Application Guide

For

Gyrostar

Piezoelectric Vibrating Gyroscope

Model: ENV-05F-03
Support sensor for car navigation systems

Model: ENC-03J Type
Support sensor for video cameras

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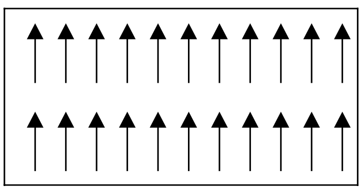
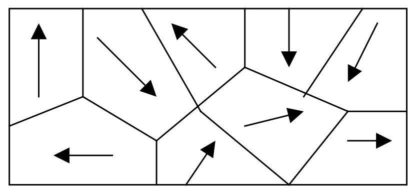
The Piezoelectric Effect

A piezoelectric substance is one that produces an electric charge when a mechanical stress is applied (the substance is squeezed or stretched). Conversely, a mechanical deformation (the substance shrinks or expands) is produced when an electric field is applied. This effect is formed in crystals that have no center of symmetry. To explain this, we have to look at the individual molecules that make up the crystal. Each molecule has a polarization, one end is more negatively charged and the other end is positively charged, and is called a dipole. This is a result of the atoms that make up the molecule and the way the molecules are shaped. The polar axis is an imaginary line that runs through the center of both charges on the molecule. In a monocrystal the polar axes of all of the dipoles lie in one direction. The crystal is said to be symmetrical because if you were to cut the crystal at any point, the resultant polar axes of the two pieces would lie in the same direction as the original. In a polycrystal, there are different regions within the material that have a different polar axis. It is asymmetrical because there is no point at which the crystal could be cut that would leave the two remaining pieces with the same resultant polar axis. Figure 1 illustrates this concept.



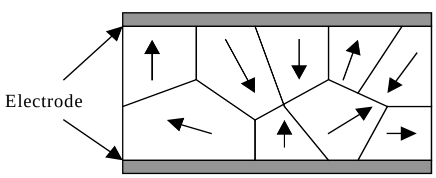
Monocrystal with single polar axis



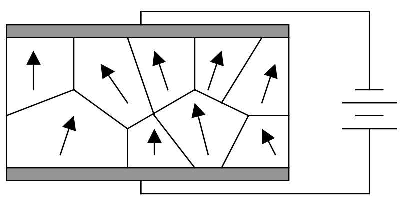
Polycrystal with random polar axis

Figure 1

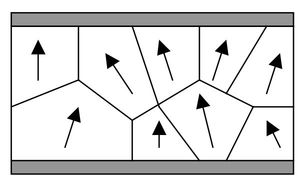
In order to produce the piezoelectric effect, the polycrystal is heated under the application of a strong electric field. The heat allows the molecules to move more freely and the electric field forces all of the dipoles in the crystal to line up and face in nearly the same direction (Figure 2).



Random Dipole



Polarization



Surviving Polarity

Figure 2

The piezoelectric effect can now be observed in the crystal. Figure 3 illustrates the piezoelectric effect. Figure 3a shows the piezoelectric material without a stress or charge. If the material is compressed, then a voltage of the same polarity as the poling voltage will appear between the electrodes (b). If stretched, a voltage of opposite polarity will appear (c). Conversely, if a voltage is applied the material will deform. A voltage with the opposite polarity as the poling voltage will cause the material to compress, (d), and a voltage with the same polarity will cause the material to expand (e). If an AC signal is applied then the material will vibrate at the same frequency as the signal (f).

