CONTROL TECHNIQUES™

KNOWLEDGEBASE DOCUMENT **UNIM063**

Subject:	Advanced Motion Control (AMC) User Unit and Profile Setup		
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Revision History

Revision	Date	Revising Author	Authorised By	Comments
1.0	07/04/2020	Artem Oskin	Rob Francis	Initial Version

Summary of Contents

This document details the setup of the user units scaling and profile setup for the Advanced Motion Controller (AMC).

Disclaimer: This document doesn't consider linear position feedback devices and covers only rotary position feedback devices. If you have a linear position feedback device, please use Parameters Reference Guide for specific details, but since the main approach to user units and setup is the same, you can use this document for better understanding.

Part 1. Normalised Position and feedback device resolution.

By default, the Advanced Motion Controller (AMC) is configured that user units (UU) represent normalised encoder counts. But typically, most applications would like to work in more practical linear or rotary units, such as degrees or millimetres.

Basically, user units (UU) represent how many units of any measure (counts, degrees, millimetres, etcetera) are equal to one rotation of the AMC slave feedback device. That's why initially it's very important to setup the AMC feedback device correctly and decide how many bits for the position resolution we need.

There are 48 bits which represent a current position of a motor feedback device in the drive (Figure 1).

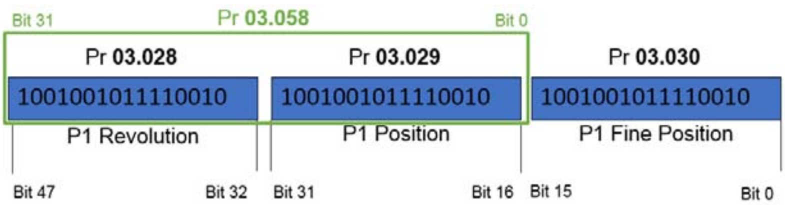

Figure 1

This 48-bit position value cannot be used directly by the Advanced Motion Controller. Position feedback from a drive or an option module position feedback interface is given for the AMC as a 32-bit signed value *P1 Normalised Position* (03.058) including the effect of the marker input for the interface (if relevant).

A user should decide how many bits are going to be used for position and how many bits are going to be used for turns.

P1 Normalised Position Bits = 32 - P1 Normalisation Turns (03.057)

From the formula above it is obvious that if we want more bits for a normalised position, we need to reduce number of turns bits included in the normalisation turns. By default, we have *P1 Normalisation Turns (03.057) = 16 bits* which means *P1 Normalised Position Bits = 16 bits* also.

Please note that there is no point to provide more than 16 bits for *P1 Normalised Position Bits* if an effective resolution of the AMC slave feedback device is lower than 16 bits.

For example, if we have a quadrature encoder with 4096 pulses per revolution (PPR) its effective resolution would be 4096*4=16384 counts per revolution (CPR). For such encoder 1 increment in counts would give 4 increments in *P1 Normalised Position* (03.058). In other words, if we will rotate such encoder very slowly, we will see that a value in *P1 Normalised Position* (03.058) changes with a step = 4 (0 → 4 → 8 → 12 → 16 and so on). For such encoder we need only 14 bits to cover its resolution, but the maximum value of *P1 Normalisation Turns (03.057) = 16 bits* so the minimum value of *P1 Normalised Position Bits = 16 bits* also.

An opposite example would be a SINCOS encoder which have very high resolution. Let's take a Unimotor with Stegmann SRS50 SINCOS encoder. It has 1024 sine waves per channel per revolution, which gives us an effective maximum resolution more than 2^21 counts per revolution: 1024 x 4 x 900 = 3686400.

For SRS50 you may decrease *P1 Normalisation Turns (03.057) = 11 bits* which gives *P1 Normalised Position Bits = 21 bits* and we will be able to use full resolution of that feedback device for more precise positioning in the AMC.

When we have decided how many bits we need for a position, we can setup our UU further.

Part 2. AMC Slave UU Ratio and AMC resolution.

As mentioned earlier UU represents how many units of any measure are equal to one rotation of the AMC slave feedback device.

