AP-12
APB Depth Monitoring

Introduction

The Ingram Products Level Monitor and Controller provides 6 user defined depth setpoints for use in tank depth monitoring systems. Applications include waste water treatment plants, food processing, reservoir systems and any system where it is required to track the inflow and outflow of material.

In waste water treatment applications it is necessary to detect the level within holding tanks and to activate pumps to pump down the waste water when it reaches certain levels. To handle high inflow situations, or possible pump failures, all such lift stations have a minimum of two pumps. When the waste water level reaches the *low* level a *lead* pump will be activated. If the level continues to rise to the *mid* level a *lag* pump will be activated. In some applications a third or even fourth pump may be utilized. All applications will include a *high* level detector that indicates a pending overflow situation.

Once the pump(s) have been activated they will remain on until the level drops below the *off* level. In cases where a pump may fail to shut off or a leak has developed that may expose the submersible pumps to air an *empty* level detector may be used.

There are a variety of mechanism's used to detect the level within the holding tank. Simple float switches may be used but stainless steel floats can be become expensive. In systems that require intrinsically safe detectors that additional barriers required for each float further adds to the cost.

Alternative methods include air bubblers, that detect the back pressure of passing air bubbles up through the depth of the water, hydro-static pressure measurements, radar and ultrasonic depth measurements.

These solutions provide a linear analog signal representing the current depth of the liquid. Analog sensors reduce the overall system cost, reduce failures caused by jammed or faulty float switches and will eliminate, or greatly reduce the intrinsically safe barriers required.

A further advantage of analog sensors is that real-time flow rate information may be collected by comparing the change in levels.

These analog detection systems must include some mechanism to detect the discrete levels (*empty, off, low, mid, high),* especially in applications where the analog sensors is being retrofitted into a system that previously used discrete float switches.

Example Controller

The following describes a controller application that will monitor an analog input signal (0-10 Vdc or 4-20 mA) and compare the level to six user defined setpoints to activate digital outputs corresponding to the measured depth. Each setpoint definition includes a hysteresis value to prevent false triggering and a counter that tracks the number of times that each level is detected.

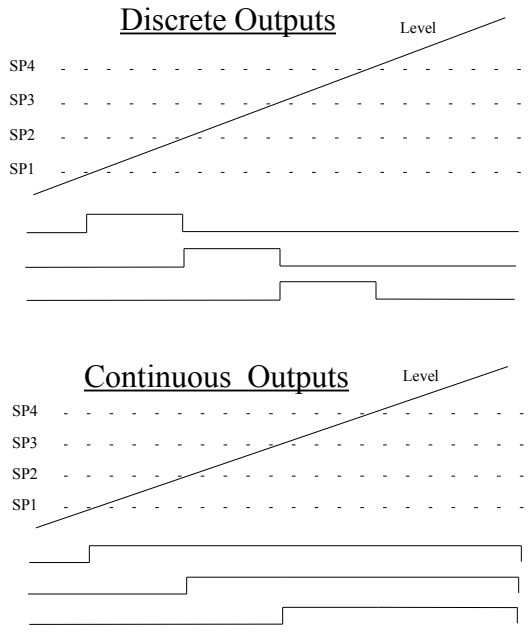
In addition to setting the outputs based on the measured depth the controller monitors the change in the level at a user defined sampling rate (default 1/second) to provide digital outputs indicating whether the level is INCREASING or DECREASING. If both outputs are off it indicates that no level change was detected.

The rate of change of the level is updated and based on user supplied tank area and depth information the current and average calculated gallons/minute inflow and outflow is provided.

Finally, two warning/error signals are provided. If the level stays above a user specified setpoint for a extended period of time a HIGH TIME warning is generated. If the flow rate (either inflow or outflow) exceeds a certain rate a HIGH FLOW output is activated.

Continuous vs Discrete Outputs

There are two approaches to handle the outputs for the level detection. To best emulate float switches, as each level is detected an output is activated and all lower level outputs remain on (continuous). In other situations it may be necessary that as a level is detected a specific output turns on and all other outputs remain off (discrete).



Two sets of outputs are provided, referred to as *Level* 1..6 and *Alt Level* 1..6 One set can be used to drive a pump sequencer and the second to drive indicators. *Configuration options* allow setting Level 1..6 and Alt Level 1..6 to either continuous or discrete.

