ABB MEASUREMENT & ANALYTICS | TECHNICAL DESCRIPTION

ControlMaster CMF310

Universal process controller, fieldmount

Dual sensor validation
in the water industry

Measurement made easy

—
ControlMaster CMF310

Introduction

The pH of a substance is an indication of the number of hydrogen ions it forms in a certain volume of water. Acids and alkalis are simply chemicals that dissolve in water to form hydrogen ions. An acid forms positively charged ions whereas an alkali forms negatively charged ions. The stronger the solution the more hydrogen ions it contains.

The normal pH of surface and ground water is between 6 and 8.5 pH; this is considered an acceptable level for potable water and guidelines across the world dictate as such. However, freshwater pH varies across the globe due to a number of factors such as local weather patterns, natural processes and human activity. This means that the treatment requirement to ensure that water is safe for consumption differs depending on those factors.

The pH level of water can be an indicator of pollutants. A very high or low pH can mean the supply is polluted and cannot be consumed. A high or low pH also means there is potential for corrosion of pipes and damage to the underlying water transport infrastructure.

However, a pH of 7 to 7.5 is not only perfect for potable water, it is also the optimum pH for the survival and replication of harmful microbes such as salmonella, which if left untreated can cause serious illness in anything that consumes the water. Part of the water treatment process involves the addition of chemicals to prevent this. This is done in the form of a process called chlorination.

Chlorination is a process where a chlorine compound is added to the water to kill any harmful microbes. At room temperature, chlorine is a pale green gas. However, it is highly reactive and so most of the chlorine found in the earth’s crust is in the form of a compound (table salt being the most widely known).

When a chlorine is dissolved in water it creates an equal mixture of chlorine, hypochlorous acid and hydrochloric acid. The creation of these acids has a profound effect on the pH of the water.

When monitoring levels of chlorine and pH in potable water during treatment, water companies often employ techniques such as triple and dual validation.

Multiple sensor validation

Multiple sensor validation means utilizing measured values from 2 or 3 sensors within the system.

Multiple sensors are employed to measure the same value and are positioned in the same location close to one another. The reason for multiple sensors is that in an environment that can be acid or alkali, over time the pH probes succumb to corrosion from the water and slowly but surely become less and less accurate before failing entirely and remote sites must have a redundancy system.

Dual and triple validation enable an average of the sensor readings to be taken, while ensuring that they all remain within a strict tolerance of one another. If the reading from one of the sensors drifts outside of the tolerance band, the device measuring the values discounts it, but continues to display the average of the other values being measured by the remaining sensor(s).

pH sensors

Because an acidic solution has a higher concentration of positively charged ions , it has a greater potential to produce an electric current than an alkaline one.

pH sensors work by measuring the voltage generated within a solution and comparing it to the voltage of a known solution. It then uses the difference between these voltages to calculate the pH of the solution.

pH sensors typically comprise two electrodes – a reference electrode and a glass electrode.

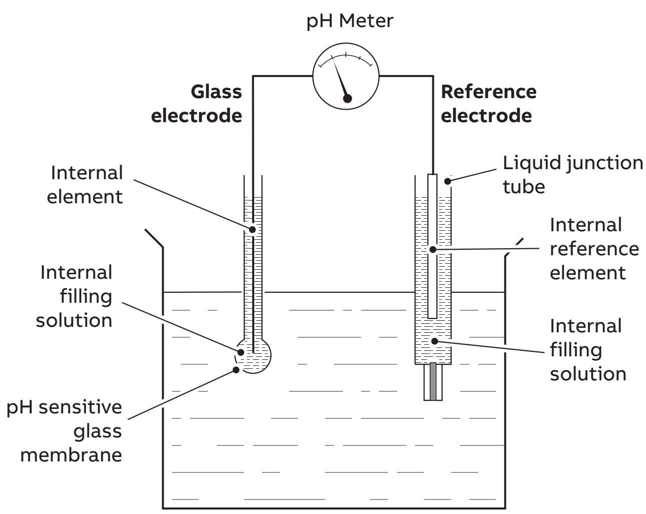


Figure 1 Basic pH measuring system

The reference electrode assembly consists of a potassium chloride wire suspended in a solution of potassium chloride. The potassium chloride solution is a neutral solution with a pH of 7, therefore it contains a known number of hydrogen ions.