<u>Example №1:</u>

Let's consider we have a 1024 PPR quadrature encoder as the AMC slave feedback device, we decided to have *P1 Normalisation Turns (03.057) = 16 bits* and *P1 Normalised Position Bits = 16 bits*. That means one rotation of the AMC slave feedback device is equal to 65536 in *P1 Normalised Position* (03.058). Now we need to consider how many UU are equal to that value.

Let's say we would like to work with 1UU = 1 degree. One rotation represents 360 degrees, so 65536 in *P1 Normalised Position* (03.058) is equal to 360 degrees or 360 UU. For such setup we need to set:

AMC Slave User Units Ratio Numerator (31.006) = 360
AMC Slave User Units Ratio Denominator (31.007) = 65536

That looks logical, but we have forgotten about the AMC resolution we would have with such setup. For such an encoder CPR = 4096, so its effective minimal increment in position is 65536/4096 = 16 and one real physical count would give 16 increments in *P1 Normalised Position* (03.058). In other words, one AMC slave feedback device rotation gives 4096 unique values in *P1 Normalised Position* (03.058). From the AMC point of view one AMC slave feedback device rotation gives 65536*(360/65536) = 360 unique values in *AMC Slave Position* (33.004).

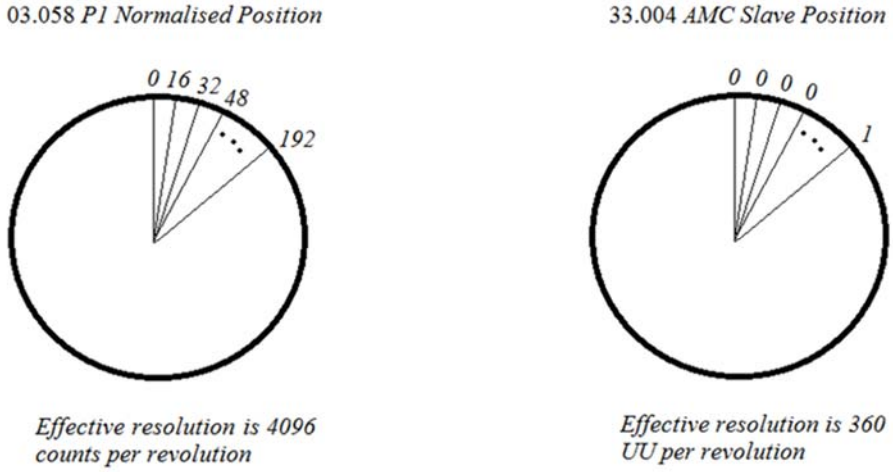

Figure 2

That means for the AMC we would have 4096/360 = 11.4 times lower resolution compare to one our feedback device can provide. AMC will not consider the first 11 counts and we will have 1UU increase only at the 12th count (Figure 2 and Table 1).

Table 1

count	1	2	3	4	5	6	7	8	9	10	11	12	13
03.058	16	32	48	64	80	96	112	128	144	160	176	192	208
33.004	0	0	0	0	0	0	0	0	0	0	0	1	1

To increase the AMC resolution, we can take 1 UU = 0.001 degree. One rotation represents 360 degrees, so 65536 counts from the AMC slave feedback device are equal to 360.000 degrees or 360/0.001 = 360000 UU. For such setup we need to set:

AMC Slave User Units Ratio Numerator (31.006) = 360000
AMC Slave User Units Ratio Denominator (31.007) = 65536

With that setup one real physical count would give 360000/4096 = 88 UU in *AMC Slave Position (33.004)* (Figure 3 and Table 2).

Table 2

count	1	2	3	4	5	6	7	8	9	10	11	12	13
03.058	16	32	48	64	80	96	112	128	144	160	176	192	208
33.004	88	176	264	352	440	528	616	704	792	880	968	1056	1144

