Flow metering tutorial - Part 2: Pulse-based counting in flow meters

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Introduction
In Part 1 of this series, we covered the fundamental concepts and principles incorporated by flow meters along with various flow measurement methods used in mechanical flow meters. Part 2 covers the pulse based counting method and the various sensors that are used in industry and the way they generate different pulse waveforms to be used in variety of flow meters.

Pulse Counting Theory
The pulse counting method for flow measurement involves converting the kinetic energy from the flowing fluid into rotation, detecting this rotation and converting it into electrical energy in the form of digital pulses comprising '0's and '1's of varying periods in accordance with the flow being measured. The periods of '0' and '1' can then be measured to determine the speed and direction of rotation; hence determining the rate of flow and amount of fluid flown over a period of time.

Some flow measurement methods may generate analog signals that must be converted to digital signals before being used by a Micro-controller unit (MCU). A fast flow generates pulses/waveform of higher frequency while a slow flow generates low frequency pulses/waveforms.

Figure 1: Pulse Counting - Conversion of Kinetic Energy to Electric Energy
Figure 1 shows a representation of the pulse counting theory where the fluid flowing in a pipe activates a mechanism to create rotation and a sensor to then generate the analog or digital waveform. This waveform can be then measured using an MCU having a pulse counter.

**Sensors based on Pulse Counting Theory**

There are various sensors available that employ different techniques to generate electrical pulses in accordance with the flow being measured. Some of the commonly employed sensors include:

- Optical Sensors
- Magnetic Sensors

Use of one sensor allows measurement of rotation without detecting the direction. A second sensor makes it possible to also detect the direction of the rotation.

**Optical Sensors**

Optical sensors sense light through a perforated disc which rotates when the fluid flows through the meter. This sensor comprises a LED, a light sensor and a rotating disc located between LED and the light sensor. Figure 2 shows the arrangement of the individual components of the optical sensor.

![Optical Sensors](image)

**Figure 2: Optical Sensors for Flow Measurement**

The rotating disc is cut to make perforations in it which are encoded in different ways. The light sensor or photo diode conducts current in accordance with the perforations on the disc to generate pulses which can be measured using a counter on an MCU. The perforations on the rotating disc can be encoded in:

- 2-bit or 3-bit Binary/Gray encoding
- 2-bit Quadrature encoding

Figure 3 shows 3-bit Gray and Binary encoded discs. The white portions indicate the perforations through which the LED is visible to the photo diode and will conduct. The black portions block the
LED and the photo diode does not conduct.

**Figure 3: 3-bit encoded perforated disc**

The output of the optical sensors is analog. Some sensors may include a comparator on-chip to provide a digital output which can be counted using a count on a MCU.

**Magnetic Sensors**

There are various techniques which are employed by magnetic sensors to generate pulses in accordance with the rate of flow of fluid being measured. The various magnetic sensors include:

- GMR (Giant Magneto Resistive)
- Hall Sensors
- LC Sensors

**GMR Sensors:** These sensors employ the GMR phenomenon for sensing the varying magnetic field which varies with the flow being measured. The varying magnetic field is used to vary a resistance in the sensors, which in turn varies (i.e. decrease in resistance with increase in magnetic field) resulting in current flowing through the sensor.

A GMR sensor comprises magnetic field sensors and permanent magnets placed on a rotating disc. Figure 4 shows the arrangement of the individual components of a GMF sensor.
Figure 4: Magnetic sensor and mounting of magnets and sensor on PCB

The magnetic field sensors are placed and configured in such a way that they conduct current only when the magnet is directly above the sensor and do not conduct current otherwise. Thus, a sensor gives a '1' when the magnet is directly above it and a '0' when the magnet moves away from it. The placement of magnets on the rotating disc generates waveforms having different encodings. The following configurations are commonly used:

- **180° separation of magnets** - In this configuration, the magnets are placed 180 degrees apart from each other as shown in the above figure
- **90° separation of magnets: Quadrate encoding** - In this configuration, the magnets are placed 90 degrees apart from each other

In either configuration, a different digital waveform is generated which can be measured using a counter inside an MCU.

**Hall Sensors:** These sensors utilize the Hall Effect to sense the flow of fluids. When a magnetic field is applied to a current carrying conductor, this force disturbs the current distribution, resulting in a
potential difference (voltage) across the output.

A basic Hall Effect sensor comprises a Hall Element which is simply a magnetic field sensor. The Hall element is connected to a signal conditioning block to make the output usable for the application. These sensors are placed near a magnet on a rotating disc in an arrangement similar to GMR sensors. Figures 5 and 6 show the basic Hall Effect sensor and placement of magnets and sensor on a PCB.

![Figure 5: Basic Hall Effect sensor](image)

In a flow meter based on Hall Effect sensors, the sensors are placed in such a way that one sensor lies in the field of the magnet at one time. The sensor can be placed in one of the following configurations:

- **180° separation of sensors** - In this configuration, the sensors are placed 180 degrees apart from each other as shown in the above figure
- **90° separation of sensors: Quadrate encoding** - In this configuration, the sensors are placed 90 degrees apart from each other

In either configuration, the generated waveform can be measured using a counter inside an MCU.
**LC Sensors:** These sensors realize rotation from a flow by placing the inductor of a resonant circuit (LC circuit) near a rotating plate. Half of the plate is covered with a metallic coating such as copper. The damping factor of the stimulated resonant circuitry depends on the position of the inductor relative to the metal.

If the inductor is above the metallic half of the plate the damping factor is higher than if located above the non-metallic half of the plate. By detecting the different damping behavior, the rotation measurement is realized.

![Figure 7: LC Sensor](image)

In a flow meter based on LC sensors, the inductors are placed in one of the following configurations:

- **180° separation of inductors** - In this configuration, the inductors are placed 180 degrees apart from each other as shown in the above figure
- **90° separation of inductors: Quadrature encoding** - In this configuration, the inductors are placed 90 degrees apart from each other

In either configuration, by detecting the envelope of the generated waveform and converting it to digital, the flow can be measured using a counter inside an MCU.

Consider the LC sensor with 90° separation (as shown in figure 7), rotating anti-clockwise, such that Sensor 1 is over the metal plate (position 'a'), followed by both sensors being over the metal plate (position 'b'), followed by Sensor 2 being over the metal plate (position 'c') and finally both sensors being over the non-metallic part of the plate. The waveform from the sensors would be as shown in figure 8.
Figure 8: LC Sensor output during rotation

The equivalent digital waveform is determined by detecting the envelope of the damped and undamped waveforms shown in figure 9. By decoding the previous and current sensor positions, the direction of rotation can also be determined.

Figure 9: Equivalent digital waveform (after envelope detection)

This is not a complete list of methods used for flow measurement. The actual method will vary and be specific to the kind of fluid being measured.

Part 3 of this series will explain how the waveforms from the various sensors can be measured by a MCU and determine the rate and direction of flow.