The glass electrode consists of a silver-based electrical wire suspended in a neutral solution of potassium chloride and contained within a thin bulb or membrane made from a special glass that contains metal salts.

When the glass electrode is placed Into a solution to measure its pH, some of the hydrogen ions move across the glass membrane from the solution, while some of the metal ions move from the potassium chloride solution. This is called ion exchange. Because the two solutions have different pH levels, a different amount of ion swapping occurs on the two sides of the glass membrane. This causes a different electrical charge to build up on either side of the membrane, creating a potential difference between the two sides of the glass. It is this difference in voltage that enables the meter to calculate the pH of the solution.

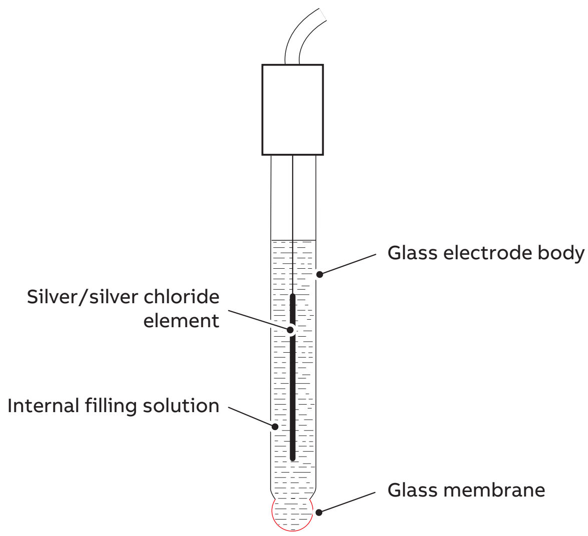


Figure 2 Glass electrode

There are a number of factors that affect the mV produced, including the temperature of the solution, but a simple example of where a 7 pH is equivalent to 0 mV can explain the relationship.

The graph in Figure 3 shows that as the mV value increases the pH increases. This means that a high mV value indicates the solution is an acid, whereas a low (including negative voltages) mV reading indicates an alkali solution.

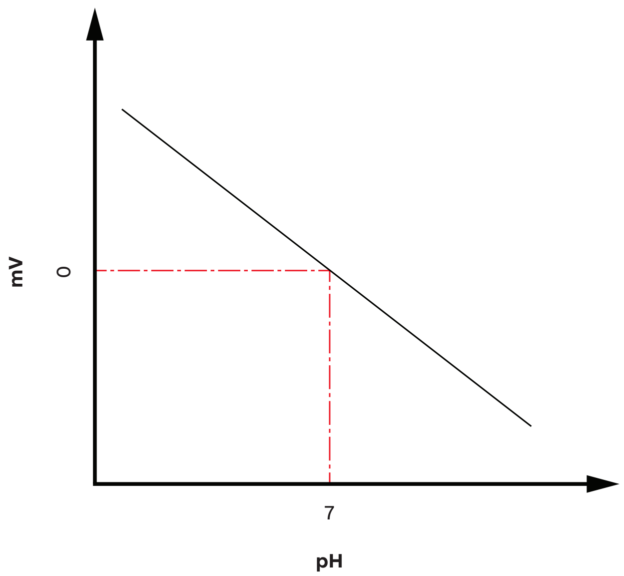


Figure 3 **mV/pH relationship**

Dual sensor validation

This configuration is designed to take the average of 2 pH readings and retransmit the value as a 4 to 20 mA signal via analog output 1. In the event that the 2 readings differ from each other by more than a designated amount (in this case ±0.4 pH), an alarm is activated and a relay operates. The PV and analog output continue based on the instantaneous calculated value. If any alarms are generated, the system must be checked to identify any issues causing the error.