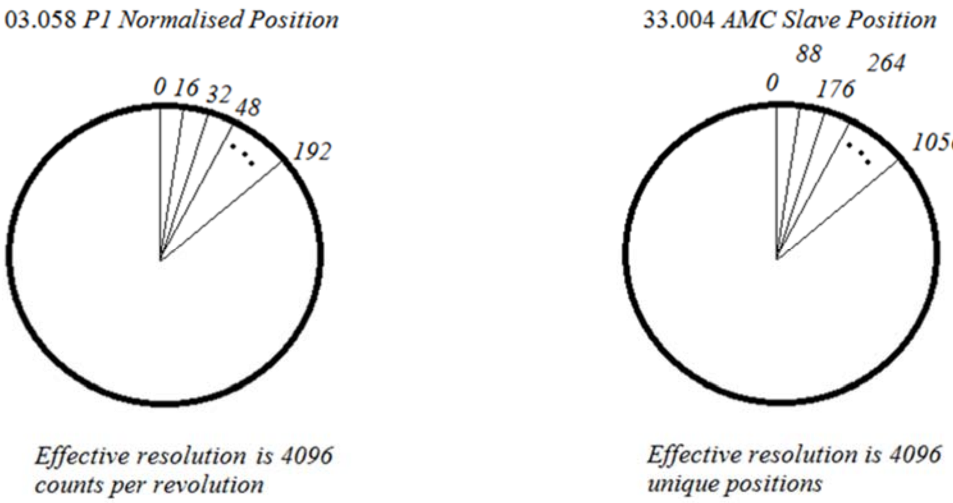

Figure 3

Now we are using the full resolution capability of our encoder.

To summarise that, please follow a common rule to always keep $\frac{Pr31.006}{Pr31.007} \geq 1$.

Another aspect is the AMC Output User Units Ratio. If we don't have a dual loop configuration (Figure 5), then the AMC Output User Units Ratio should be set to *Pr 31.008 = Pr 31.007* and *Pr 31.009 = Pr 31.006*, so if we have the AMC Slave User Units Ratio more than or equal to unity, then the AMC Output User Units Ratio is always less than or equal to unity, which provides good resolution for the *AMC Output Speed (Pr 39.012)* and gives the least granular speed output.

If we have a dual loop configuration, then it's possible to have the AMC Output User Units Ratio more than unity, which could reduce the *AMC Output Speed (Pr 39.012)* resolution. In such case it's recommended to use *AMC Auto Resolution Enable (31.015).*

When *AMC Auto Resolution Enable (31.015)* = 1 the resolution of the internal units used by the Advanced Motion Controller is automatically increased by an internal scaling factor (*AMC Auto Resolution Scaling (31.016)*) which is the largest value (power of two) that maintains the AMC Output User Units Ratio less than or equal to unity.

Part 3. AMC Output and Master UU Ratios.

After we've decided about Slave UU Ratio we can setup Output UU Ratio and Master UU Ratio. In systems where slave and motor feedback device physically are the same one device (Figure 4) just set *Pr 31.008 = Pr 31.007* and *Pr 31.009 = Pr 31.006*. Dual loop configuration, where different motor and slave feedback devices are presented, will be described later in this document.

