What Is Full Scale Output

A practical guide to what is full scale output, covering the reader intent, the relationship to what is full scale output, key evaluation criteria, common risks, and the information the intended project audience should confirm before taking the next step.

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In the field of industrial instrumentation and process control, precision is the cornerstone of operational safety and efficiency. Whether monitoring the level of a chemical storage tank or managing water treatment facilities, engineers must rely on sensors that translate physical properties into measurable electrical signals. One of the most critical specifications used to define the performance and range of these sensors is Full Scale Output (FSO). Understanding what is full scale output is essential for anyone involved in the selection, calibration, and maintenance of level measurement devices.

This guide provides a comprehensive technical overview of Full Scale Output, its calculation, and its practical implications in industrial level measurement applications.

Understanding the Fundamentals of Sensor Output

Before diving into the specific definition of Full Scale Output, it is necessary to understand the basic measurement principle of industrial sensors. A level transmitter—whether it utilizes radar, ultrasonic, or hydrostatic technology—functions as a transducer. It detects a physical change (the height of a liquid or solid) and converts it into a standardized electrical signal that a Programmable Logic Controller (PLC) or Distributed Control System (DCS) can interpret.

Industrial sensors are designed to operate within a specific range, known as the "Span." For example, a radar level meter might be calibrated to measure a tank from 0 meters to 10 meters. The electrical signal produced at 0 meters is the "Zero Output," and the signal produced at 10 meters is the "Full Scale Value." The difference between these two electrical points is what defines the Full Scale Output.

Defining Full Scale Output (FSO) in Level Measurement

Technically, what is full scale output? Full Scale Output is defined as the algebraic difference between the electrical output signal measured at the maximum rated input (Full Scale) and the electrical output signal measured at the minimum rated input (Zero).

In most industrial contexts, FSO is expressed in the same units as the output signal, such as milliamperes (mA), volts (V), or millivolts (mV). It represents the total usable range of the signal that communicates the measurement data to the control system.

The FSO Formula

To calculate FSO, the following simple formula is used:

FSO = Output_{max} - Output_{min}

For example, consider the industry-standard 4-20mA current loop:

Output_{max} (Full Scale): 20 mA

Output_{min} (Zero): 4 mA

FSO: 20 mA - 4 mA = 16 mA

In this scenario, the 16 mA span is the actual Full Scale Output used to represent the 0% to 100% measurement range of the vessel. If a sensor uses a 0-10V output, the FSO would be 10V (10V - 0V).

Common Output Signal Types and Their FSO Characteristics

Different level measurement technologies and environments require different signal types. The choice of signal directly impacts how the FSO is perceived and utilized by the receiving equipment.

1. 4-20mA Current Loops

The 4-20mA signal is the most common in industrial automation. It is highly resistant to electrical noise and can travel long distances without signal degradation. Because the "Zero" is offset at 4mA (known as a live zero), the system can easily distinguish between a 0% level reading and a broken wire (0mA).

2. Voltage Signals (0-5V, 0-10V)

Voltage signals are simpler to interface with some data acquisition systems but are susceptible to voltage drops over long cable runs and electromagnetic interference (EMI). The FSO is typically the maximum voltage value.

3. Millivolt (mV) Signals

Often found in unamplified strain gauges or pressure-based level sensors, these signals have a very small FSO (e.g., 0-100mV). They require local amplification before being sent to a PLC to prevent signal loss.

4. Digital Outputs (HART, Modbus, RS485)

In digital communication, FSO is represented numerically. While the physical layer still exists, the "output" is a digital value representing the engineering units directly. However, many digital sensors still provide a secondary 4-20mA output where the FSO remains a critical parameter.

The Relationship Between FSO, Accuracy, and Calibration

Understanding what is full scale output is vital because most performance specifications are expressed as a percentage of FSO. This is often referred to as "% FS" or "% FSO."

Accuracy and Linearity

If a radar level meter has an accuracy rating of ±0.1% FSO, and it uses a 4-20mA output, the allowable error in the signal is:

16 mA (FSO) × 0.001 = ±0.016 mA.

This error remains constant regardless of whether the tank is 10% full or 90% full. If the accuracy were instead defined as "% of Reading," the allowable error would shrink as the level decreases. Therefore, engineers must be careful to distinguish between these two when reviewing product options and application support on the Main Page.

Calibration and Scaling

Calibration involves aligning the physical measurement range with the FSO. If a tank height changes due to a process modification, the sensor must be re-spanned. Re-spanning changes the relationship between the physical level and the FSO, but the electrical FSO (e.g., 16mA) usually remains constant to match the PLC input card requirements.

