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RMS Resolver Calibration Process

Revision 0.9

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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.

It is very important to correctly complete this resolver calibration process before attempting to run the motor. The resolver calibration process will ensure that the motor and resolver are properly connected to the controller.

The resolver is a position feedback device. It has 6 connections. The controller provides power to the two excitation winding connections at a fixed frequency equal to the PWM frequency. There are two SIN winding connections and two COS winding connections. The SIN and COS windings provide information about the motor shaft angular position. The angle is calculated using an arctangent function within the controller software.

The controller does not understand which direction for a vehicle is "Forward" and which is "Reverse". However, to simplify the understanding of the control RMS will often refer to a reverse or forward direction. This definition could be the opposite of the actual direction depending on the wiring of the motor and the resolver.

Generally for most motors the Forward direction is counter-clockwise rotation when facing the motor shaft. There are exceptions though.

The direction a motor will rotate in is defined by both the resolver connections and by the motor phase connections. These connections must define the same direction as "Forward" or the motor will not operate properly.

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

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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 RMS GUI software will not update values.** It will only show the values for when the fault occurred.

If you are using a CAN application to monitor parameters, it will be continuously updated whether there is a fault or not.

Change the following EEPROM parameters. If using GUI, Program the EEPROM and cycle power to the controller for them to take effect. If using CAN[1], the parameter is automatically programmed, just recycle power.

Parameter Name	GUI Address	CAN Address	Change to
DC_UnderVolt_Thresh_EEPROM	0x0117	104	0
Precharge_Bypassed_EEPROM	0x0115	140	1

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

In addition the Motor Type EEPROM parameter should already be set for the motor that you are using. If you do not know the number for your motor please contact RMS for more information.

[1] Please refer to the document, RMS CAN Protocol for information about CAN data and other important details.

2.1 Resolver Delay (Optional)

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/cosine wave coming from the resolver.

The Resolver Delay is factory preset to a default value. This value will generally be accurate enough for motor operation. Fine tuning the value will maximize the signal coming from the resolver.

Following parameters associated with the Resolver Delay can be accessed by the RMS GUI software and CAN application:

Resolver_PWM_Delay_EEPROM_(Counts)	This parameter is used to program the Resolver Delay into the non-volatile memory of the controller.
Resolver_Delay_Command	This parameter allows active adjustment of the Resolver Delay during the calibration process.
Sin_corr_(V)_x_100	This parameter shows the Sine value of the resolver input. It is a times 100 value between ±1.5V.
Cos_corr_(V)_x_100	This parameter shows the Cosine value of the resolver input. It is a times 100 value between ±1.5V.

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 aprogram (RMS GU) to monitor parameters can be used.

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

3. Using the RMS GUI bring the following three parameters to the watch window:
   (a) Resolver_Delay_Command
   (b) Sin_corr_(V)_x_100
   (c) Cos_corr_(V)_x_100

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_(V)_x_100. The value is updated by clicking the refresh button on the RMS GUI. 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.

Resolver_Delay_Command	Cos_corr_(V)_x_100
700	
800	
900	
1000	
1100	
1200	
1300	
1400	
1500	

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2.2 Verify Resolver and Motor Direction

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

Following parameters associated with the Resolver Direction can be accessed by the RMS GUI software or CAN application[2]:

Parameter Name	GUI Address	CAN Address	Description
Gamma_Resolver_(DEG)_x_10	0x0075	ID 0x0A5 Bytes 0,1	This parameter 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.
Feedback_Speed_(RPM)	0x0097	ID 0x0A5 Bytes 2,3	This parameter will show the motor shaft speed as calculated from the resolver. The speed will be positive for forward direction rotation and negative for reverse direction rotation.
Voltage_Feedback_Speed_(RPM)	0x00BA	Not Available	This parameter will show the motor shaft speed as calculated from monitoring the back EMF of the motor. The speed will be positive for forward direction rotation and negative for reverse direction rotation.
Sin_corr_(V)_x_100	0x0073	Not Available	This parameter shows the Sine value of the resolver input. It is a times 100 value between ±1.5V.
Cos_corr_(V)_x_100	0x0074	Not Available	This parameter shows the Cosine value of the resolver input. It is a times 100 value between ±1.5V.

[2] Please refer to the document, RMS CAN Protocol for information about CAN data and other important details.

As the motor shaft is slowly turned by hand in the **Forward** direction 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_(V)_x_100 and Cos_corr_(V)_x_100 should also adjust as if they were running through a circle. Imagine Cos_corr_(V)_x_100 on the x-axis and Sin_corr_(V)_x_100 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.

When spinning the motor the Feedback Speed parameter should indicate either a positive number for forward rotation or a negative number for reverse rotation.

The next step is to verify the motor direction as determined by the motor phase connections to the inverter. The only way to do this is to spin the motor from an **external source** at a speed sufficient for the controller to measure the back EMF of the motor. Monitor the Voltage Feedback Speed parameter to determine the direction of rotation as being calculated by the controller.

The direction of rotation as measured by Voltage Feedback Speed must match the direction as determined by the resolver.