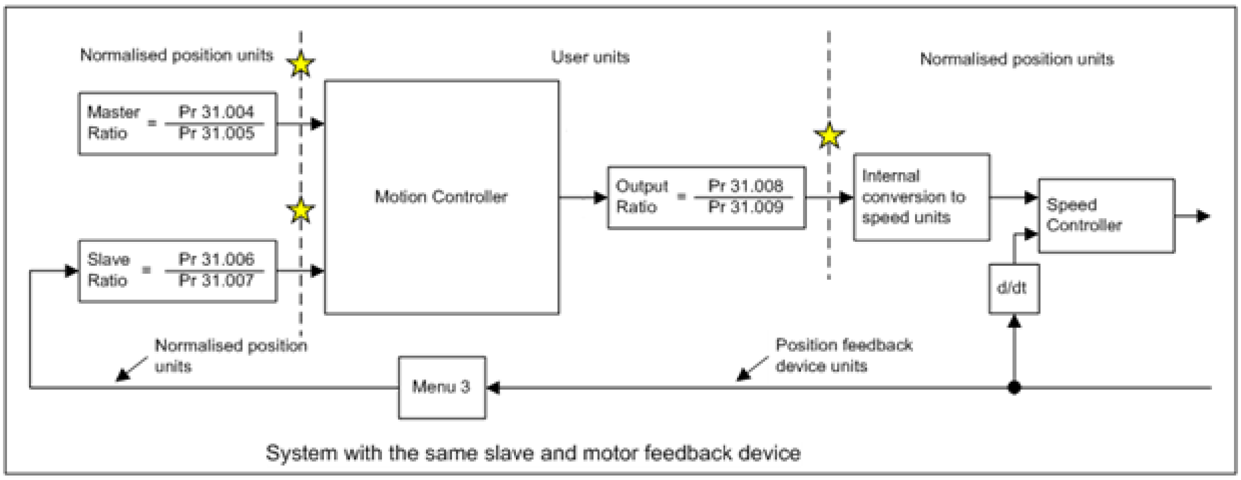

Figure 4

If you want 1 revolution of the master encoder to represent 1 revolution of the slave encoder you need to set *Pr 31.004 = Pr 31.006* and *Pr 31.005 = Pr 31.007*.

For a dual loop configuration (Figure 5) you need to consider a gear ratio between the slave encoder feedback and motor encoder feedback.

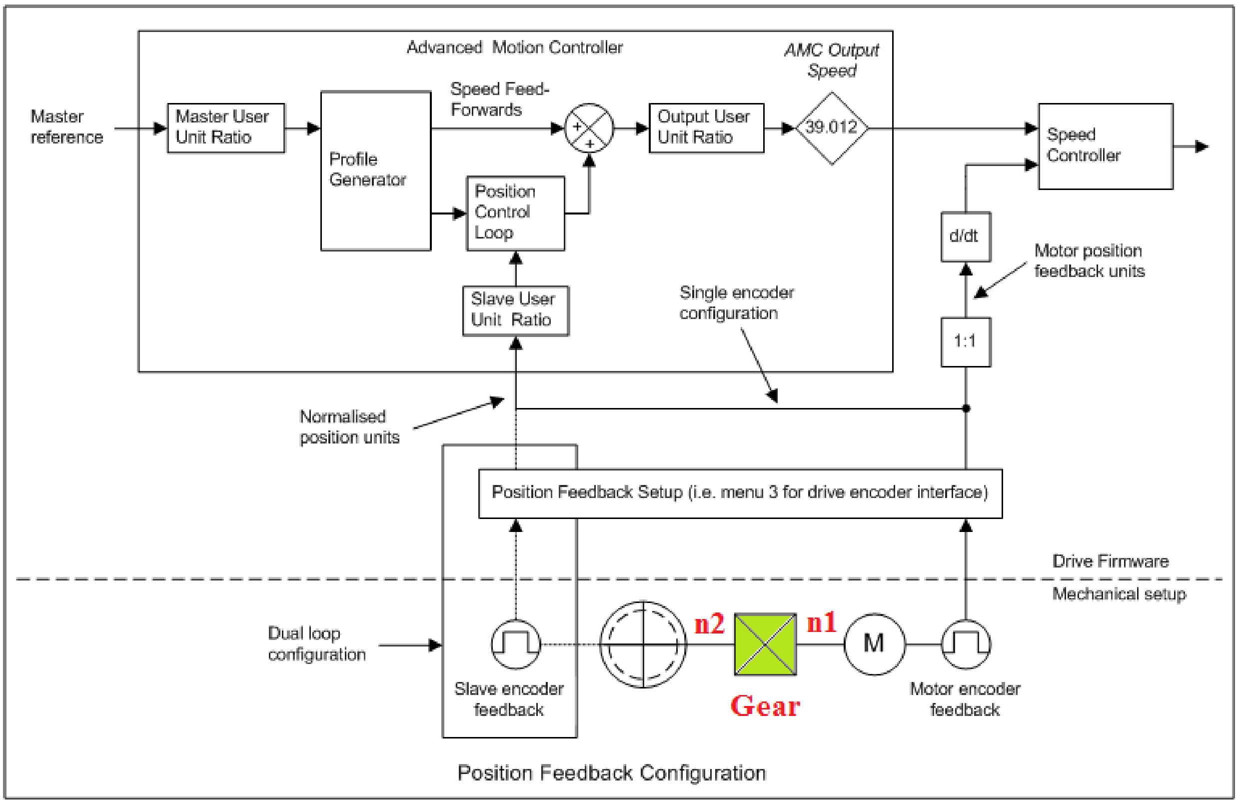

Figure 5

Let's consider several dual loop configurations below.