In the event that a sensor is removed or goes over- or under-range, it is removed from the calculation and the remaining single sensor value is used as the PV. An alarm is triggered if any the following conditions occur:

- The PV goes outside of the specified bands
- The deviation between sensors is larger than the specified value
- Any of the sensors are removed or are over or under range

Configuring the CMF310

The flow chart in Figure 4 provides an overview of the logic used within the CMF310's math blocks and logic equations, and how they link together to provide the calculation values required. The logic equations are used to provide the conditional digital signals within the configuration.

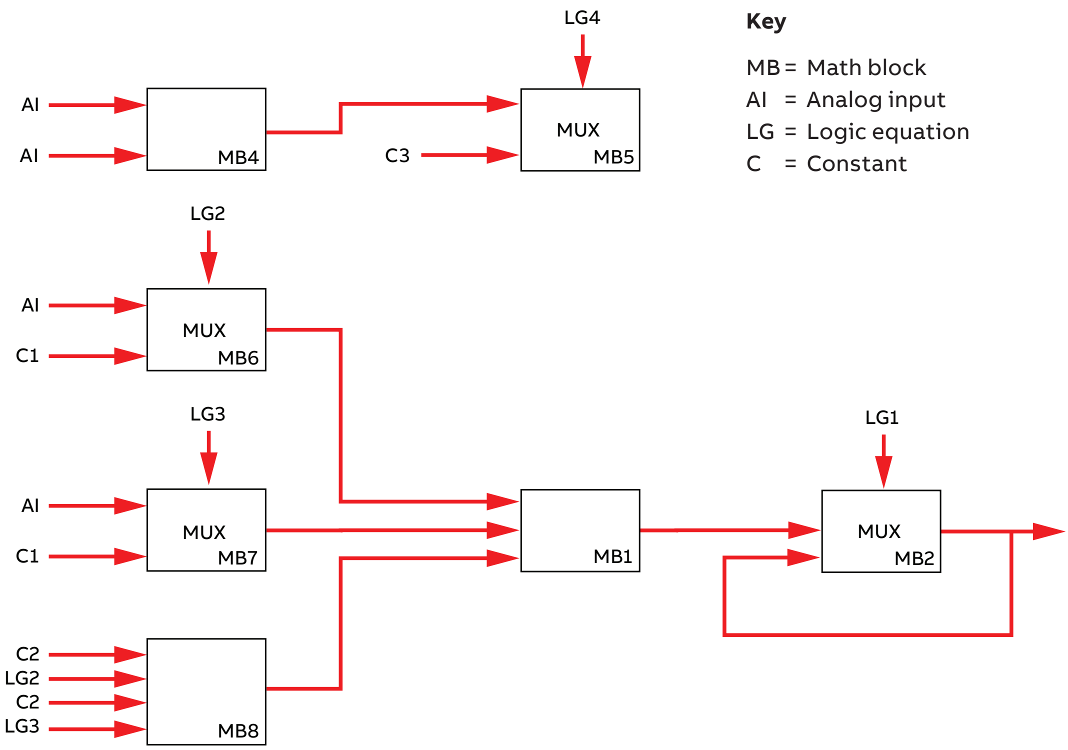


Figure 4 **CMF310 configuration overview**

...Configuring the CMF310

Math block configuration

Math block 1

Math block 1 is a standard equation-type math block. It calculates the average of the 2 sensors and is assigned as the process variable (PV) that the control loop uses.

Block Type	Equation	Fault Action	Upscale
Eng. Low	2.00 pH	Eng. High	12.00 pH
Eng. Dps	x.xx	Eng. Units	pH
Operand 1	Maths Block 6	Operand 1 Constant	0
Operator 1	Add		
Operand 2	Maths Block 7	Operand 2 Constant	0
Operator 2	Divide		
Operand 3	Maths Block 8	Operand 3 Constant	0
Operator 3	End		

The sensor readings are passed through a number of math blocks prior to this calculation to ensure that the controller reading is always a valid one. This means that in the event of a sensor reading falling outside of the specification, the calculation will not fail and the bad value is removed from the equation.

