AP-14
Universal Control Relay

Introduction

The controls industry has a near infinite number of special function relays available. Typically units will provide one or two inputs, some form of 'signal monitoring/conditioning' and one or two outputs. Special function relays provide a fixed function such as measuring a time (TIMERS), detecting signal changes (COUNTERS) or detecting a change in a resistance, voltage or current level (THRESHOLD DETECTORS). These capabilities are combined to provide simple sequential control functions, such as detecting a certain voltage level and then delaying a fixed time before activating an output.

The cost for special function relays varies from $30 for common units that have a wide range of use (timers) to well over $300 for specialty products that combine analog sensing with timer, counter and sequencing functions.

In many applications, the special function relay is used in combination with other control elements or several special function controllers are combined together to realize the final control system. In these applications the use of a 'universal' control relay offers numerous advantages.

The APB-12MRDL controller provides all the 'building blocks' to act as a universal control relay. The unit provides 8 inputs which may be treated as either digital (24 Vdc) or analog (0-10 Vdc) and 4 that support high speed (10 khz) counter functions.

Four relay or solid state outputs are available and two of the solid state outputs support high speed (10 khz) Pulse and PWM outputs. The integrated HMI display provides up to 64 user defined screens (4 lines X 10 characters), graphics support and input keys to allow modifying values and screen navigation.

	Special Function Relays	Universal Control Relays
Cost	$30-$300+. Fixed function with limited (manufacturer) defined options.	$65-$100 Economic if more than 2 'special function' relays required.
Wiring	Power to each unit must be applied and each point must be interconnected	Power applied to single unit. The interconnect between internal functions requires no wiring.
Space	Typically 1-2 DIN spaces per unit.	Available in 2 DIN and 4 DIN size.
Field Settings	Typically switch or screw driver (pot) settings. Prone to incorrect adjustment in field by inexperienced operators.	Adjusted thru HMI interface which can be locked with password to prevent unauthorized adjustments.
Inventory	Requires individual units stocked for production. Increased field spares.	Standard hardware which can be factory or field programmed for specific functions.
Features	Fixed or limited features determined by manufacturer.	Features may be easily enhanced. Field upgrades possible with no additional equipment or wiring.
Operator Feedback	Often limited to 'go-no/go LED' indicators. New units may offer digital displays as found in counter and timer relays.	Integrated HMI provides display of graphics and text information. User set-up may be menu driven and outputs may include 'meaningful' text.

The APB family of controllers are configured using *Function Blocks* that are linked together using a 'drag and drop' configuration tool. The configuration tool operates on any Windows based PC and includes a built in interactive simulator to allow function verification and real time monitoring of the relay functions.

There is no cost for the configuration tools.

Function blocks provided on the APB controller can be grouped in 8 major categories. A APB controller supports up to 320 function blocks which far exceeds the number required to replace special function relays.

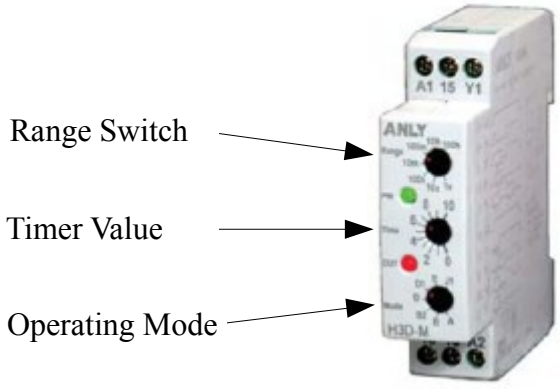
FUNCTION TYPE	
I/O (not included in function block count)	Digital Input, Output Analog Input, Output Memory Input, Output
Timers	Time ON delay, Time Off delay, Time ON-OFF Delay, Keep ON delay, Blinker, Time Sequencer (Drum timer), Time of Day Timer, Special Function
Counters	Up/Down Counter, Quadrature (2 phase) counter, Increment- Decrement, Frequency, latches
Threshold	Analog amplifiers (linearization) Compartors with hysteresis (Counters & Timers include comparators and support hysteresis)
Pulse Generation	PWM (pulse width modulation), PTO (frequency generation), Accel/Decel ramp generation.
Logic	AND, OR, XOR, INVERTERS and special edge detect logic elements used to combine signals.
HMI Display	Text, values, Parameters (counter, timers etc), Digital States, graphics, password (protection)
Communications (not required for standard special function relay applications)	Modbus, Ethernet, SMS

Special Function Relay Examples

The following examples illustrate the APB as a universal control relay replacement for various special function relays. The examples may be freely mixed and combined to build more complex or specialized relay replacements.

