RMS Resolver Calibration Process

Revision 0.2
## Revision History

<table>
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<tr>
<th>Version</th>
<th>Description of Versions / Changes</th>
<th>Responsible Party</th>
<th>Date</th>
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<tr>
<td>0.1</td>
<td>Initial version</td>
<td>Chris Brune</td>
<td>5/24/2011</td>
</tr>
<tr>
<td>0.2</td>
<td>Updated document to calibrate motor in forward direction (+90 degrees) or reverse direction (-90 degrees).</td>
<td>Azam Khan</td>
<td>6/27/2011</td>
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1. Introduction

This document describes the method to calibrate the resolver for the electric motor to work with the PM controller.

2. Resolver Calibration Process

There are two aspects to resolver calibration. The first one is to calibrate the resolver circuitry within the PM controller (Resolver Delay). The other adjusts for any angle offset between the resolver and the magnetic field of the motor (Gamma Adjust).

**Important Note:** It is not necessary for the high-voltage DC to be connected to the inverter. However, spinning the motor will generate a DC voltage in the inverter, even if the inverter is off. This voltage is dangerous, take proper precautions. If a high-voltage DC is connected to the inverter make sure that it is high enough in value that the voltage generated by the motor will be less than this battery voltage.

If the high-voltage is not connected to the motor then two parameters need to be changed so that the controller does not generate a fault. **When a fault is generated the DSPGui software will not update values.** It will only show the values for when the fault occurred.

Change the following EEPROM parameters via the DSPGui. Program the EEPROM and cycle power to the controller for them to take effect.

- Change DC_UnderVolt_Thresh_EEPROM to be 0
- Change Precharge_Bypassed_EEPROM to be 1

Be sure to change them back when you are finished working with the controller with no DC bus voltage.

2.1 Resolver Delay

The Resolver Delay adjustment provides a calibration of the timing of the reading of the resolver by the analog to digital converter of the Digital Signal Processor (DSP). The goal is to read the peak of the sine wave coming from the resolver.

There are two parameters associated with the Resolver Delay accessed by the DSPGui software.
RMS Resolver Calibration Process

<table>
<thead>
<tr>
<th>Resolver_PWM_Delay_EEPROM_(Counts)</th>
<th>This parameter is used to program the Resolver Delay into the non-volatile memory of the controller.</th>
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<td>Resolver_Delay_Command</td>
<td>This parameter allows active adjustment of the Resolver Delay without reprogramming the EEPROM.</td>
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The Resolver Delay is a number between 0 and 6250.

To calibrate the delay use the following procedure:

1. Hook the controller up to a computer so that the DSPGui program can be used.

2. Hook the controller to the resolver of the motor.

3. Using the DSPGui bring the following three parameters to the watch window: sin_corr/2, cos_corr/2 and Resolver_Delay_Command.

4. If needed, set the Resolver_Delay_Command to 1100 (default value).

5. Turn the shaft of the motor slowly by hand to maximize the value of cos_corr/2. The value is updated by clicking the refresh button on the DSPGui. Leave the shaft at the position that creates the maximum value. It is not important that the position be extremely accurate, the cogging torque of the motor will not allow the motor to rest at the exact maximum.

6. Now adjust the Resolver_Delay_Command to fill in the table below. Remember to click the Refresh button to update the display.

7. Using this information it is now possible to narrow in on the maximum. Try increments of 100. It is not important to be more accurate than 100 counts.

8. Once a value has been determined it can be programmed into the EEPROM using Resolver_PWM_Delay_EEPROM using the normal EEPROM programming process.
2.2 Verify Resolver Direction

With the Resolver Delay completed the operation of the resolver can now be checked.

Add the following parameter to the DSPGui watch window: Gamma_Resolver_(DEG)_x_10. This parameter, Gamma_Resolver_(DEG)_x_10, is the actual electrical angle of the motor in degrees times 10. That is a value of 3600 is equal to 360 degrees. A value of 0 is 0 degrees. The electrical angle of the motor should not be confused with the mechanical angle. The electrical angle reflects the number of poles the motor has. For example, if a motor has 12 poles (6 pole pairs), the resolver will go through 6 rotations electrically for every shaft rotation.

As the motor shaft is slowly turned by hand in the Forward direction (defined as counter-clockwise when facing the shaft end of the motor) the value of Gamma_Resolver_(DEG)_x_10 will slowly increase. When the value reaches 3600 it will reset back to 0. Verify that when the shaft is turned in the forward direction than the value of Gamma_Resolver_(DEG)_x_10 increases. The values of sin_corr/2 and cos_corr/2 should also adjust as if they were running through a circle. Imagine cos_corr/2 on the x-axis and sin_corr/2 on the y-axis.

If the value of Gamma_Resolver_(DEG)_x_10 decreases or does not change when turning forward then there is wiring issue with the resolver.
2.3 Gamma Adjust

The next step is to align the magnetic field of the motor with the resolver. The resolver rotational position on the shaft is not necessarily always in the same place due to manufacturing tolerances, nor is it always aligned with the magnetic field.

