# RPM Measurement Techniques

## Introduction

This document discusses field devices and methods for measuring the rotational speed of a shaft in revolutions per minute (RPM). RPM measurement is important when controlling or monitoring the speed of motors, conveyors, turbines, etc.

## Sensors for RPM Measurement

A sensor is necessary to sense shaft speed. Typical devices used for this purpose are shaft encoders (rotary pulse generators), proximity sensors, and photoelectric sensors.

Each of these devices sends speed data in the form of pulses. Two factors affect the quality of this data:

- Number of pulses per revolution of the shaft (referred to as PPR). Higher PPR values result in better resolution.
- Symmetry of pulses. The symmetry of one pulse to the next can play a role in how consistent the RPM readings are. Symmetrical pulses give more accurate data.

### Encoders

Shaft encoders are the best solution for the sensing device. They offer high resolution (typically 1 to 5000 PPR) and clearly defined, symmetrical pulses. However, sometimes it is not feasible to mount an encoder to the shaft being monitored.

### Proximity Sensors

Proximity sensors provide medium- or low-resolution sensing, depending on the number of pulses measured per revolution. The best method of using a proximity sensor is to sense the teeth on a gear. This type of sensing typically has options for 60, 120, or 240 PPR, and the pulses are relatively clearly defined and symmetrical.

If a gear is not available, a proximity sensor can be used to sense the head of a bolt attached to the shaft. The drawback of this method is the low PPR (low resolution). If more than one bolt head is used, resolution improves, but pulses are often inconsistent and not symmetrical.

### Photoelectric Sensors

Photoelectric sensors usually provide low resolution, due to the low number of pulses measured per revolution. A photoelectric sensor must sense a reflective target on the shaft. If more than one target is used to increase the PPR, then the symmetry from one pulse to the next is likely to be poor.

### Matching Sensor Resolution to Shaft Speed

When choosing sensors, make sure the resolution of the sensor is appropriate for the speed of the shaft.

For example, if you use a 5000-PPR encoder on a fast-moving shaft, the resulting pulses might exceed the maximum input frequency of the system, causing inaccurate readings.

## Methods of Determining RPM

We'll discuss two methods for determining RPM: the *Frequency measurement method* and the *Period measurement method*.

Frequency measurement is better for fast-moving devices such as motors and turbines that typically turn in thousands of revolutions per minute.

Period measurement is better for devices that move more slowly, such as shafts that turn in less than 10 RPM.

### High PPR Solutions Using the Frequency Measurement Method

For this discussion, high PPR is considered to be at least 60 PPR.

When using high PPR sensors, such as shaft encoders or proximity sensors sensing gear teeth, the easiest way to determine RPM is to monitor the pulse frequency from the sensor using a digital input module and the Get

Frequency command in PAC Control. Then calculate the RPM using this equation:

$$\text{RPM} = \frac{\text{(Pulse Frequency in pulses/sec) x (60 sec/min)}}{\text{(Sensor pulses/revolution)}} = \frac{\text{Revolutions}}{\text{Minute}}$$

## Understanding the Frequency Method

When using frequency measurement as a method of monitoring RPM, the key factor is the number of pulses being sensed per revolution, or the PPR. This method works well with high PPR sensors and works poorly for low PPR sensors. On the next page are some examples that show why.

**With a 600 PPR sensor,** the equation becomes:

$$\text{RPM} = \frac{\text{Pulse Frequency x 60}}{600} = \frac{\text{Pulse Frequency}}{10} = \text{Pulse Frequency x 0.1}$$

- At a pulse frequency of 1 Hz, the shaft speed is 0.1 RPM.
- At a pulse frequency of 2 Hz, the shaft speed is 0.2 RPM.
- At a pulse frequency of 3 Hz, the shaft speed is 0.3 RPM.

This means that for each increment of 1 Hz, the RPM indication will change by 0.1 RPM. With a 600 PPR sensor, the shaft speed resolution is 0.1 RPM, which meets most application requirements.

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**With a 60 PPR sensor,** the equation becomes:

$$\text{RPM} = \frac{\text{Pulse Frequency x 60}}{60} = \text{Pulse Frequency}$$

- At a pulse frequency of 1 Hz, the shaft speed is 1 RPM.
- At a pulse frequency of 2 Hz, the shaft speed is 2 RPM.
- At a pulse frequency of 3 Hz, the shaft speed is 3 RPM.

This means that for each increment of 1 Hz, the RPM indication will change by 1 RPM. With a 60 PPR sensor, the shaft speed resolution is 1 RPM, which is the lowest acceptable resolution for most applications.

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**With a 1 PPR sensor,** the equation becomes:

$$\text{RPM} = \frac{\text{Pulse Frequency x 60}}{1} = \text{Pulse Frequency x 60}$$

- At a pulse frequency of 1 Hz, the shaft speed is 60 RPM.
- At a pulse frequency of 2 Hz, the shaft speed is 120 RPM.
- At a pulse frequency of 3 Hz, the shaft speed is 180 RPM.