Timers

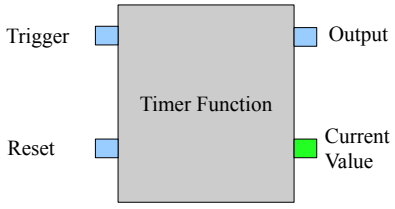
Low end timers typically cost ~ $30 - $40 and provide a user adjustable (potentiometer) delay time and often a 'timer range' switch is add to provide different ranges. These timers often will provide multiple different operating modes such as Time-ON , Time-OFF, Time ON-OFF or Blinking. Timers that offer digital displays cost ~ $70 and advanced units offering time-of-day scheduling cost ~ $180.



The timer shown provides two LED's to indicate when the input is active and whether the 'elapsed' time has expired.

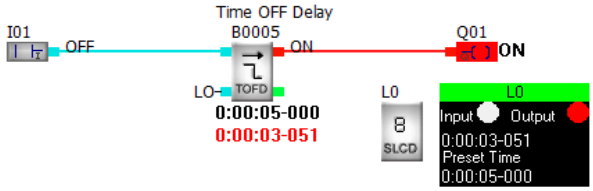
Timers are used extensively in control systems to filter signals and to provide orderly start up and shutdown. Many special function relays will incorporate a timer to provide filtering against false triggering on the input signals.

Generic Timer Symbol



The APB controller uses a generic timer function block symbol and differences between the timer types reflect how the timer responds to the Trigger input.

The following shows a single APB timer FUNCTION BLOCK, in this case a Time OFF delay connected to a digital input and digital output. When operating, the HMI display screen shows the state of the input, the output, the 'preset time' and the elapsed time, not available on the dedicated special function relay.



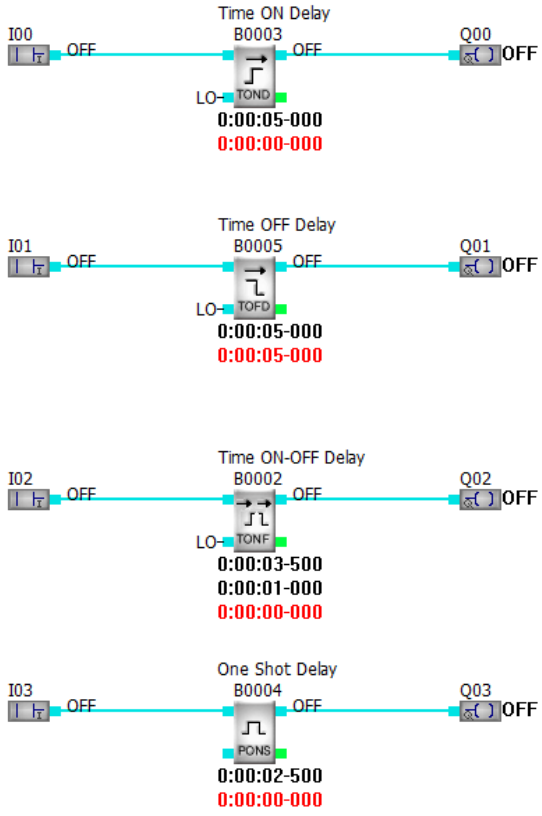
The configuration screen is shown in the 'simulate' mode that includes the preset and current elapsed time immediately below the timer block. The HMI screen shown will appear on the device HMI when the controller is running.

If the application only requires a single timer a dedicated timer may be the best solution if the added diagnostic information is not required. If two or more timers are required or if a more advanced digital timer that includes a display or provides time of day capability an APB universal control relay will provide both a cost savings and enhanced functionality.

The following shows a single APB-12MRDL configured to provide 4 different timers in one unit. These could be all of one type or a mix of different types, as shown. Each timer could have a dedicated HMI screen to show the current states and a 'main' screen showing the overall states of the special function 'timer' relay.

The timer presets are all configurable using the integrated HMI and may be password protected to prevent unauthorized users from making changes.

Application note 'AP-11 APB Timer Functions' available at the Ingram Products web site discusses numerous timer examples, including time of day, elapsed time, drum timers and retentive timers that retain time information when power is removed.



Counters

Digital counters detect when an input signal changes from a 1 to a 0 (or 0 to 1) and will increment or decrement a count. They are used extensively to record the total number of events and will often cause an output to activate at a certain preset value.

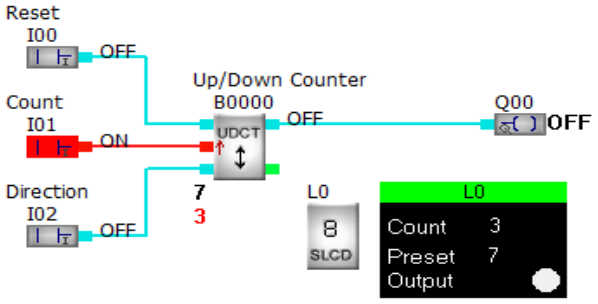
Often counters are provided with both a trigger signal and a count direct signal. These inputs may be used to detect direction of travel and to track position. By counting the number of events over a

fixed time period the frequency or speed of rotation may be measured. Refer to 'AP-2 Speed and Position' for a more in depth discussion on counter use.