Math block 2

Math block 2 is configured as a multiplexing (MUX) math block. This means it has a switch function, the output of which depends on the state of a digital signal from logic equation 1.

Block Type	Multiplexer	Fault Action	Upscale
Eng. Low	2.00 pH	Eng. High	12.00 pH
Eng. Dps	x.xx	Eng. Units	pH
Operand 1	Maths Block 1	Operand 1 Constant	0
Operator 1			
Operand 2	Maths Block 2	Operand 2 Constant	0

In this example, when the output from logic equation 1 is 0 (digital signal not present) the output of math block 2 is the value of math block 1. When the output from logic equation 1 is 1 (digital signal present), the output of math block 2 is returned to math block 2 until the digital signal is not present.

Math block 4

Math block 4 is a standard math block that subtracts analog input 3 from analog input 1. This provides the difference between the 2 readings and as they should always measure a very similar value, it detects if either of the sensors are beginning to degrade.

Block Type	Equation	Fault Action	Upscale
Eng. Low	-99.99	Eng. High	999.99
Eng. Dps	x.xx	Eng. Units	
Operand 1	Anlg IP 1	Operand 1 Constant	0
Operator 1	Subtract		
Operand 2	Anlg IP 3	Operand 2 Constant	0
Operator 2	End		

The result of math block 4 is assigned to math block 5.

Math block 5

Math block 5 is a MUX math block that ensures that the deviation between the 2 measured readings creates an alarm if it exceeds a certain value, but only if both of the input signals are valid. If one reading fails completely the alarm is not triggered.

Block Type	Multiplexer	Fault Action	Upscale
Eng. Low	-99.99	Eng. High	999.99
Eng. Dps	x.xx	Eng. Units	
Operand 1	Maths Block 4	Operand 1 Constant	0
Operator 1			
Operand 2	Constant 3	Operand 2 Constant	0

In this example, the result of math block 4 is assigned to math block 5 together with a constant with a value of 0 and the result of logic equation 4. When the output of logic equation 4 is 0, the output of math block 5 is the result of math block 4. When the output of logic equation 4 is 1, the output of math block 5 is the constant value of 0.

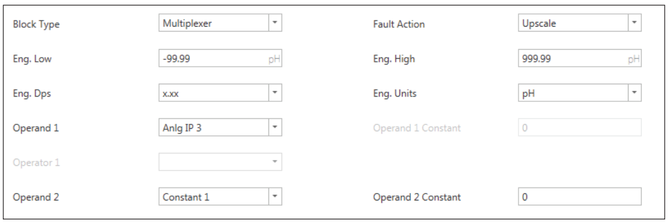
Math block 6

Math block 6 is a MUX math block that removes analog input 1 from the equation in the event that it fails.

In this example, analog input 1 is assigned to math block 6 together with a constant value of 0. The output from math block 6 depends on the value of a digital signal from logic equation 2. When the output of logic equation 2 is 0, the output of math block 6 is the value of analog input 1. When the output of logic equation 2 is 1, the output of math block 6 is the constant value of 0.

Math block 7

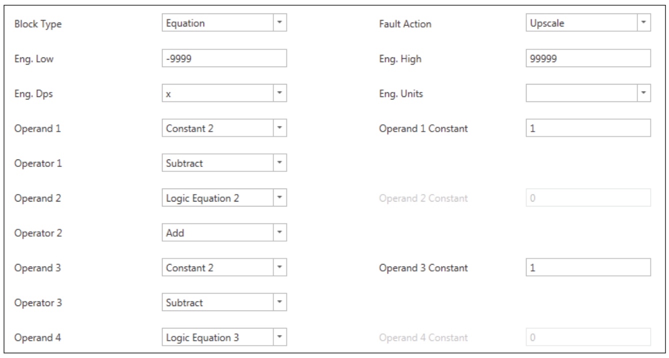
Math block 7 is a MUX math block that removes analog input 3 from the equation in the event that it fails.