This means that for each increment of 1 Hz, the RPM indication changes by 60 RPM! This is unacceptable for any application. With a 1 PPR sensor, the shaft speed resolution is 60 RPM. So when using low PPR sensors, the better solution is to measure the pulse period.

## Low PPR Solutions Using the Period Measurement Method

For this discussion, low PPR is considered to be anything less than 60 PPR.

Because it can be measured with higher resolution (0.1 ms), measuring the pulse period is the best method of measuring RPM when using low PPR sensors, such as proximity sensors sensing a bolt head or photoelectric sensors. Period is the time from the start of one pulse to the start of the next pulse. This
equation shows the relationship between frequency and period:

$$\text{Frequency} = \frac{1}{\text{Period}}$$

When using period measurement to monitor RPM, calculate the RPM using this equation:

$$\text{RPM} = \frac{60}{\text{Pulse Period x PPR}}$$

The main issue when using Period measurements occurs when the PPR is greater than 1 and the pulses are not symmetrical. For example, when shaft speed is constant and you are sensing two bolt heads per revolution, if the bolts are not exactly evenly spaced, the periods will be different, causing the RPM indication to be erratic.

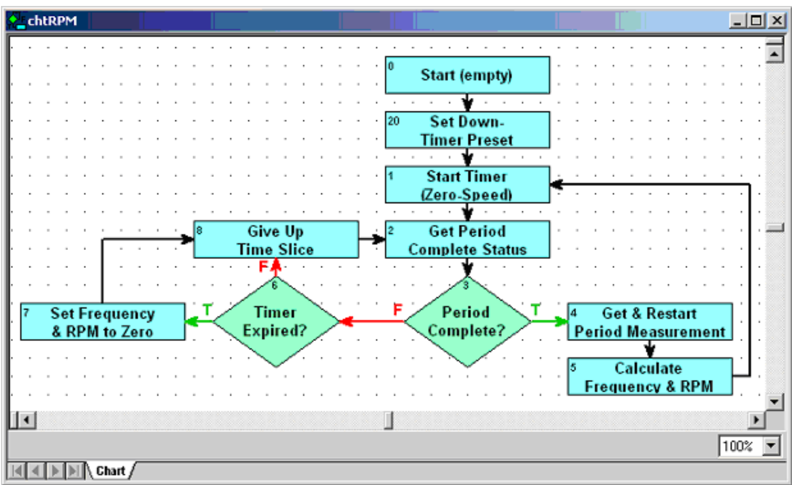
When using the Period method, you configure the digital input with the *Period* feature. Use the following PAC Control Pro commands:

- Get Period Measurement Complete Status
- Get & Restart Period

You have to wait until a period measurement is complete before you can read the period. When you read the period, you should also restart the period measurement so that it will measure the next available period.

### Logic Overview of Period Measurement Method

Here's what the logic might look like in your PAC Control flowchart:




A sample PAC Control strategy showing this logic for the Period measurement method is available for free download from the Samples & Freeware downloads page on our website, www.opto22.com.

## Zero Speed Detection

Detecting when the shaft has stopped is important in many applications, for example, to determine whether a conveyor has failed. If you use the Frequency method to monitor RPM, you will know the shaft has stopped when the frequency being sensed drops to zero.

If you use the Period method, the main issue is determining how much time to allow between pulses before deciding that the shaft has stopped. This time will vary from one system to the next. Essentially, this method requires a little extra logic that will start (or restart) a timer after each complete pulse and then monitor the timer while checking to see if another pulse has been generated. If a pulse is not received before the timer expires, then the shaft has stopped.

## System Requirements

For either the Frequency or Period method of measuring RPM, the following are required:

- PAC Control Professional, version 8.1 or higher or PAC Control Basic, version 9.0 or higher
- One of these SNAP PAC I/O processors, which include high-speed digital functions (frequency and period are measured in the processor, not in the module):
  - SNAP-PAC-R1
  - SNAP-PAC-EB1
  - SNAP-PAC-SB1
- For Frequency method, a SNAP digital input module configured as a frequency input
- For Period method, a SNAP digital input module configured for period measurement

### Choosing the Module

Although frequency and period are measured in the processor, the speed of the module affects the maximum achievable frequency and the minimum achievable period. For this reason, be sure to review the Turn-on and Turn-off ratings of the digital module before choosing it. For example, measurement of a frequency as high as 20,000 Hz or a period as short as 0.1 ms requires one of these modules:

- SNAP-IDC5FAST
- SNAP-IDC5-FAST-A

In addition, please note the following:

- Digital input frequency resolution is 1 Hz.
- Digital input frequency range is 0 to 20,000 Hz.
- Digital input period resolution is 0.1 ms.

## For Help

If you have questions about RPM measurement techniques or using Opto 22 products to measure RPM and you cannot find the answer you need in this document, please contact Product Support.

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