As with the case of dedicated timer relays, there are numerous digital counters available. These devices will usually include a display showing the current count and provide a preset that causes an output to be activated.

Prices typically start at $100 and for high speed devices (> 1 Khz) prices may quickly exceed $200.

The APB-12MRDL provides a generic up/down counter block with a user settable threshold and may be configured to count when the input goes active or inactive. The count direction is controlled by a second input and the counter may be reset using the reset input.



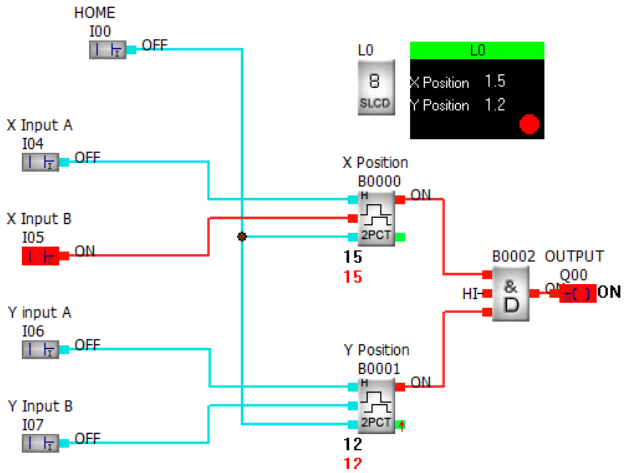
The HMI has been configured to display both the current count and the preset value.

To support advanced counter applications an up/down counter is available with 2 preset values. One preset value is used to turn the output ON and the second to turn the output OFF.

ON Preset > OFF Preset	Hysteresis: Once counter turns ON it remains on until the count drops below the OFF preset
ON Preset < OFF Preset	Range: Output will be active if count is in the range of OFF < count < ON.

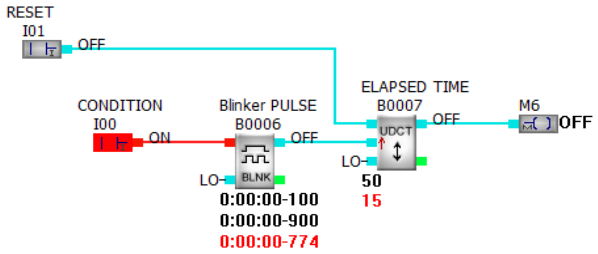
Counters are often used to track position using 'quadrature inputs' for linear or shaft encoders where the phase relationship between two signals determines the direction of travel. The APB controller includes a Two Phase counter that uses edge detection and phase to determine the count direction.

The following accepts 2 sets of quadrature inputs and provides a display of the X-Y position. The 'HOME' input allows zeroing the counters at the 0,0 position.



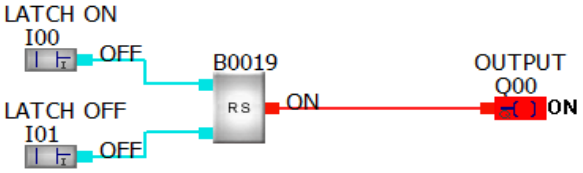
Four high speed inputs are available on the APB controller providing count rates up to 10 khz.

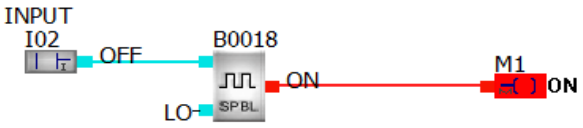
Counters may also be used to track time for 'elapsed time' applications. The follow shows a simple elapsed time monitor that will record the number of seconds (or minutes, or hours etc) that the input 'CONDITION' is active.



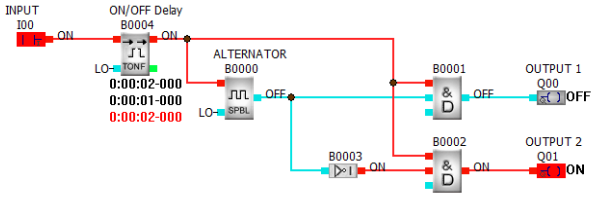
Multiple State Relays

The simplest form of a multi-state special purpose relay is the latching relay. Two forms are shown below. In the first example, the ON input will latch the output ON and the OFF input turns it OFF. In the second case, when the input goes active the output switches ON. The next time the input goes active the output switches OFF.



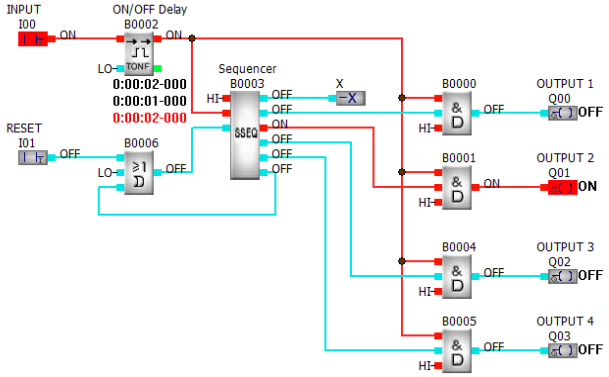


An 'alternating' special purpose relay is used extensively to switch between pumps in pumping applications to provide 'even' usage where lead/lag pumps are used. In the configuration shown when the input goes active output 1 will become active. Each time the input is reactivated the active output will alternate between output 1 and 2.