In this example, analog input 3 is assigned to math block 7 together with a constant value of 0. The output from math block 7 depends on the value of a digital signal from logic equation 3. When the output of logic equation 3 is 0, the output of math block 7 is the value of analog input 3. When the output of logic equation 2 is 1 the output of math block 6 is the constant value of 0.

Math block 8

Math block 8 is a standard math block that calculates the number of valid inputs assigned to the equation.



It is first assigned a math block constant with a value of 1; it then subtracts logic equations 1 and 3 that contain the input validity signal. If the signals are both valid the output of the math block is 2 and this is assigned to math block 1 that creates the average value that is shown as the PV.

…Configuring the CMF310

Logic equation configuration

Logic equation 1

Logic equation 1 is the source for math block 2 that is used to feed the PV back on itself and hold a last known good value in the event of a failure.

Operand 1	Anlg IP 1 Fail	Invert 1	Yes
Operator 1	OR		
Operand 2	Anlg IP 3 Fail	Invert 2	Yes
Operator 2	AND		
Operand 3	Alarm 1 State	Invert 3	No
Operator 3	OR		
Operand 4	Alarm 2 State	Invert 4	No
Operator 4	END		

This logic equation detects the failure of either input **accompanied by** an active alarm. This event is an indication that one of the pH sensor readings is out of specified limits or is not valid and the CMF310 must hold a fixed PV until the signal is restored.

Logic equation 2

Logic equation 2 is the source for math block 6 that is used to switch between the actual value of analog input 1 and a constant of 0 in the event the signal fails.

Operand 1	Anlg IP 1 Fail	Invert 1	No
Operator 1	END		

Logic equation 3

Logic equation 3 is the source for math block 7 that is used to switch between the actual value of analog input 3 and a constant of 0 in the event the signal fails.

Operand 1	Anlg IP 3 Fail	Invert 1	No
Operator 1	END		

Logic equation 4

Logic equation 4 is the source for math block 5 that is used to switch between the result of math block 4 (that calculates the difference between the 2 analog input signals) and a constant with a value of 0 in the event either signal fails.

Operand 1	Anlg IP 1 Fail	Invert 1	No
Operator 1	OR		
Operand 2	Anlg IP 3 Fail	Invert 2	No
Operator 2	END		

Process alarm configuration

Process alarm 1

Process alarm 1 is assigned to math block 5 and is configured as high process alarm that is triggered if the difference between the 2 analog signals is **higher** than the required differential. In this is example, the required difference between the signals is ±0.4 so process alarm 1 is configured with a trip point of 0.4.

Type	High Process	Tag	A1 Sensor Match?
Source	Maths Block 5	Trip	0.40
Hysteresis	0.10	Time Hysteresis	0
Display Enable	On		

Process alarm 2

Process alarm 2 is also assigned to math Block 5 and configured as high process alarm that is triggered if the difference between the 2 analog signals is **lower** than the required differential. In this is example, the required difference between the signals is ±0.4 so process alarm 2 is configured with a trip point of –0.4.

Type	Low Process	Tag	A2 Sensor Match?
Source	Maths Block 5	Trip	-0.40
Hysteresis	0.10	Time Hysteresis	0
Display Enable	On		

Process alarm 3

Process alarm 3 is used to indicate to the operator when the process variable is outside the process limits. In this example, process alarm 3 is configured as a high process alarm with a trip point of 8.4.

Type	High Process	Tag	A3 High pH
Source	Maths Block 1	Trip	8.40
Hysteresis	0.10	Time Hysteresis	0
Display Enable	On		

Process alarm 4

Process alarm 4 is used to indicate to the operator whether the process variable is outside the process limits. In this example, process alarm 4 is configured as a low process alarm with a trip point of 6.0

Type	Low Process	Tag	A4 Low pH
Source	Maths Block 1	Trip	6.00
Hysteresis	0.10	Time Hysteresis	0
Display Enable	On		

Notes

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TD/RandC/024-EN Rev. A 01.2020