Example №2:

- The normalised position for the slave position feedback has 14 *P1 Normalisation Turns (03.057)* and 18 position bits;
- The normalised position for the motor feedback has 16 *P2 Normalisation Turns (03.157)* and 16 position bits;
- User units are to represent one revolution in degrees with three decimal places (1 revolution = 360000 user units);
- There is a gear ratio of 7:1 between the motor encoder feedback and slave encoder feedback i = n1/n2 = 7/1 (Figure 5);

The slave user units ratio can be setup to convert the 32-bit normalised position into 0.001 degree units as follows:

- Change of user units over the required range = 360000;
- Change of normalised position over the required range = 2^18;

AMC Slave User Units Ratio Numerator (31.006) = 360000;
AMC Slave User Units Ratio Denominator (31.007) = 2^18 = 262144;

In that step always make sure that $\frac{Pr31.006}{Pr31.007} \geq 1$ which means we are using the full resolution capability of our encoder.

In this example the output ratio is setup to convert from user units to the normalised position units for the motor feedback and must include the inverse of the gear ratio to ensure that the required output speed is seen at the slave feedback.

AMC Output User Units Ratio Numerator (31.008) = (2^16) x 7
AMC Output User Units Ratio Denominator (31.009) = 360000

If the AMC Output User Units Ratio is more than unity it's recommended to use *AMC Auto Resolution Enable (31.015)* = 1.

Example №3:

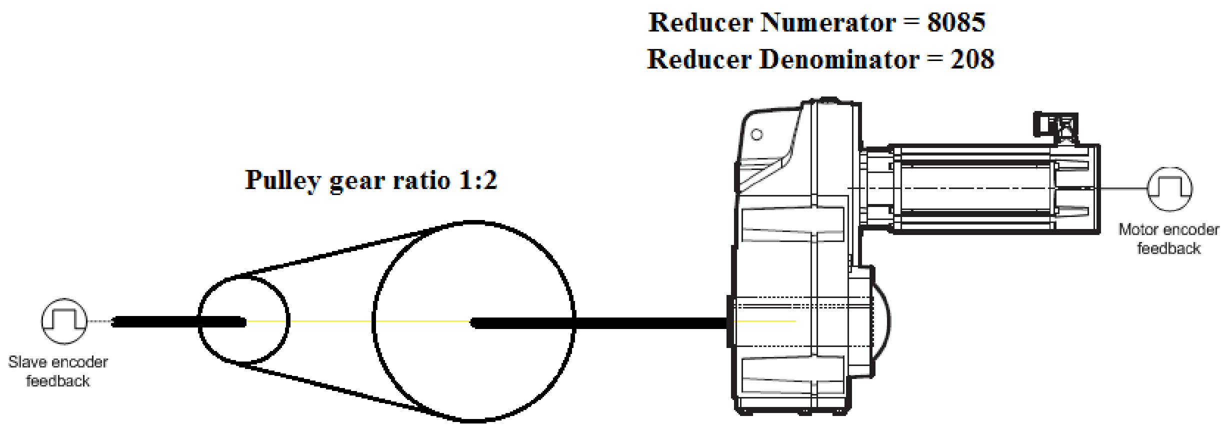

Figure 6

- The normalised position for the slave position feedback has 14 *P1 Normalisation Turns (03.057)* and 18 position bits;
- The normalised position for the motor feedback has 16 *P2 Normalisation Turns (03.157)* and 16 position bits;
- User units are to represent one revolution in degrees with three decimal places (1 revolution = 360000 user units);
- There is a pulley gear ratio of 1:2 between the motor reducer and the slave encoder feedback (Figure 6);
- There is a motor gear (reducer) with ratio of 8085:208 between the motor reducer and the motor encoder feedback (Figure 6);

The slave user units ratio can be setup to convert the 32-bit normalised position into 0.001 degree units as follows:

- Change of user units over the required range = 360000;
- Change of normalised position over the required range = 2^18;

AMC Slave User Units Ratio Numerator (31.006) = 360000;
AMC Slave User Units Ratio Denominator (31.007) = 2^18 = 262144;

In that step always make sure that $\frac{Pr31.006}{Pr31.007} \geq 1$ which means we are using the full resolution capability of our encoder.