The configuration uses a ON/OFF delay timer to filter the input signal which is then applied to a toggle block which acts as a simple counter that switches from ON to OFF each time the input transitions from 0 to 1. Simple combinatorial logic is used to activate the corresponding outputs.

The preceding alternating relay can be considered a special case of a broader range of *sequencers* that change the output 'state' of the relays based on an input change.



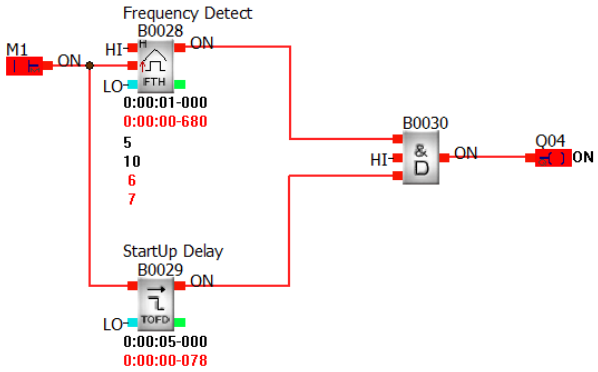
The sequencer shown above provides 4 relay outputs that will be sequenced each time the input transitions. A separate 'RESET' input is provided to allow resetting the sequence. The 'quadraplex' relay could be enhanced by providing separate ON/OFF delays for each output or by adding additional logic so that various combinations of outputs would be activated each time the input switched.

The step sequencer function block supports 8 outputs and sequencers may be cascaded to provide an arbitrary number of control states.

Pulse Detection

The 'missing pulse' detector is a special function relay that is often used to ensure that a machine, such as a conveyor, is operating at the correct speed. In the simplest form, the relay accepts inputs that continually reset a timer. If a pulse is missed the timer will time out and set an output.

The APB-12MRDL has a integrated Frequency detector that verifies that the pulse rate is within a certain range, allowing detection if the pulses are too slow or too fast. The StartUp delay has been added to allow the machine to reach a stable operating range.



Threshold Detection

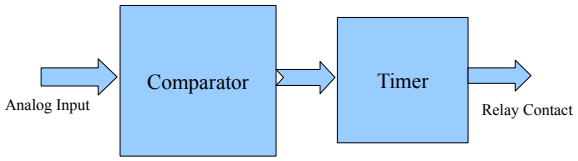
Numerous applications involving the measurement of weight, conductivity or levels use analog signals coupled to a special function relay that provides a preset threshold. As the analog signal (resistance, voltage or current) increases above a certain threshold the output will be activated.

To avoid false or erratic signals as the analog input passes thru the threshold value these devices will offer some form filtering, often in the form of a simple timer function that ensures that the signal is stable for a period of time before activating the output. More advanced units may offer hysteresis, where once the output is activated the signal must vary by a certain amount before the signal is deactivated.

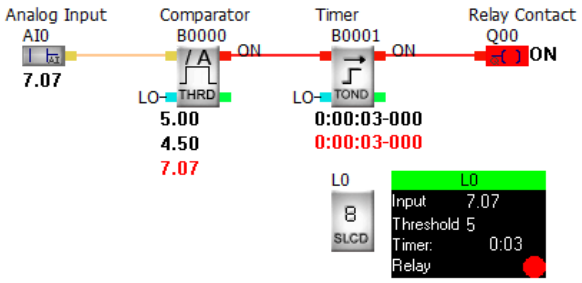
Prices typically start ~ $50 for a single point relay and will quickly raise to several hundred dollars for multiple threshold detectors.

The APB 12MRDL controller allows any (or all) of the 8 inputs to be treated as an analog (0-10 Vdc) signal. For current sensing, a 500 ohm resistor across the input converts 4-20 mA signals to 2-10 Vdc inputs. The input impedance is ~ 50K ohms, allowing the inputs to directly monitor resistive probes with sensitivity of up to ~250K ohms.