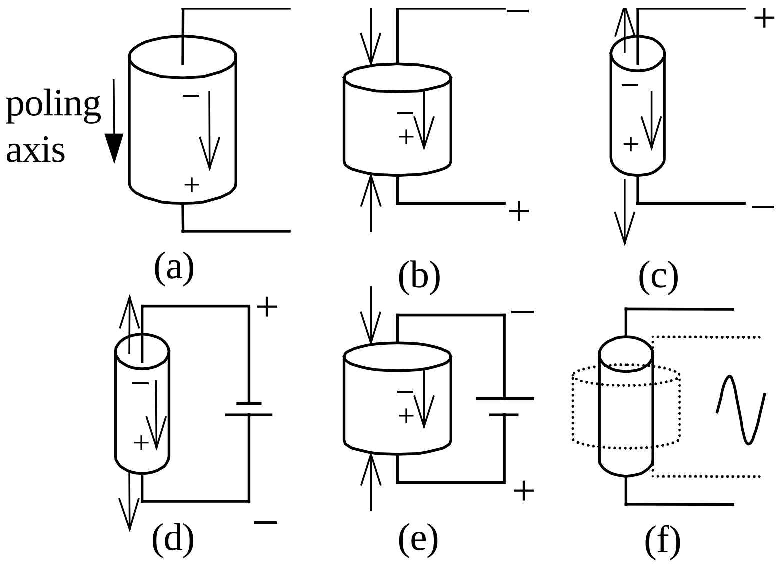


Figure 3

The Coriolis Effect

Most people recognize the Coriolis force as it relates to the earth. The Coriolis Force effects the weather, currents, and the way the water flows down the sink. This force is basically a study into angular kinetics with the Coriolis Equation as the focal point of discussion:

$$F_{Coriolis} = -2\, m\, (\omega * v_r)$$

m : the object's mass
ω : the angular velocityof the rotating frame of reference
v_r : the velocity in a rotating frame

See figure 5 for a 2 dimension graphical representation of how the force is acting at a 90 degree offset to the drive direction:

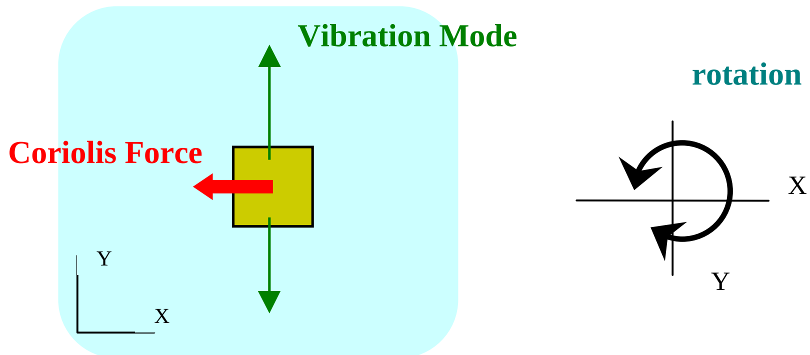


Figure 5:

This force that is created due to the angular velocity and the velocity of the object is known as the Coriolis Force. The force will always be on the same plane as the rotational velocity and 90 degrees from the vibration direction. This force is the basis on how a ceramic vibrating gyroscope operates.

Bimorph Ceramic Material

We must next look at how the coriolis effect can be used to measure this angular velocity. The way that the coriolis force is measured is by looking at the phase difference between the two outputs. For this reason we use a Bimorph material. The Bimorph material is built upon two pieces of piezoelectric ceramic material. Each piece has opposing induced polarity. The material is constructed this way in order to reduce the effect of the material onto the drive frequency. The drive unit is placed on the bottom of the ceramic material. This causes the material to vibrate at it's resonant frequency. From this vibration and when the angular vibration is applied, the Coriolis force causes a phase change in the drive frequency that was applied. When we measure this phase change, it will show us our angular velocity. See Figure 6:

