



Application Note 607003

Title: **Converting quaternions from EM7180SFP**

Product Family: **Motion and optical sensing**

Part Number: EM7180SFP

Keywords: Quaternion conversion

1- Introduction

You have extracted the quaternion quantities (Qw, Qx, Qy, Qz) from the EM7180SFP module. The quaternions are based on a North-East-Down (NED) convention, this format does not correspond to the orientation format you want to work with and you need to perform some conversion. Please read this application note.

2- Scope

This application note provides information on how to convert NED oriented quaternions to:

- ENU oriented quaternion (East North up)
- Heading Pitch and Roll
- Rotation vector
- Rotation Matrix, or Direction Cosine Matrix (DCM)

3- Conversion to ENU quaternion

While the North-East-Down (NED) convention is common in many industries, both Android and Windows 8 use the East-North-Up convention. Below is the equation to convert from NED to ENU.

$$Q_{\text{ENU}} = \begin{pmatrix} 0.707 & 0.707 & 0 & 0 \end{pmatrix} \begin{pmatrix} Q_w & -Q_z & Q_y & -Q_x \\ Q_z & Q_w & -Q_x & -Q_y \\ -Q_y & Q_x & Q_w & -Q_z \\ Q_x & Q_y & Q_z & Q_w \end{pmatrix}_{\text{NED}} \begin{pmatrix} 0 & 0 & -0.707 & 0.707 \\ 0 & 0 & 0.707 & 0.707 \\ 0.707 & -0.707 & 0 & 0 \\ -0.707 & -0.707 & 0 & 0 \end{pmatrix}$$

4- Conversion to Heading, Pitch, and Roll format

Most end users are searching for orientation data reported as heading, pitch, and roll. Below are the Excel transformation equations. Note that for other programs, such as Matlab, the ATAN2 arguments may be reversed.

Heading = atan2[(Qx2 - Qy2 - Qz2 + Qw2), 2*(QxQy + QzQw)]

Pitch = asin[-2*(QxQz - QyQw)]

Roll = atan2[(-Qx2 - Qy2 + Qz2 + Qw2), 2*(QxQw + QyQz)]

Where:

- Results are in radians.
- The quaternions are the outputs from Sentral in NED convention.
- Heading increases as the device rotates clockwise around a positive Z axis, and the range is 0° – 360°. (i.e. it matches what you would expect on a compass.)
- Pitch increases when pitching upward and the range is ±180°.
- Roll increases when rolling clockwise and the range is ±90°.

5- Conversion to Rotation Vector format

The rotation vector consists of the first three elements of the quaternion output, Qx, Qy, and Qz. The fourth element, Qw, is not included in the rotation vector. The rotation vector in ENU convention will be the first three elements of QENU, discussed above.

6- Conversion to Rotation Matrix, or Direction Cosine Matrix (DCM)

The rotation matrix, also known as the direction cosine matrix (DCM), can be established from the quaternion output using the following conversion. QENU values can be substituted to give the rotation matrix with an ENU convention.

R =	$Q_w^2 + Q_x^2 - Q_y^2 - Q_z^2$	$2*(Q_x*Q_y + Q_w*Q_z)$	$2*(Q_x*Q_z - Q_w*Q_y)$
	$2*(Q_x*Q_y - Q_w*Q_z)$	$Q_w^2 - Q_x^2 + Q_y^2 - Q_z^2$	$2*(Q_y*Q_z + Q_w*Q_x)$
	$2*(Q_x*Q_z + Q_w*Q_y)$	$2*(Q_y*Q_z - Q_w*Q_x)$	$Q_w^2 - Q_x^2 - Q_y^2 + Q_z^2$

EM Microelectronic-Marín SA ("EM") makes no warranties for the use of EM products, other than those expressly contained in EM's applicable General Terms of Sale, located at <http://www.emmicroelectronic.com>. EM assumes no responsibility for any errors which may have crept into this document, reserves the right to change devices or specifications detailed herein at any time without notice, and does not make any commitment to update the information contained herein.

No licenses to patents or other intellectual property rights of EM are granted in connection with the sale of EM products, neither expressly nor implicitly.

In respect of the intended use of EM products by customer, customer is solely responsible for observing existing patents and other intellectual property rights of third parties and for obtaining, as the case may be, the necessary licenses.

Important note: The use of EM products as components in medical devices and/or medical applications, including but not limited to, safety and life supporting systems, where malfunction of such EM products might result in damage to and/or injury or death of persons is expressly prohibited, as EM products are neither destined nor qualified for use as components in such medical devices and/or medical applications. The prohibited use of EM products in such medical devices and/or medical applications is exclusively at the risk of the customer