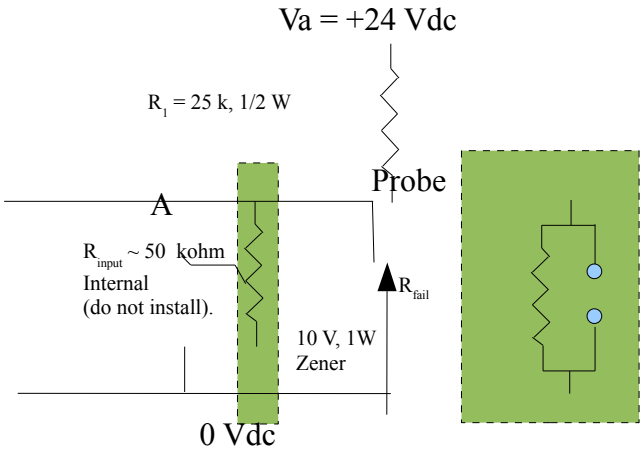
Although the exact functionality of these special function relays vary, the basic building blocks consist of a analog comparator coupled to a timer. When the input level reaches a specific threshold the output is activated. The timer provides a simple filtering to avoid false triggering.



The APB controller has an extensive set of analog comparators, amplifiers and 'math' functions available to manipulate the applied signal. The following shows a configuration that will activate a relay contact when the input signal exceeds the input threshold (5 volts) for a 3 second period. The comparator has been configured to not switch off until the input voltage drops below 4.5 volts, providing a 'hysteresis' of 0.5 volts in addition to the timer filter.



By connecting a biasing resistor to the input the previous configuration acts as a 'seal leak detector' used to detect leakage in submersible pumps.

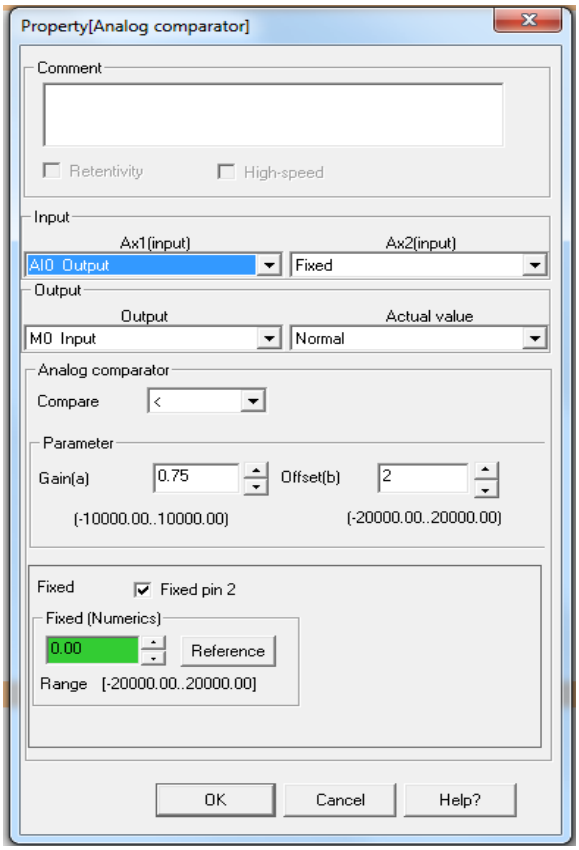


If water leaks past the pump seal the resistance between the internal pump probe leads (R_{fail}) will decrease and the voltage measured by the controller input (A) will drop from 10 to ~ 2 volts.

Seal leak relays typically cost ~ $40. The APB-12MRD can be configured to act as 4 independent seal leak detectors.

Conductive probes are frequently used to measure levels in conductive (water) liquids. The resistive measurement approach used for seal leak detection may be used to implement a level detection system.

APB-12MRDL function blocks that support analog signals all provide a 'gain' and 'offset' parameter which may be used to scale the input signals. Shown below is a typical 'parameter' (comparator) block used by the configuration and simulation tools.



The input signal may be compared (>, <, =, >=, <=, !=) to either another analog signal, an internal 'reference' value or a fixed constant. When the condition is met the output will become active. The parameters may set in the configuration tool or modified, under password control, using the HMI interface.

The offset and gain value may be used to scale the input signal and to eliminate the 2 volt offset present in 4-20 mA applications.

The following table summarizes the analog specific input function blocks available.

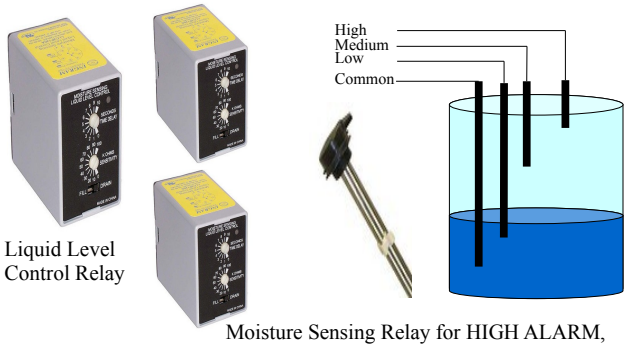
Comparator	Compares and analog signal to another signal, an internal value or a fixed value
Threshold Detector	Compares and analog signal to another signal, an internal value or a fixed value. Provides hysteresis.
Amplifier	Provides gain & offset scaling
WatchDog	Latches analog signal and then compares, with hysteresis
Differential Trigger	Compares and analog signal to another signal, an internal value or a fixed value. Provides hysteresis.
Multiplexer	Select between 4 different analog sources
Math	4 variable, 3 operator generic math

Level Control

The threshold detect may be combined with a latched relay to build a simple level controller. These special function relays typically cost in the $50-$75 dollar range and provide a simple control relay to maintain conductive liquid (water) levels.