Practical Selection: Choosing the Right Output for Industrial Applications

When selecting a level meter, the output type must match the environment and the control architecture. Below is a comparison table for common level measurement outputs.

Signal Type	Typical FSO	Best For	Limitations
4-20mA	16 mA	Long distances, high-noise environments	Requires two wires and a power source
0-10V	10 V	Short distances, low-cost PLC inputs	Susceptible to voltage drop and EMI
0-5V	5 V	Battery-powered or low-voltage systems	Limited resolution compared to 10V
HART	Digital + 16mA	Intelligent diagnostics and remote config	Requires HART-compatible master
Modbus RTU	Digital	Multi-drop networks (many sensors on one line)	Requires programming and addressing

Technology-Specific Considerations

Radar Level Meters: These high-precision devices often use 4-20mA with HART. The FSO represents the distance from the sensor flange to the bottom of the tank.

Ultrasonic Sensors: Since these are affected by air temperature and humidity, the FSO might fluctuate if temperature compensation is not properly applied.

Hydrostatic Transmitters: These measure the pressure exerted by a liquid column. The FSO is tied to the maximum pressure the diaphragm can withstand while maintaining linearity.

Installation and Maintenance Considerations for Signal Integrity

To ensure the Full Scale Output remains accurate throughout the sensor's lifecycle, proper installation is paramount.

1. Cable Shielding: For both voltage and current signals, shielded twisted-pair cables should be used to prevent electromagnetic interference from distorting the FSO.

2. Impedance Matching: For 4-20mA loops, the total loop resistance (cables + PLC input resistance) must not exceed the transmitter's maximum load capacity. If the resistance is too high, the sensor will be unable to reach its 20mA Full Scale value, leading to capped readings.

3. Grounding: Ensure the system is grounded at a single point to avoid ground loops, which can introduce an offset to the "Zero" signal, thereby skewing the entire FSO.

4. Environmental Factors: High temperatures can cause "thermal drift," where the FSO shifts slightly as the electronics heat up. High-quality sensors, such as those from Welk, include internal compensation to minimize this effect.

Limitations and Potential Errors in Full Scale Output

While FSO is a standard metric, it is not without limitations. Engineers should be aware of the following risks:

Non-Linearity: No sensor is perfectly linear. The FSO assumes a straight-line relationship between input and output. The "Linearity Error" is the maximum deviation from this ideal line, usually expressed as a percentage of FSO.

Saturation: If the level exceeds the rated 100% mark, the sensor may "saturate" and output a signal slightly higher than the Full Scale (e.g., 20.5mA or 21mA). This is often used as a diagnostic to indicate an overfill condition.

Zero Drift: If the 4mA signal drifts to 4.1mA due to aging or temperature, the entire measurement scale is shifted. Regular calibration is required to reset the Zero and Span to ensure the FSO remains representative of the actual process.

Frequently Asked Questions (FAQs)

What is the difference between Full Scale and Full Scale Output?

Full Scale refers to the maximum physical input the device can measure (e.g., 20 meters). Full Scale Output refers to the electrical range used to communicate that measurement (e.g., 16mA).

Why is 4-20mA preferred over 0-20mA?

4-20mA allows for "Live Zero" detection. If the wire breaks, the signal drops to 0mA, which the controller recognizes as a fault. In a 0-20mA system, 0mA could mean either a 0% level or a broken wire, creating a safety risk.

Can I change the Full Scale Output of my sensor?

Most modern digital transmitters allow you to "re-span" the device. While you cannot usually change the electrical FSO (it stays 4-20mA), you can change what physical level corresponds to 20mA. For example, you can change a 0-10m range to a 0-5m range.

How does FSO affect resolution?

Resolution is the smallest change in level that the sensor can detect. In an analog system, resolution is limited by the noise floor of the FSO. In a digital system, the FSO is divided into "bits" (e.g., a 12-bit converter divides the FSO into 4,096 discrete steps).

Does a higher FSO mean a better sensor?

Not necessarily. A larger voltage FSO (like 0-10V vs 0-5V) might offer better resolution against background noise, but the most important factor is the signal-to-noise ratio and the stability of the signal over time and temperature.

By understanding what is full scale output and how it interacts with industrial hardware, process engineers can better specify equipment and troubleshoot inaccuracies in their level measurement loops. For those looking to implement robust measurement solutions, selecting the appropriate output signal is the first step toward a reliable automation strategy.