Output Configuration

The application program supports up to 16 outputs (6 Levels, 6 Alt Levels and 4 Warning/Status indicators). Not all systems will require the entire functionality. The APB-12MRDL controller provides 4 outputs, the APB-22 MRDL controller provides 8 outputs and the APB-22ERD expansion unit provides 8 outputs. Four different hardware configurations are supported, providing 4, 8, 12 or 16 outputs.

Output Configuration Options

Q	Option 1	Option 2	Option 3	Hardware			
0	Level 1	Increasing	Increasing	APB12MRDL	APB22MRDL	APB12MRDL	APB22MRDL
1	Level 2	Decreasing	Decreasing				
2	Level 3	Level 1	High Flow				
3	Level 4	Level 2	High Time				
4	Level 5	Level 3	Level 1				
5	Level 6	Level 4	Level 2				
6	Alt Level 1	Level 5	Level 3				
7	Alt Level 2	Level 6	Level 4				
10	Alt Level 3	Alt Level 1	Level 5			APB22ERD	APB22ERD
11	Alt Level 4	Alt Level 2	Level 6				
12	Alt Level 5	Alt Level 3	Alt Level 1				
13	Alt Level 6	Alt Level 4	Alt Level 2				
14	Increasing	Alt Level 5	Alt Level 3				
15	Decreasing	Alt Level 6	Alt Level 4				
16	High Flow	High Flow	Alt Level 5				
17	High Time	Max Time	Alt Level 6				

The output configuration option defines 3 different output configurations to determine which signal outputs are available for each of the hardware configurations. Relay outputs are recommended, although NPN or PNP outputs are available.

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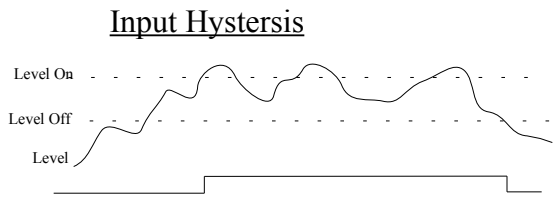
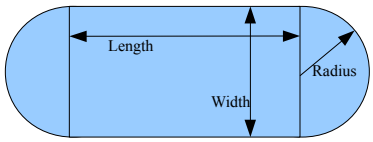
Setpoints

Each level setpoint may be configured by specifying the measured level at which the corresponding output should be activated and a value at which the output should be deactivated. By setting the 'off' value slightly below the 'on' value hysteresis is provided, eliminated signal 'jittering' if the measured level experiences any noise.



Holding Tank Geometry

The holding tank geometry is used to calculate the flow rate in gallons/minute or liters/minute. To perform the calculation the length, width and radius of the tank must be known.



Top View

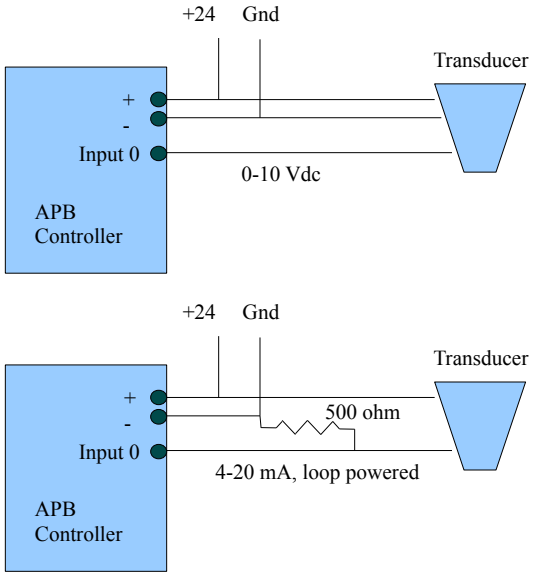
For a square tank, set the radius to 0. For a circular tank set the length and width to 0. For oblong tanks the length, width and radius can be used. If the tank surface area is non-geometric the measured area may be entered as the Length and the Width and Radius would be set to 0.

The surface area is calculated as:

$$\text{Area} = (\text{Length} \times \text{Width}) + (\text{Radius}^2 \times \text{PI})$$

Input Connection

The APB controller will accept a 0-10 Vdc analog input signal from the depth transducer. If the transducer generates a 4-20 mA signal it may be connected using a 500 ohm resistor across the input and the power negative terminal.