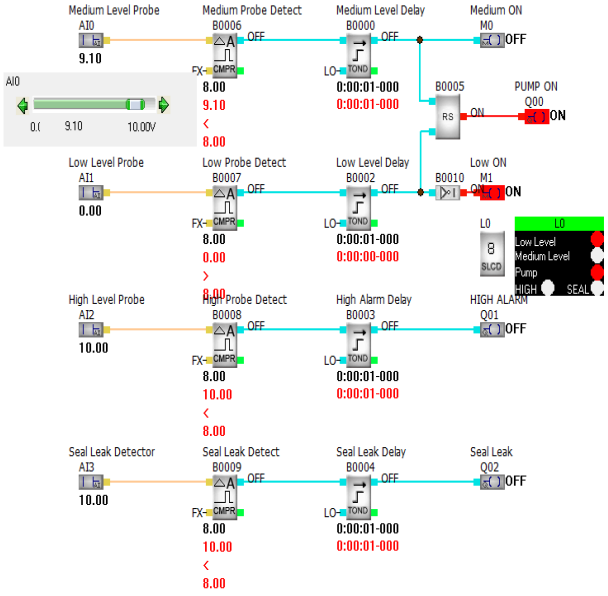
Typically four probes are inserted into holding tank with one probe acting as a 'common'. The 'common', 'low' and 'medium' probes are connected to the moisture control relay which is used to turn on and off a pump. The 'common' and 'high' probe is connected to a 'moisture sensing' relay to activate a 'high alarm' if the level rises to the high probe level. Often a third moisture sensing relay is required for the pump seal leak detection.

When the liquid level is detected at the 'medium' probe level the pump will start, drawing the liquid down. When the level drops below the 'low' level the pump will be turned off.



Liquid Level Control Relay

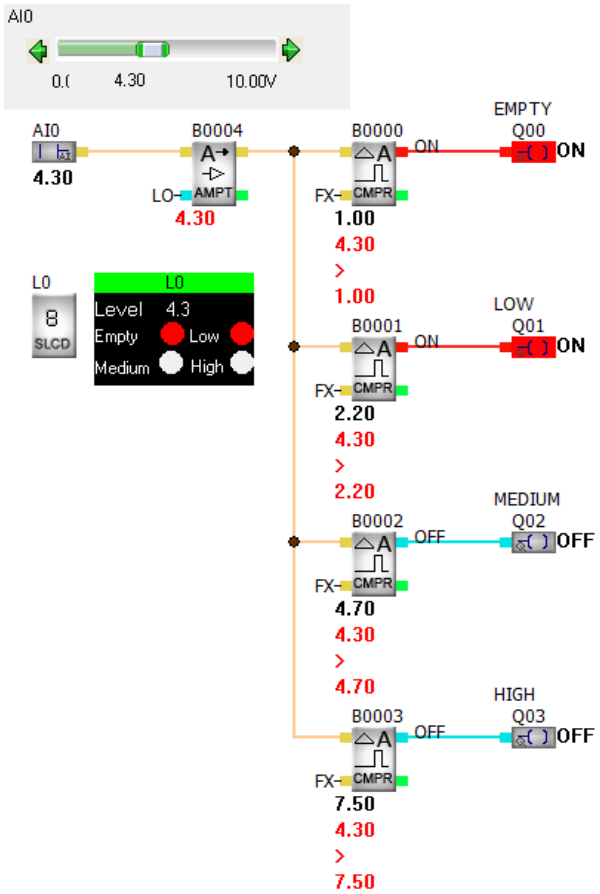
Moisture Sensing Relay for HIGH ALARM, possibly another for seal leak detection



The APB-12MRDL implements the liquid level control function as well as the high alarm and seal leak detect as a single special function relay. Note that the inputs could easily be converted to accept float switch closures.

Several application notes are available that further discuss use of the APB controller in pump control systems.

Multiple Threshold Detectors



By connecting an analog input to multiple threshold detector blocks the MPB-12MRDL will act as a analog signal to digital threshold converter.

The configuration accepts a linear input, such as a ultra-sonic level measurement device and converts it to 4 distinct digital setpoints. The HMI provides a convenient display of the scaled input level and the four output states. The configuration could be combined with the previous liquid level control configuration to implement a liquid level control relay that accepts either an analog input, resistive probe inputs or discrete float switch inputs.

