ω)

k_t = motor torque constant, in newton meters per amp rms (Nm/A rms)

Power is also dissipated in the drive itself—these losses are known as *drive losses*. (Notice that we use the absolute value of the torque.)

$$P_{drive} = 5\sqrt{2} \left(\frac{|T|}{k_T} \right)$$

The peak power dissipated in the regeneration resistor, then, is equal to the peak shaft power, less copper and drive losses.

$$P_{peak} = P_{shaft} - P_{copper} - P_{drive}$$

Substituting the values from the previous equations, we obtain the equation for calculating peak power:

$$P_{peak} = (2\pi v_{max} T) - \frac{3}{2} \left(\frac{T}{k_T} \right)^2 R - 5\sqrt{2} \left(\frac{|T|}{k_T} \right)$$

Substitute values from your application into this equation.

- If P_{peak} is less than the Peak Power Dissipation Rating, the internal resistor is adequate.
- If P_{peak} is greater than the Peak Power Dissipation Rating, install an external resistor.

Calculating Average Power

Time plays a role in average power calculations. Total regenerated energy is equal to the area of the triangle under the deceleration portion of the move profile. In the move profile shown earlier, the time of deceleration is t_1 . Total energy, W , is therefore:

$$W_{regen} = \frac{1}{2}(\text{height})(\text{base}) = \frac{1}{2}(2\pi v_{max} T)t_1$$

During the deceleration time, copper losses and drive losses will dissipate some of the regenerated energy. To determine how much energy these losses will dissipate, each of these losses must be multiplied by the time t_1 :

$$W_{copper} = \left[\frac{3}{2} \left(\frac{T}{k_T} \right)^2 R \right] t_1 \quad W_{drive} = \left[5\sqrt{2} \left(\frac{|T|}{k_T} \right) \right] t_1$$

The total energy that must be dissipated in the regen resistor consists of the total regenerated energy, less copper and drive losses:

$$W_{total} = \left[\frac{1}{2}(2\pi v_{max} T) - \frac{3}{2} \left(\frac{T}{k_T} \right)^2 R - 5\sqrt{2} \left(\frac{|T|}{k_T} \right) \right] t_1$$

To find the average power, we must consider how frequently energy is "dumped" into the resistor. The period of the move profile is the time t_2 . Frequency and period are related by:

$$frequency = f = \frac{1}{t_2}$$

To find the average power dissipation in the resistor, we can multiply the equation for total energy by the frequency, or, as shown below, we can divide by the period of the repetitive move profile.

Finally, we obtain the equation for average power:

$$P_{average} = \left[\frac{1}{2}(2\pi v_{max} T) - \frac{3}{2} \left(\frac{T}{k_T} \right)^2 R - 5\sqrt{2} \left(\frac{|T|}{k_T} \right) \right] \frac{t_1}{t_2}$$

Substitute values from your application into this equation.

- If $P_{average}$ is less than the Continuous Power Dissipation Rating, the internal resistor is adequate.
- If $P_{average}$ is greater than the Continuous Power Dissipation Rating, install an external resistor.

Installing an External Regeneration Resistor

If you install an external resistor, ensure that it is adequately mounted and cooled. The internal resistor is cooled by the APEX615n's fan. The external resistor should be maintained at the same temperature, or cooler, as the internal resistor. Excessive heating of the external resistor can cause component failure.

CAUTION

Adequately cool the external resistor. Forced air cooling may be required. Maintain resistor temperature at same or lower temperature as internal resistor.

Specifications for the internal resistor are as follows:

APEX6151:

- | | |
|-----------------------------|--|
| • Resistor Size and Type | 150 ohm, 95 watt, 5% non-inductive resistor: |
| • Manufacturer Name: | Dale |
| • Manufacturer Part Number: | NHL-95-16N 150 OHM
5%, 3/16 QUICK CONNECT |
| • Compumotor Part Name | APEX10 REGEN KIT |

APEX6152: (for reference only: do not install external resistor)

- Resistor Size and Type 50 ohm, 100 watt, 5% non-inductive resistor:
- Manufacturer Name: Memcor-Truohm Inc.
- Manufacturer Part Number: FRV01006-2500-QM-NI ("NI " - Non Inductive)
- Mounting Bracket: Memcor-Truohm Inc.
Part Number 1141-006-001

APEX6154:

- Resistor Size and Type 25 ohm, 100 watt, 5% non-inductive resistor:
- Manufacturer Name: Memcor-Truohm Inc.
- Manufacturer Part Number: FRV01006-2250-QM-NI ("NI " - Non Inductive)
- Mounting Bracket: Memcor-Truohm Inc.
Part Number 1141-006-001
- Compumotor Part Name APEX40 REGEN KIT

Use these, or an equivalently rated resistors, for your external resistor. Be sure to specify a *non-inductive* resistor.

To connect the external resistor, wire its two terminals to **V BUS+** and **Regen Resistor**, located on the motor connector. Do not install more than one external resistor. The regeneration control circuit will automatically dissipate half of the excess regenerated power in the external resistor (provided that it is the the value indicated above).

CAUTION

Do not install more than one external regeneration resistor with the APEX6151 or APEX6154. Do not install an external regeneration resistor with the APEX 6152.

Building Your Own Regeneration Circuit

If you need more continuous power dissipation than the internal and external resistors provide for the APEX6151 and APEX6154, or the internal resistor provides for the APEX6152, you can design and build your own network of external regeneration resistors.

The next table shows specifications for maximum continuous and peak dissipation that the APEX615n can sustain. It also shows the minimum resistance for an external network. Do not use a resistor network with less resistance than the values in this table.

	Continuous Power Dissipation	Peak Power Dissipation	Resistance (min.)
APEX6151	286 W	2080 W	75 ohms
APEX6152	1560 W	3112 W	50 ohms
APEX6154	5760 W	12480 W	12.5 ohms

The APEX615n controller/drive's internal IGBT power switch is the component that determines the above specifications. With the standard external resistors discussed previously, the switch is already at its peak power dissipation level. However, the switch can dissipate more continuous power than the standard resistors allow. Your network, therefore, can dissipate additional continuous power, but must not dissipate more peak power. This is shown in the table above.

To use an external network, you must take the following two steps.

1. Set DIP Switch 1, position #1, in the ON position. This disables the APEX615n's Regen Fault circuit.
2. Disconnect the internal regeneration resistor.

Step 2 above requires opening the APEX615n's cover. Please call Compumotor's Application Engineering Department (see the inside front cover of this Installation Guide for the toll free number) for instructions on opening the cover and disconnecting the resistor, and to obtain information about designing your external resistor network.

Sharing the High Voltage Power Bus, using *V Bus+* and *V Bus-*

In some applications with multiple APEX615n units, one or more may continuously receive regenerated power from their loads. For example, in a tensioning application, two APEX615n units apply tension (opposite torques) to a single moving load. In this situation, one APEX615n could receive substantial regenerated power from its motor.

In such applications, you can connect the power buses from the APEX615n in parallel, through the **V BUS+** and **V BUS-** terminals, located on the motor connector. With the buses connected in parallel, the regenerated power from one APEX615n is dissipated by the power consumption of the other. Otherwise, all of the regenerated power would be continuously dumped into the APEX615n's own internal resistor.