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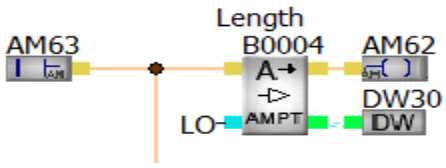
Configuration

The application may be configured to specific requirements by modifying the preset values of various function blocks.

To allow setting constant values, such as the output configuration or width, length and radius information a analog amplifier block is used, with the input set to '0'. By setting the 'offset' parameter a constant value is available at the output.



AM63 is preset to a value of 0. By entering the 'parameter set-up' screen on the HMI the 'OFFSET' parameter may be set to a user specified value. This value is then available as both an 'analog' value (AM62) or a 'fixed integer' value (DW30).

Blocks B000 and B001 allow setting the Level outputs and Alt Level outputs to operate in either the continuous or discrete mode.

Block B002 selects one of the 3 different output mapping configurations.

Block B003 selects which level is monitored for the 'HIGH TIME' alarm and block B004 determines the HIGH ALARM timer value. If the selected level stays active greater than the time defined in the HIGH ALARM timer the HIGH TIME output will become active.

The holding tank geometry is defined by blocks B005 (length), B006 (width) and B007 (radius).

The Depth Factor is determined after the linearization parameters have been set. Record the Raw Level readings at two distinct depths (depth A and Depth B). the Depth Factor is calculated and entered as:

Depth Factor = (Reading A – Reading B)/(Depth A – Depth B)

The Units value is used to convert the volume to either gallons (9.75 Gallons/ft3). Other units of measurement may be used.

The flow information is calculated by the controller as:

Flow volume = Area X Depth Factor X Units.

Block B040 provides the Offset and Gain used to convert the raw analog input signal to the depth information.

Blocks B041..B046 are used to set the threshold (ON level) and hysteresis (OFF level) for each of the 6 detection levels.

The INCREASE and DECREASE outputs are generated by comparing the current level with the previous level. The outputs are generated by re-triggered timers with a pulse width set by B130 and B131. The sampling time between each comparison is determined by B132.

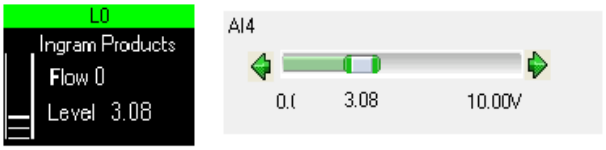
The HIGH FLOW rate output is activated if the flow is greater than the level determined by B133 (inflow rate) or less than the level determined by B134 (outflow rate).

The Flow rate calculation is performed 1/second, as determined by B135.

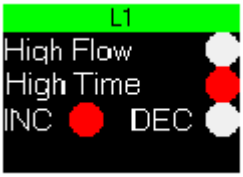
Block	Value	Description
B000	0	Level outputs continuous
	1	Level outputs discrete
B001	0	Alt Level outputs continuous
	1	Alt Level outputs discrete
B002	1 (<2)	Output Configuration 1
	2	Output Configuration 2
	3 (>2)	Output Configuration 3
B003	0..6	Selects which Level will trigger High Alarm. 0 disables the High Alarm.
B004	High Time	Set Max Time for High Time Detect
B005	Length	Area of tank calculated as: Area = (Length X Width) + (Radius^2 X 3.14)
B006	Width	
B007	Radius	
B008	Depth Factor	Span count / span depth.
B009	Units	9.75 (gallons/ft^3)
B040	Linearization	Set Gain & Offset (see text)
B041	Level 1	The ON parameter determines the setpoint. The OFF parameter determines the hysteresis and must be set lower than the ON setpoint.
B042	Level 2	Setpoint and hysteresis of level 2
B043	Level 3	Setpoint and hysteresis of level 3
B044	Level 4	Setpoint and hysteresis of level 4
B045	Level 5	Setpoint and hysteresis of level 5
B046	Level 6	Setpoint and hysteresis of level 6
B130		Decrease output pulse width
B131		Increase output pulse width
B132		Increase/Decrease sample time
B133		Maximum In Flow rate (+ve number)
B134		Maximum Out Flow rate (-ve number)
B135		Flow Rate Sample Time
B150		Set to 1 to reset counters, 0 to enable.