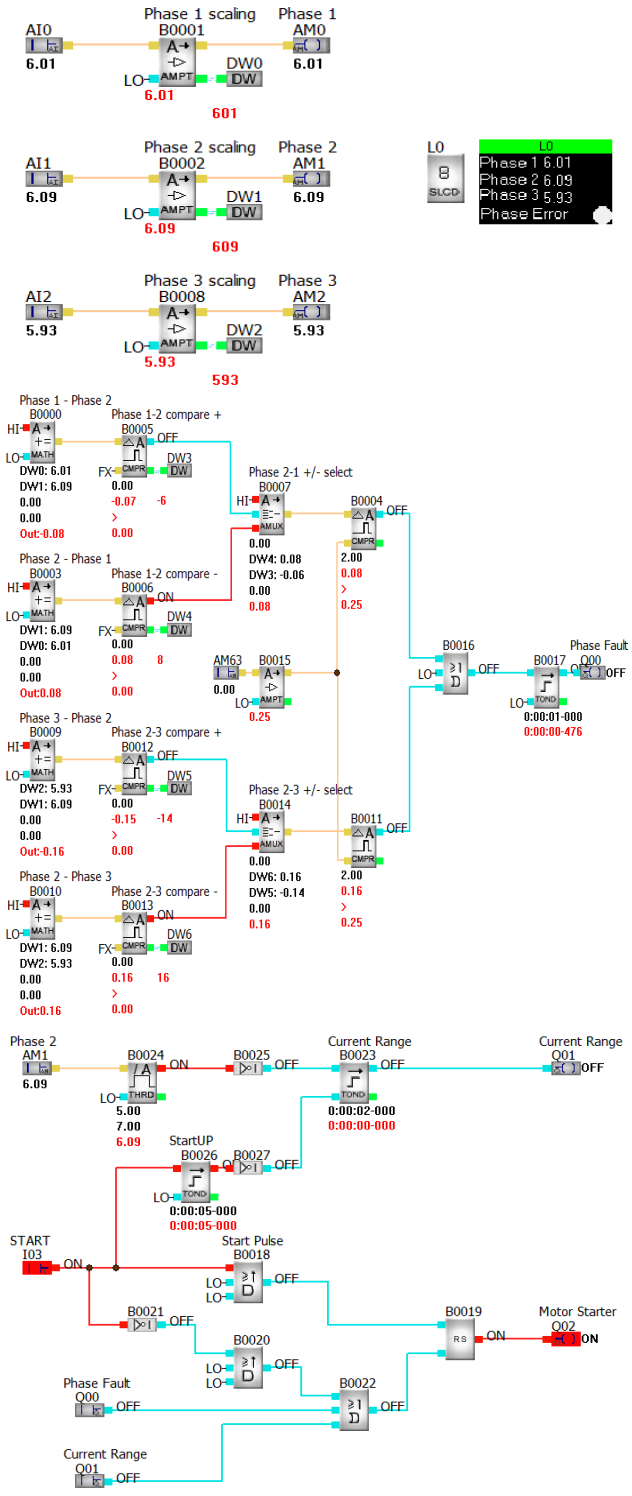
3 Phase Current Monitoring

Another common special function relay is a 3 phase current monitor that ensures that the current flowing in each winding of a three phase motor is balanced.

Low cost current sensors such as the Furison FCS521 are coupled to each phase of the pump supply and the sensors generate a 0-10 Vdc signal proportional to the AC current flowing to the motor winding. These units 'clamp on' to existing power cables and require no direct electrical connection.

NOTE: The configuration shown does NOT replace the thermal overload relay.

Each phase input is linearized and applied to comparators that compare the absolute difference between each of the phases. Phase 2 is also compared to an analog threshold detector to ensure that the running current is within a specified range.



Start/stop control logic has be added to the current sense configuration to create a special function control relay that provides a complete current monitor relay.

When the START signal is activated the Motor Starter output will be activated to activate the external motor starter. A StartUp delay disables the current monitoring during the inrush period and then enables both the phase comparator and current range comparator.

If a phase inbalance is detected or if the operating current is not within the specified range the Motor Starter output is locked off. If a fault is detected the START signal must be reset and reactivated before the motor will restart. Current Range fault and Phase fault output relays are provided.

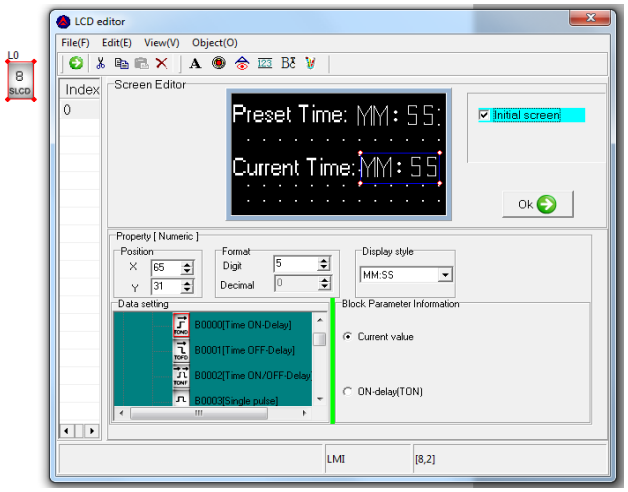
HMI Display Information

Many special function relays have no display capability – the parameter values are set with DIP switches or potentiometers and any error indication is provided by one or more LED indicators.