Here we have two gears with 1/2 and 8085/208 ratios. With such setup we need to set the following values for Output UU Ratio:

AMC Output User Units Ratio Numerator (31.008) = (2^16) x (1/2) x (8085/208)
AMC Output User Units Ratio Denominator (31.009) = 360000

If the AMC Output User Units Ratio is more than unity it's recommended to use *AMC Auto Resolution Enable (31.015)* = 1.

Part 4. AMC Profile Generator Parameters Setup.

When the AMC is selected *AMC Select (31.001)* = 1 the output of the motion controller is written to *Hard Speed Reference (03.022)* (Figure 7).

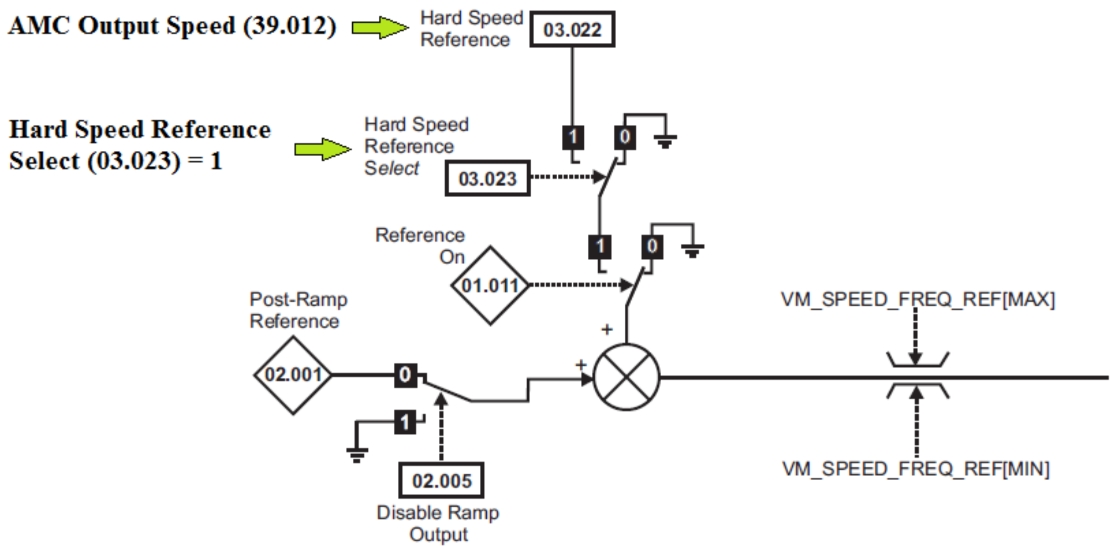

Figure 7

The *Hard Speed Reference (03.022)* is a reference value which does not pass through the ramp system, but is added directly to the *Post Ramp Reference (02.001)*. That means now the Ramp from menu 2 is out of use and to arrange our movement we should setup the following parameters related to the AMC Profile Generator:

AMC Profile Acceleration *(38.001)* (0.001 UU/ms^2)
AMC Profile Deceleration *(38.002)* (0.001 UU/ms^2)
AMC Profile Maximum Speed *(38.003)* (0.01 UU/ms)
AMC Profile Jerk 1 *(38.011)* (0.0001 UU/ms^3)
AMC Profile Jerk 2 *(38.012)* (0.0001 UU/ms^3)
AMC Profile Jerk 3 *(38.013)* (0.0001 UU/ms^3)
AMC Profile Jerk 4 *(38.014)* (0.0001 UU/ms^3)

As mentioned earlier, by default, the AMC assumes that the user units represent normalised encoder counts.

The default value of 1.092 UU/ms^2 for AMC Profile Acceleration *(38.001)* and AMC Profile Deceleration *(38.002)* is the equivalent of an acceleration of 1000rpm/s for a feedback device with 16 normalised position bits per revolution and a user unit ratio of unity. In other words, if we use default settings, we would have:

P1 Normalisation Turns (03.057) = 16 bits
P1 Normalised Position Bits = 16 bits
AMC Slave User Units Ratio Numerator (31.006) = 1000
AMC Slave User Units Ratio Denominator (31.007) = 1000
AMC Slave Source Select (*33.001*) = *P1 Drive*

$\frac{Pr31.006}{Pr31.007}$ = 1 and one rotation of the AMC slave feedback device gives