To adjust this angle it is necessary for the motor to be connected to the inverter.

To run this calibration it is necessary to spin the motor at 1000 RPM in forward or reverse direction. Ideally this can be done by some external means. If it can’t then it is possible to try and spin the motor with the PM100. The PM100 firmware is not very sensitive to the exact gamma adjust value when operated at no-load. Run the motor with as little load as possible. Use a small torque command to bring the motor speed up to some value above 1000 RPM. Then command the inverter off. As the motor coasts down through 1000 RPM you can read the values from DSPGui software as described below.

We will use internal sensors in the inverter to measure the back EMF of the motor and thus determine the alignment. The internal sensors that measure back EMF can only measure the voltage when the motor is NOT enabled. Thus it is necessary to have the motor be disabled when monitoring the back EMF.

Put the following variables into the watch window of the DSPGui:

- Delta_Resolver_In_Fil_(DEG)_x_10
- Feedback_Speed_(RPM).

The Delta_Resolver_In_Fil_(DEG)_x_10 variable shows the angle (in degrees times 10) between the back EMF of the motor and the resolver. The Feedback_Speed_(RPM) shows the actual speed of the motor.

Click the continuous refresh button so that the values will continuously update.

The Delta_Resolver_In_Fil_(DEG)_x_10 will now display an angle in per unit (3600 = 360 degrees). The goal is to get this angle to be 900 (90 degrees) if the motor is running in forward direction or -900 (-90 degrees) if the motor is running in reverse direction. If the resolver is properly connected the displayed angle should remain relatively constant (less than ±18 degrees) as the motor is spun. If the value is constantly changing and rolling over then it is likely that the motor phasing is not correct. Try swapping two of the motor leads.
The parameter \( \text{Gamma_Adjust\_}(\text{Deg})\_x\_10 \) adjusts the calibration angle between the resolver and the back EMF of the motor. The parameter is set in degrees times 10.

While the motor is spinning in **forward** direction at 1000 RPM (but NOT enabled) monitor \( \text{Delta\_Resolver\_In\_Fil\_}(\text{DEG})\_x\_10 \) with the DSPGui. Next determine the angle represented by \( \text{Delta\_Resolver\_In\_Fil\_}(\text{DEG})\_x\_10 \). Divide the value shown in the DSPGui by 10 to convert it to degrees. Now determine the amount of adjustment necessary to make \( \text{Delta\_Resolver\_In\_Fil\_}(\text{DEG})\_x\_10 \) be 90 degrees. Increasing \( \text{Gamma\_Adjust\_}(\text{Deg})\_x\_10 \) will decrease \( \text{Delta\_Resolver\_In\_Fil\_}(\text{DEG})\_x\_10 \).

Repeat the process until \( \text{Delta\_Resolver\_In\_Fil\_}(\text{DEG})\_x\_10 = 90 \) degrees (900). The goal would be to adjust the \( \text{Gamma\_Adjust\_}(\text{Deg})\_x\_10 \) parameter until \( \text{Delta\_Resolver\_In\_Fil\_}(\text{DEG})\_x\_10 \) reads within ±0.7 degrees at 1000 RPM. Once this goal is achieved, program the value in \( \text{Gamma\_Adjust\_}(\text{Deg})\_x\_10 \) into its EEPROM equivalent, \( \text{Gamma\_Adjust\_EEPROM\_}(\text{Deg})\_x\_10 \) to save it permanently as a calibration parameter.

\( \text{Gamma\_Adjust\_}(\text{Deg})\_x\_10 \) can be either positive or negative as needed.

If the motor is spinning in **reverse** direction (but NOT enabled), the monitored speed should be -1000 RPM and the goal is to update \( \text{Gamma\_Adjust\_}(\text{Deg})\_x\_10 \) until \( \text{Delta\_Resolver\_In\_Fil\_}(\text{DEG})\_x\_10 \) reads -90 degrees (±0.7) at -1000 RPM.

Example:

1. While spinning the motor at 1000 RPM (when it is NOT enabled), the \( \text{Delta\_Resolver\_In\_Fil\_}(\text{DEG})\_x\_10 \) parameter reads a value of 828.

2. Convert the value to degrees by dividing by 10. \( 828 / 10 = 82.8 \) degrees.

3. To get to 90 degrees we need to change by \( 90 - 82.8 = 7.2 \) degrees.

4. The value of \( \text{Gamma\_Adjust\_EEPROM\_}(\text{Deg})\_x\_10 \) while running the test was 2.9 degrees. So to increase \( \text{Delta\_Resolver\_In\_Fil\_}(\text{DEG})\_x\_10 \) we need to decrease \( \text{Gamma\_Adjust\_EEPROM\_}(\text{Deg})\_x\_10 \). So we calculate the adjustment as 2.9 degrees - 7.2 degrees = -4.3 degrees.

5. We program this new value for \( \text{Gamma\_Adjust\_EEPROM\_}(\text{Deg})\_x\_10 \) as -43. We reset the controller and repeat the test to confirm the change.