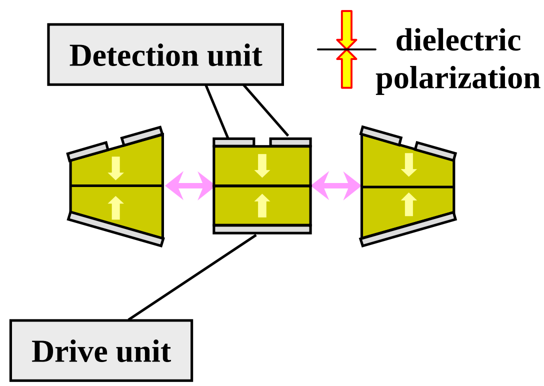
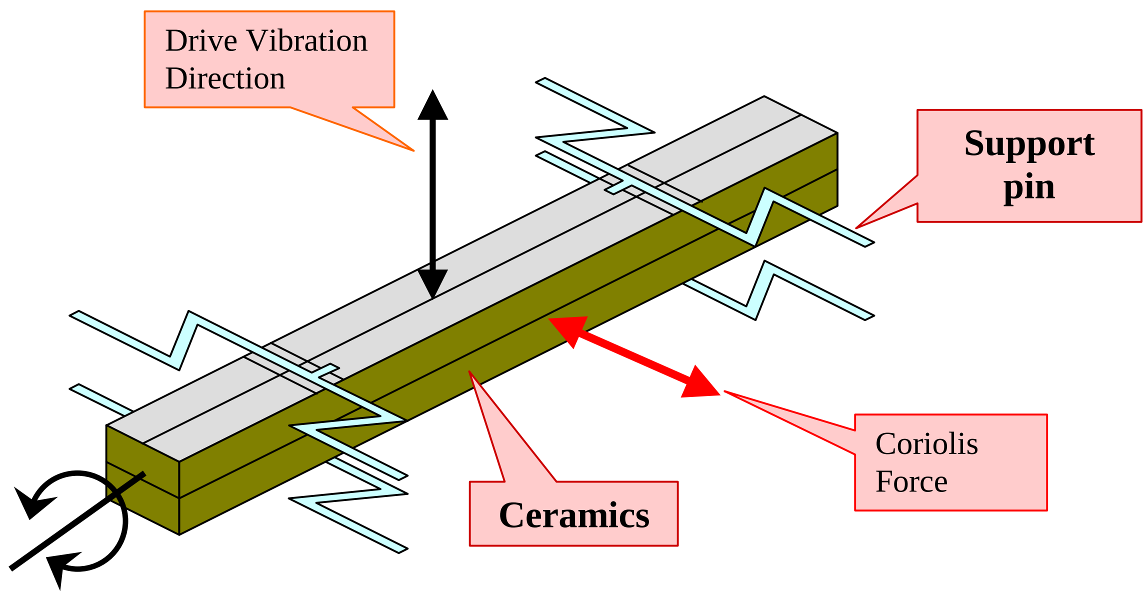


Figure 6

Piezoelectric Gyroscopes

Piezoelectric Gyroscopes use all of the above principles. The piezoelectric ceramic vibrates at the resonant frequency in a vertical direction. When a rotational velocity is introduced into the system, the Coriolis force causes the ceramic to vibrate in the horizontal direction. This horizontal vibration causes the ceramic material to distort from the left to the right of the material. (See figure 6) This distortion causes the piezoelectric material change the phase angle of the inputted voltage from the left side to the right side. As the vibration moves from peak to peak, the Coriolis force will change as well. This causes the material to vibrate at the same frequency as the resonant frequency. The sensors on the top of the Bimorph material read the analog output voltages. These forces are in relation to the angular velocity only. The Coriolis effect delays the signal by 90 degrees at the full force. The change in phase angle will allow the voltage to pass through the amp when the Coriolis effect is full(90degrees).. If the Coriolis force did not shift the phase, the voltage would cancel out and you would get a zero output. See Figure 7 below:



Ceramics Bimorph vibrator

Figure 7

The piezoelectric material vibration and the resulting coriolis forced vibration can be seen from the following diagrams. See figure 8. The forced vibrations are the same as the above diagram. Since the sensor can only detect angular rotation in one dimension, in order to detect the rotation in a three dimensional plane, you would require three gyroscopes.

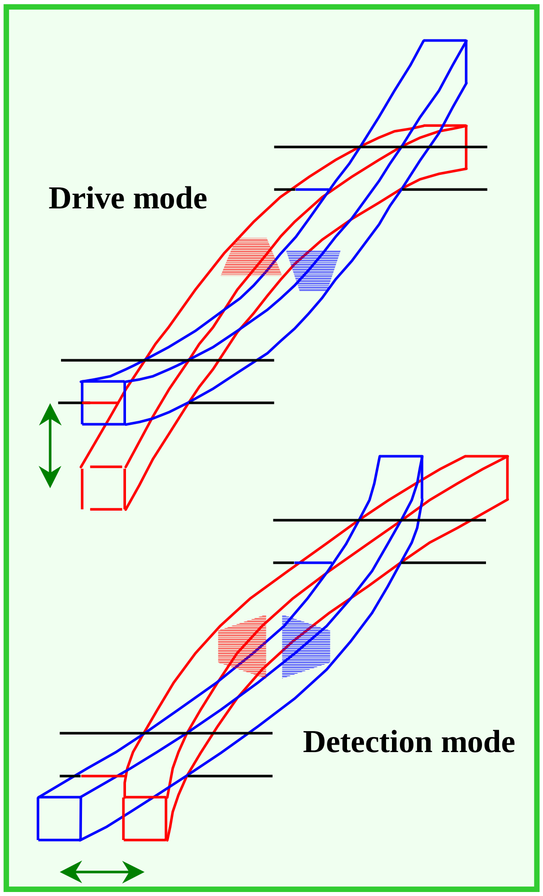


Figure 8

Parts:

There are two main types of gyroscopes. The first part number is the ENV-05F series. This gyroscope is popular in the navigational industry because it detects very precise slow movements. The second part number is the series ENV-03J. This series is mostly being used in the video electronics industry due to the fact that it detects fast movements. The main difference in the two gyroscopes is that the ENV-05F gyroscope is supplied with the internal circuitry. This allows you to supply the gyroscope with DC voltage, and your output will be a DC voltage as well. The ENC-03J series must be supplied by a DC voltage. The ENC series must be in combination with either a high pass filter with an amp or a low pass filter circuit. The ENC output will be a AC voltage after the required external circuit. Below we will discuss the characteristics of each and which series would be best for your application.

ENV-05F Series:

As before this series is mostly used in the navigational industry. This series is mostly used in the navigational industry due to the sensitivity being much greater than the ENC series. This works well in the navigational industry as we are looking for slow exact changes. The maximum angular velocity for this part is +/-60 degrees per second. See figure 9 below as how the output voltage changes per the angular velocity:

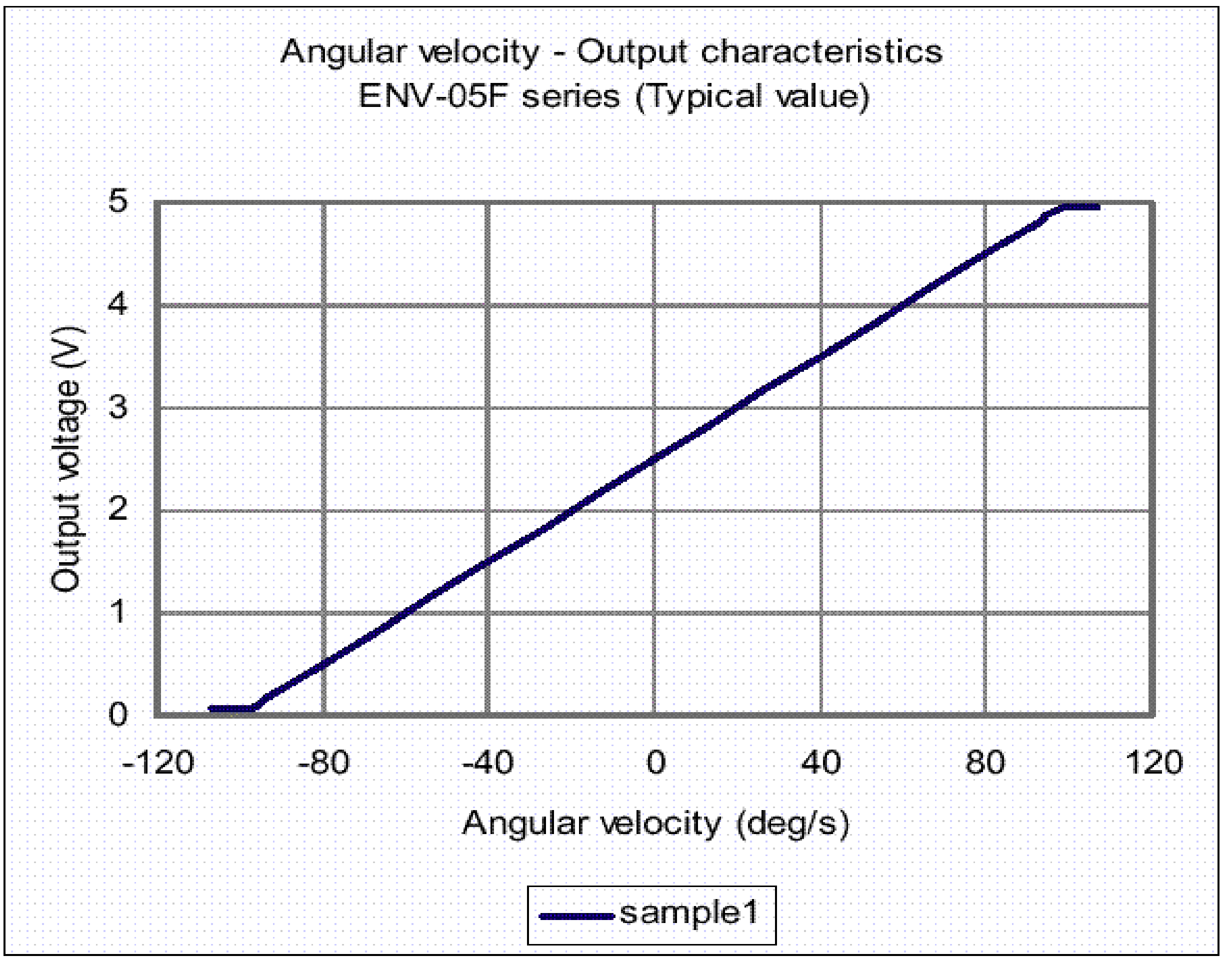


Figure 9

The other major difference in the two series is start-up characteristics. The ENV-05F series takes a much longer time to come to a steady state output voltage. This will cause problems if the start-up time is critical. See Figure 10 below:

Figure 10

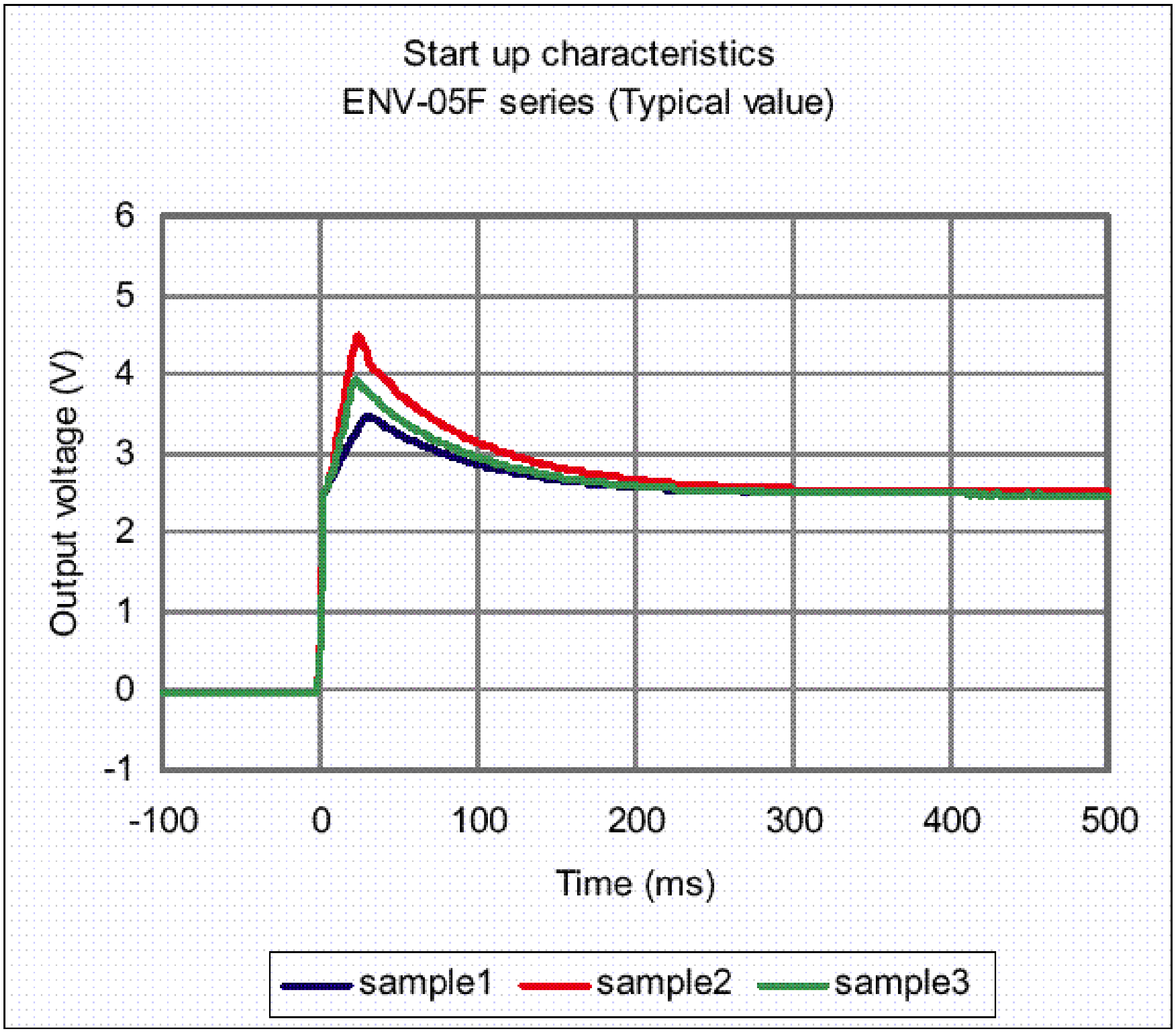


Figure 10

ENC-03J Series:

The ENC-03J series is mostly used in the camera and digital camera industry. This series is less sensitive however it can detect much greater angular velocities than the ENV series. This works well in the camera industry as they are looking for quick sudden changes. The maximum angular velocity for this part is +/- 300 degrees per second. See figure 11 below as how the output voltage changes per the angular velocity:

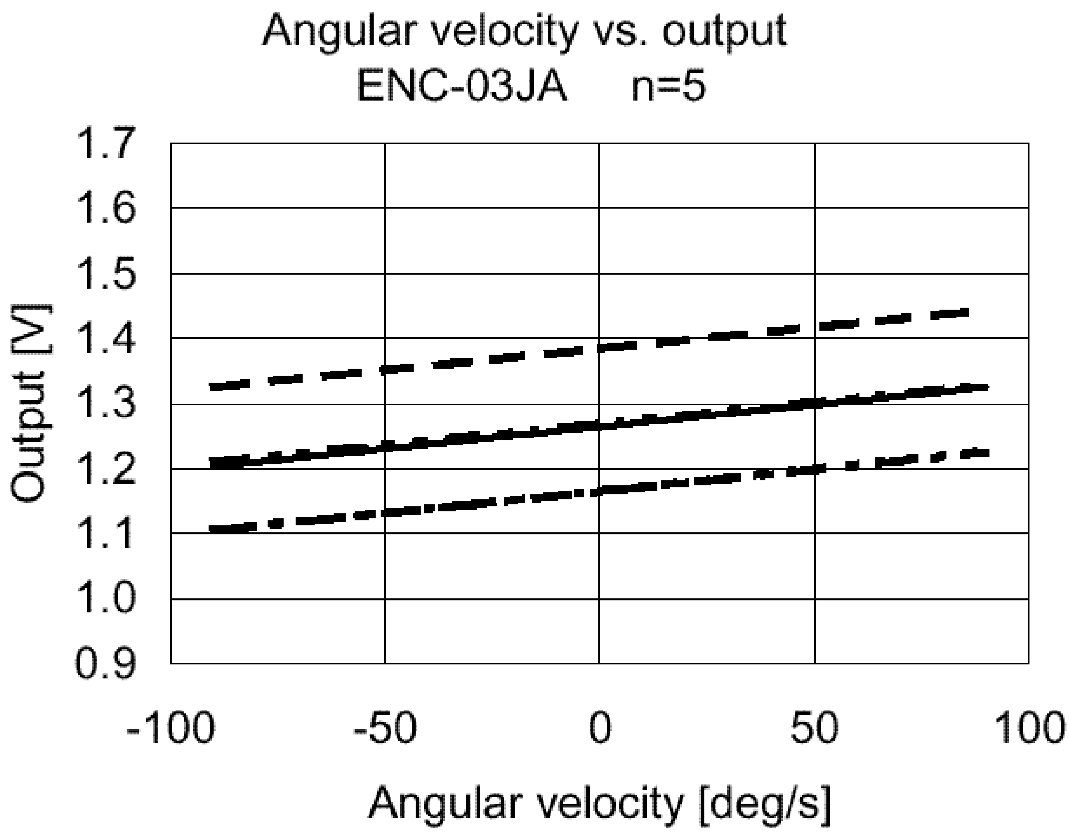
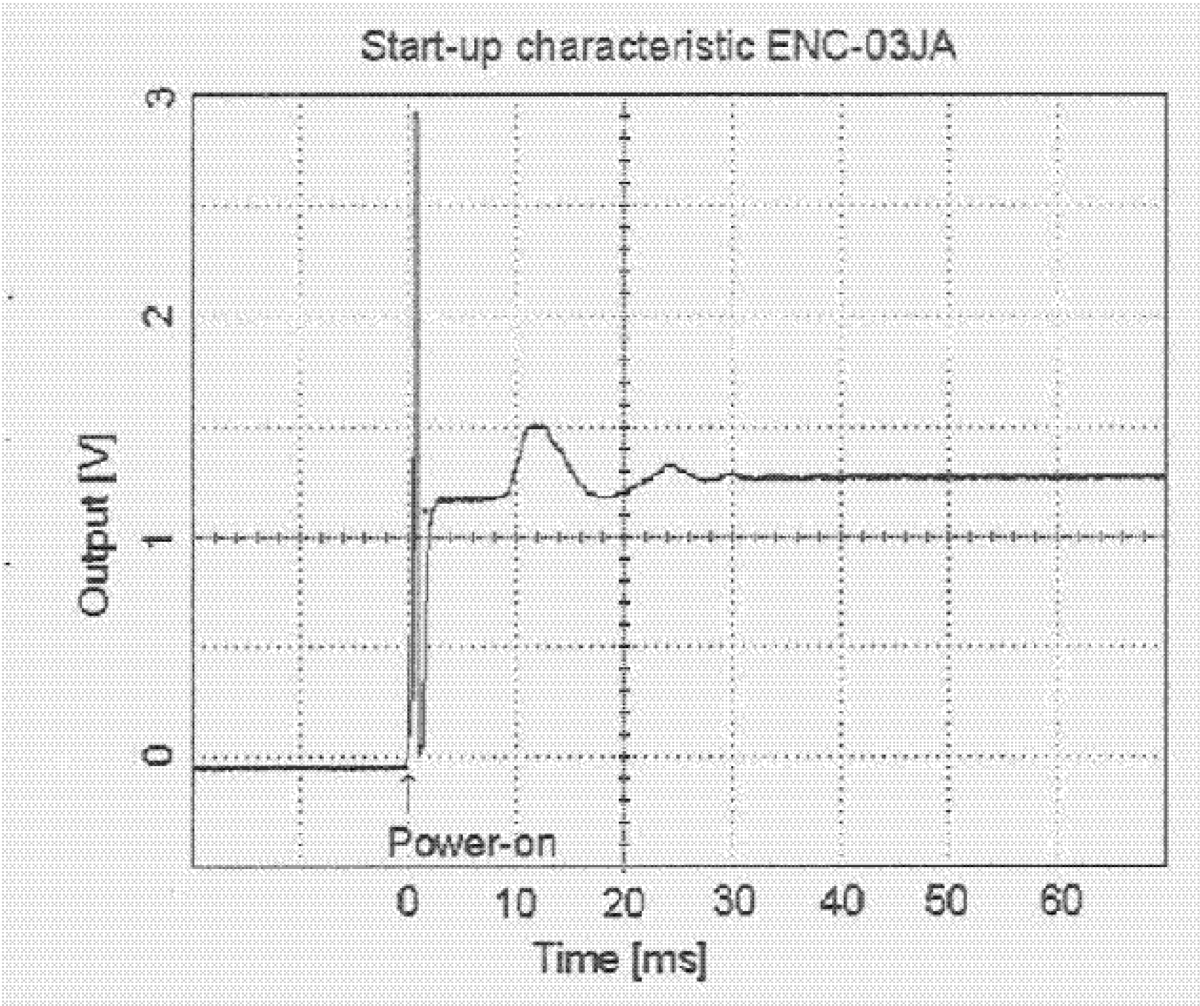


Figure 11

The start-up characteristics are also much different as was mentioned before. The ENC series allows for smaller start-up times for the system. This works well for personnel systems like the camera industry which uses batteries. See figure 12 for the start-up analysis.



Start-up characteristic ENC-03JA
Output [V]
3
2
1
0
Power-on
0
10
20
30
40
50
60
Time [ms]

Figure 12