2.3 Gamma Adjust

Following parameters associated with the Gamma Adjust can be accessed by the RMS GUI software or CAN application:

Parameter Name	GUI Address[3]	CAN Address	Description
Gamma_Adjust_EEPROM_(Deg)_x_10	0x011A	152	This parameter adjusts the calibration angle between the resolver and the back EMF of the motor. The parameter is set in degrees times 10.
Gamma_Adjust_(Deg)_x_10	0x0010	12	This parameter allows active adjustment of the Gamma Adjust during the calibration process.
Delta_Resolver_In_Fil_(DEG)_x_10	0x0089	ID 0x0A5 Bytes 6,7	This parameter shows the angle (in degrees times 10) between the back EMF of the motor and the resolver.
Delta_Resolver_In_Fil_at_1000RPM	0x00DF	NA	Displays Delta_Resolver_In_Fil_(DEG)_x_10 at around 1000 RPM.
Feedback_Speed_(RPM)	0x0097	ID 0x0A5 Bytes 2,3	This parameter shows the actual speed of the motor.

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 a speed that provides sufficient back EMF for the controller to measure. Generally 1000 rpm is

[3] GUI address should not be used as the primary reference to search for the parameter. The primary reference is Parameter Name.

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sufficient. However for some motors this speed will be too low. For some motor the speed will be too high. A good rule of thumb would be about 1/3 of the no-load base speed of the motor.

The motor must either be spinning from an external mechanism or it can be coasting down. In either case the PWM must be OFF (motor not enabled to run) when perform the calibration readings.

If it is necessary to try and operate the motor to allow it to coast down it is recommended that torque mode be used for control and not speed mode. Speed mode can result in high motor currents in an uncalibrated motor.

The controller 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 the calibration speed. Then command the inverter off. As the motor coasts down the values can be read as described below.

The internal voltage sensors in the inverter are used 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 RMS GUI or CAN application:

- Gamma_Adjust_(Deg)_x_10
- Delta_Resolver_In_Fil_(DEG)_x_10
- Feedback_Speed_(RPM)

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 (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 and the motor is spinning at a sufficient speed the displayed angle should remain relatively constant (less than ± 2 degrees) as the motor is spun. If the value is constantly changing or staying at a value near zero degrees then it is likely that the motor phasing is not correct. Try swapping two of the motor leads.

While the motor is spinning in **forward** direction at the selected calibration speed (NOT enabled) record the angle Delta_Resolver_In_Fil_(DEG)_x_10. Next determine the angle represented by Delta_Resolver_In_Fil_(DEG)_x_10. Divide the value by 10 to convert it to degrees. Now determine the amount of

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adjustment necessary to make Delta_Resolver_In_Fil_(DEG)_x_10 be plus or minus 90 degrees as determined by direction of rotation. Increasing Gamma_Adjust_(Deg)_x_10 will decrease Delta_Resolver_In_Fil_(DEG)_x_10.

Repeat the process until Delta_Resolver_In_Fil_(DEG)_x_10 = 90 degrees (900) for positive rotation, or Delta_Resolver_In_Fil_(DEG)_x_10 = -90 degrees (-900) for negative rotation. The goal would be to adjust the Gamma_Adjust_(Deg)_x_10 parameter until Delta_Resolver_In_Fil_(DEG)_x_10 reads within ± 0.7 degrees. Once this goal is achieved, program the value in Gamma_Adjust_(Deg)_x_10 into its EEPROM equivalent, Gamma_Adjust_EEPROM_(Deg)_x_10 to save it permanently as a calibration parameter.

Gamma_Adjust_(Deg)_x_10 can be either positive or negative as needed.

Example:

1. While spinning the motor at 1000 RPM (when it is NOT enabled), the Delta_Resolver_In_Fil_(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 Gamma_Adjust_EEPROM_(Deg)_x_10 while running the test was 2.9 degrees. So to increase Delta_Resolver_In_Fil_(DEG)_x_10 we need to decrease Gamma_Adjust_EEPROM_(Deg)_x_10. So we calculate the adjustment as 2.9 degrees - 7.2 degrees = -4.3 degrees.

5. Enter the new value into Gamma_Adjust_(Deg)_x_10 and repeat the process to verify that Delta_Resolver_In_Fil_(DEG)_x_10 now reads 900.

6. Program the new calibration value for Gamma_Adjust_EEPROM_(Deg)_x_10 as -43. Reset the power to the controller. Repeat the test to confirm the change.

Revision History

Version	Description of Versions / Changes	Responsible Party	Date
0.1	Initial version	Chris Brune	5/24/2011
0.2	Updated document to calibrate motor in forward direction (+90 degrees) or reverse direction (-90 degrees).	Azam Khan	6/27/2011
0.3	Changed sin_corr/2 and cos_corr/2 to Resolver_SIN_Input_x_100 and Resolver_COS_Input_x_100, respectively.	Azam Khan	12/07/2011
0.4	Added references to CAN Addresses to allow users to perform resolver calibration using CAN.	Azam Khan	1/4/2012
0.5	- Renamed Resolver_SIN_Input_x_100 as Sin_corr_(V)_x_100. - Renamed Resolver_COS_Input_x_100 as Cos_corr_(V)_x_100.	Azam Khan	7/18/2012
0.6	Minor correction of sin/cos parameter description. Clarify explanations of process. Address issues surround 1000 rpm as calibration speed. Add use of Voltage feedback to verify motor direction.	Chris Brune	8/3/2012
0.7	"Resolver Delay" calibration in section 2.1 is an optional procedure.	Azam Khan	8/7/2012
0.8	Added Delta_Resolver_In_Fil_at_1000RPM to section "2.3 Gamma Adjust".	Azam Khan	11/19/2013
0.9	Changed Cos_corr/2 value to Cos_corr_(V)_x_100 in the table in section 2.1	Azam Khan	1/23/2014