

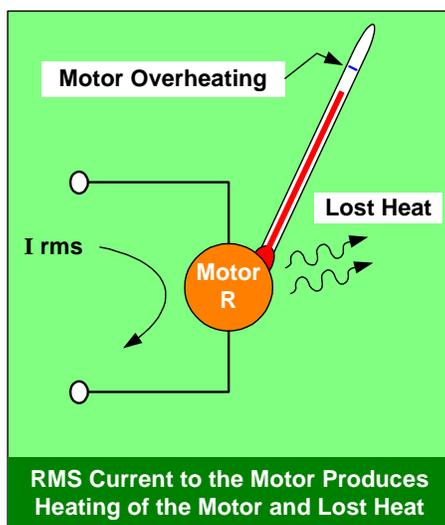
Protecting Motors against overload conditions using “I squared T” methods

The goal of an effective motor overload protection scheme is to protect the motor from damage while allowing it to operate normally up to its thermal limit. Ideally such a scheme would be based on a direct measurement of internal motor temperatures. Unfortunately the temperature at different points within a given motor varies widely and it is thus difficult to accurately measure “hot spot” temperatures. An alternative overload protection method monitors power flow to the motor and keeps track of the magnitude and duration of overload events. Such a method can provide excellent performance without the need for direct measurement of motor temperature. Since power delivered to the motor flows through the drive amplifier, an overload protection scheme based on power flow is well suited to implementation within the amplifier.

Motor Heating

Most of the energy dissipated in a motor as heat is the result of losses in the motor windings. This lost energy (not converted to mechanical energy by the motor) is calculated as $\text{Energy} = \text{Power} * \text{Time} = I^2 * R_L * \text{Time}$ where I is the RMS current and R_L is the effective motor winding resistance. In order for the motor to achieve temperature equilibrium, the flow of energy into the motor must balance with the energy flow to the mechanical load plus the energy lost as heat. The continuous current rating of the motor is determined as the maximum amount of power ($\text{Power} = I^2 * R_L$) the motor can continuously dissipate without exceeding its temperature rating.

continuous limit. The amount of overload energy the motor can handle is dependent on the motor size, cooling methods and configuration. For a given motor with winding resistance R_L the energy dissipated in excess of the continuous limit is given by: $E_{\text{trans}} = I^2 * R_L * \text{Time} - I_{\text{cont}}^2 * R_L * \text{Time}$ where I is the actual RMS current and I_{cont} is the continuous RMS current rating of the motor. The motor overload protection method presented here is achieved by continuously monitoring this transient overload energy and interrupting the amplifier output current before the transient energy exceeds the motor limits.



In a transient condition, the motor can tolerate a certain amount of energy in excess of the

AMPERES-SQUARED SECONDS

From a thermal standpoint, the key motor information is most often provided in terms of (1) The continuous current rating (Arms) (2) The transient peak current rating (Arms) and (3) The maximum duration of the peak current rating (S). Recognizing this we can drop R_L and redefine the key equation in terms of current and time only. Thus we have: $E_{\text{new}} = I^2 * \text{Time} - I_{\text{cont}}^2 * \text{Time}$ where E_{new} has units of Amperes squared-Seconds and is called “I squared T” and is a measure of the energy content of an overload transient. The comparable measure of motor overload capability is calculated as the square of the peak current rating (Amperes squared) times the rated peak current time (Seconds). The algorithm attenuates the output current when the measured I squared T of the overload exceeds the calculated I squared T rating of the motor

THE AMPLIFIER

The current sensor outputs are fed back to the microcontroller (with integral A/D) for use by the overload protection algorithm (aka I²T algorithm). The user programmable values provide the algorithm with measures of the rated continuous motor current and the motor I²T rating. The I²T algorithm is implemented independently on each output (phase U, V and W), but an overload detected on any one phase will interrupt current on all three outputs

APPLICATION EXAMPLE

In this example the amplifier is being used to drive a motor with the following overload characteristics:

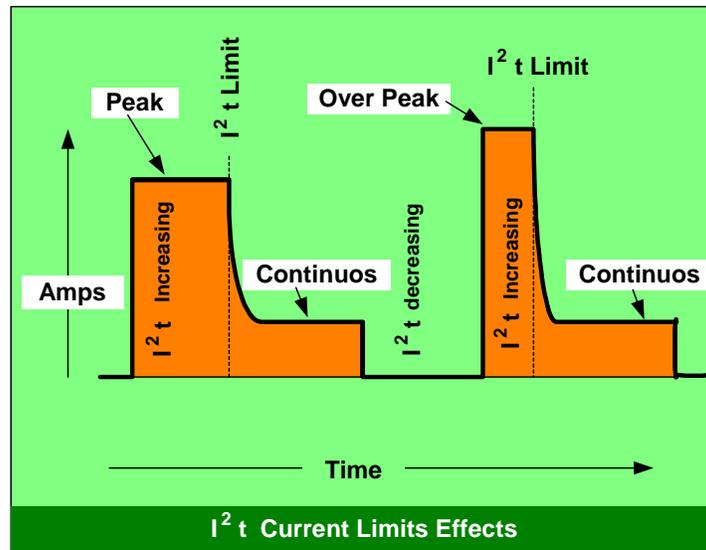
- > Continuous Current Limit: 6 Arms
- > Peak Current Limit: 18Arms
- > Max. Duration of Peak Current: 0.5 Seconds

The I²T limit can be calculated from the given data:

$$I^2T_LIM = ((18A)^2 - (6A)^2) * 0.5S = 144A^2S$$

Regardless of the input command, the amplifier will invoke current limiting following an overload on one or more phases of 18 amperes for 0.5 seconds. Note that the constant in the equation is the I²T limit of 144 A²S set by programmed values. Therefore limiting will go into effect sooner if the overload current is greater than 18A or later if the overload current is less than 18A. As an example with an overload of 23A, limiting will go into effect after a time T1 given by:

$$T1 = \frac{144A^2S}{23^2 A^2 - 6^2 A^2} = 0.29S$$



IN LIMIT EFFECT

What is the algorithm behavior when the limit has been reached? Once the current limiting occurs, the output current in all phases will fall to a level less than or equal to the continuous current settings. When the output current has fallen below the continuous limit, the difference between the actual current and the continuous limit current will be negative and the I²T tracking variable will fall. When the I²T tracking variable falls below the I²T limit, current limiting is turned off and the amplifier output then follows the output normally.