65536*1 = 65536UU for *AMC Slave Position (33.004).*

$$1000\frac{rpm}{s} = \frac{1000}{60}\frac{revolutions}{s^2} = \frac{1000}{60} * \frac{65536 * \frac{Pr31.006}{Pr31.007}}{1}\frac{\mathrm{UU}}{\mathrm{s}^2} =$$

$$= \frac{1000}{60} * \frac{65536}{1000^2}\frac{\mathrm{UU}}{\mathrm{ms}^2} = 1.092\frac{\mathrm{UU}}{\mathrm{ms}^2}$$

The default value of 1092 UU/ms for AMC Profile Maximum Speed *(38.003)* is the equivalent of 1000rpm for a feedback device with 16 normalised position bits per revolution and a user unit ratio of unity.

$$1000rpm = \frac{1000}{60}\frac{revolutions}{s} = \frac{1000}{60} * \frac{65536 * \frac{Pr31.006}{Pr31.007}}{1}\frac{\mathrm{UU}}{\mathrm{s}} =$$

$$= \frac{1000}{60} * \frac{65536}{1000}\frac{\mathrm{UU}}{\mathrm{ms}} = 1092.00\frac{\mathrm{UU}}{ms}$$

There is a default value of 0 UU/ms³ for AMC Profile Jerk 1-4 which means we will have a linear ramp and not the s-ramp by default. Please consider these jerk parameters have 4 decimal places, so you may need to increase Normalised Position or AMC Slave UU Ratio for some specific applications where the jerk values must to be very small.

Now let's move from the default settings to a specific application "Example №1" mentioned in the Part 2 of this document earlier.

P1 Normalisation Turns (03.057) = 16 bits
P1 Normalised Position Bits = 16 bits
AMC Slave User Units Ratio Numerator (31.006) = 360000
AMC Slave User Units Ratio Denominator (31.007) = 65536
AMC Output User Units Ratio Numerator (31.008) = 65536
AMC Output User Units Ratio Denominator (31.007) = 360000
AMC Slave Source Select (*33.001*) = *P1 Drive*

$\frac{Pr31.006}{Pr31.007} = \frac{360000}{65536}$ and one rotation of the AMC slave feedback device gives

65536*(360000/65536) = 360000UU for *AMC Slave Position (33.004).*

Let's say our system requires:
- acceleration rate 1000 rpm/s;
- deceleration rate 500 rpm/s;
- maximum profile speed 1000 rpm.

Acceleration rate.

$$1000\frac{rpm}{s} = \frac{1000}{60}\frac{revolutions}{\mathrm{s}^2} = \frac{1000}{60} * \frac{65536 * \frac{360000}{65536}}{1}\frac{\mathrm{UU}}{\mathrm{s}^2}$$

$$= \frac{1000}{60} * \frac{360000}{1000^2}\frac{\mathrm{UU}}{\mathrm{ms}^2} = 6.000\frac{\mathrm{UU}}{\mathrm{ms}^2}$$

Deceleration rate.

$$500\frac{rpm}{s} = \frac{500}{60}\frac{revolutions}{\mathrm{s}^2} = \frac{500}{60} * \frac{65536 * \frac{360000}{65536}}{1}\frac{\mathrm{UU}}{\mathrm{s}^2}$$

$$= \frac{500}{60} * \frac{360000}{1000^2}\frac{\mathrm{UU}}{\mathrm{ms}^2} = 3.000\frac{\mathrm{UU}}{\mathrm{ms}^2}$$

Maximum profile speed.

$$1000rpm = \frac{1000}{60}\frac{revolutions}{\mathrm{s}} = \frac{1000}{60} * \frac{65536 * \frac{360000}{65536}}{1}\frac{\mathrm{UU}}{\mathrm{s}}$$

$$= \frac{1000}{60} * \frac{360000}{1000}\frac{\mathrm{UU}}{\mathrm{ms}} = 6000\frac{\mathrm{UU}}{ms}$$

From the calculations above we have the following results:

AMC Profile Acceleration *(38.001) = 6.000* (UU/ms²)
AMC Profile Deceleration *(38.002) = 3.000* (UU/ms²)
AMC Profile Maximum Speed *(38.003) = 6000* (UU/ms)