APB Display

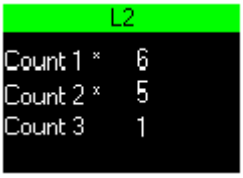
There are 4 displays shown on the APB HMI screen. The user may cycle between the different screens using the up/down cursor button on the HMI. The main display shows the current Flow Rate (gallons/minute), the numeric Level and a small bar-graph providing a graphic indication of the level. If the flow rate is decreasing the Flow value will show as a negative number.

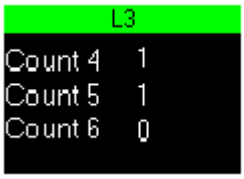


The status screen shows the state of the 4 status outputs: High Flow, High Time, Increasing, Decreasing. This screen is automatically displayed if either the HIGH TIME or HIGH FLOW output is activated.



Two Level Count display screens show the number of times each of the levels have been detected. If the level is currently active an '*' will appear.





Resource Allocation

The following tables summarize the internal registers used.

Analog Registers AM0..3 are used to hold internal calculated values. AM59..AM62 contain the values established by the configuration registers defining the size of the holding vessel. AM63 is set to 0 and used by the configuration functions.

AM0	Linearized Level Signal – Gain/Offset set by Linearization Block
AM1	Last Flow Rate – latched by Flow Sample Pulse
AM2	Current Flow Rate (Vol / time)
AM58	Units
AM59	Depth Factor
AM60	Radius
AM61	Width
AM62	Length
AM63	Preset to constant '0'

Data registers DW17..DW35 are used within the MATH functions used to calculate the flow rate.

DW17	Linearized Value
DW18	Last Linearized Value
DW19	Current Flow Rate
DW30	Length
DW31	Width
DW32	Radius
DW33	Depth Factor
DW34	Circular area ($Radius^2$ X 3.14)
DW35	Area X Depth Factor

The internal bit registers M1..M3 are generated by the configuration blocks to determine the output mapping. Bits M4..M7 contain the 4 status bit values. Bits M8 and M9 are used to control the Continuous/Discrete output settings to generate the M1x (output) and M2x (alt output) states. M3x contain the unmodified states of the 6 level threshold detectors.

M1	Output Configuration 1
M2	Output Configuration 2
M3	Output Configuration 3
M4	Level is Incrementing
M5	Level is Decrementing
M6	High Flow rate detected
M7	Max Time exceeded at selected level
M8	Outputs Continuous/Discrete
M9	Alt Outputs Continuous/Discrete
M11	Level 1
M12	Level 2
M13	Level 3
M14	Level 4
M15	Level 5
M16	Level 6
M21	Alt Level 1
M22	Alt Level 2
M23	Alt Level 3
M24	Alt Level 4
M25	Alt Level 5
M26	Alt Level 6
M31	Active 1
M32	Active 2
M33	Active 3
M34	Active 4
M35	Active 5
M36	Active 6

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Summary

Analog depth measurements are often less expensive than multiple float systems and offer the added benefit of providing real time flow information. An APB controller supports multiple threshold detection, allowing it to convert the analog depth readings into discrete relay outputs to drive pump control systems.

An application was developed that supports 6 unique level detectors and provides 2 independent sets of outputs for each level. The level thresholds include a hysteresis adjustment to avoid false triggering as the level passes through each threshold and the number of times that each threshold is detected is tracked in a counter.

By providing tank area information the controller will provide the in flow and out flow information in real time.

Additional status outputs have been provided to provide an indication of whether the level is increasing, decreasing or staying constant. A HIGH Flow warning output may be set to indicate situations where the in flow or out flow exceeds the expected maximum rates. A HIGH Time warning may be set if the level stays above a certain threshold for an extended period of time.

To support differing applications an output 're-mapping' configuration is provided, allowing systems to be implemented using 4, 8, 12 or 16 outputs.

The application program may be downloaded from the Ingram Products web site PLC Support page.

References

AP-3 APB Process Timing
AP-7 Pump Station Controllers
AP-9 Run Time Verification
AP-11 APB Timer Functions
YouTube Video Training

Ingram Products Inc.,
8725 Youngerman Court
Suite 206
Jacksonville, FL 32244
888-875-2221
West Coast Sales: 951-200-3592
e-mail: sales@ingramproducts.com

Web Site: www.ingramproducts.com