The APB-12MRDL display supports up to 64 user defined screens, each providing for 4 rows of 10 characters that can display text, function block data, I/O states or graphics.

Most of the examples shown have included a 'status' display screen. If more information is required than will conveniently fit on a single screen than multiple screens may be used.

The display screens are built using the configuration tool. While running in the simulation mode each of the display screens may be selected to allow viewing on the PC monitor.



For example, in the HMI configuration screen shown, the text 'Preset Time' and 'Current Time' can be any user defined text to describe the information. The option allows displaying any block information, in this case block B0000 which is a Time ON delay. The MM:SS characters will be replaced with the actual timer values on the HMI display.

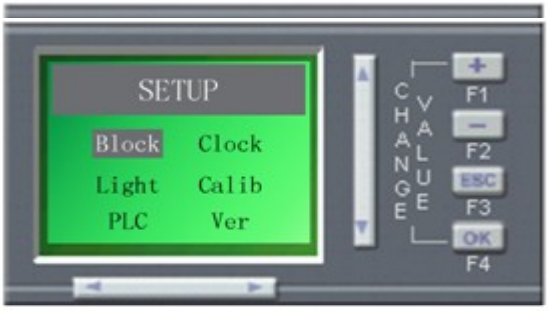
Display screens may be selected by the operator or may be configured as 'triggered', allowing error or status states to automatically select and display specific screens.

The ability to display meaningful status information and scaled parameter values greatly simplifies the maintenance of the equipment.

Modifying Parameter Presets

The HMI display allows block parameter information to be changed by entering the 'Parameter Setup' screen. Pressing the 'ESC' key will return the HMI to the main Interface screen.

The parameter setting screen allows setting the parameter preset information for each function Block, the current Clock value used by the time of day Scheduler, the Modbus address and the LCD back-light control.

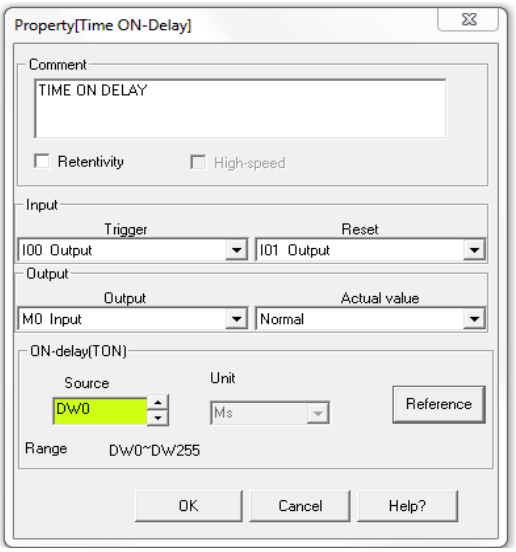


Program parameters setting

If the Block option is selected each program block may be selected and the preset values may be modified. These changes may be protected using a 4 digit 'password'.

An alternative approach is to use data register references instead of fixed preset values.

By selecting the 'Reference' option the preset may be tied to a Data Register DW0..DW255. Data registers may be directly set by the user from the user defined display screens. Refer to AP-8 Run Time Monitoring for further examples.



Customizing Control Relays

As the previous examples have illustrated the APB-12MRDL can be used to create many of the special function relays used in control systems. In many cases, multiple relay functions may be configured into one controller, reducing the overall material and installation costs.

With the powerful configuration tool that supports a simulation mode additional features may be easily added or several special function 'building blocks' may be combined to further reduce costs. For example, the three phase current monitor could easily be combined with the simple level controller to provide an advanced level control relay with integrated run verification.

The entire configuration may be saved to a file or printed as part of the system documentation. Configuration files are loaded to the APB-12MRDL using a standard USB interface and support cable, allowing production configuration of specific control relays and field upgrades using a lap top computer.

Summary

The APB controller provides an excellent alternative solution for many standard special function relays. In many cases the entire configuration requires less than a dozen function blocks and minimal configuration effort. The ability to add additional control logic to replace external relay logic, the capability of supporting up to 320 function blocks, the intermixing of analog and digital inputs and the integrated HMI display allows the APB controller to act as a universal control relay.

Applications that require several special function relays requires that each unit must be individually wired and interconnected. Using the APB controller the internal connections are done internal to the controller, eliminating the wiring costs and long term maintenance requirements.

The APB controller is DIN rail mounted, occupying 71 mm which in many cases represents a smaller 'footprint' than 2 special function relays.

Inventory costs are reduced - a single universal control relay will satisfy a wide range of application requirements, reducing the number of different units required for both production and as field spares. A single controller as a 'spares' device may be easily configured in the field using a lap top computer.

Parameters may be set using the integrated HMI display and all parameter settings may be protected using a password, eliminating problems associated with unauthorized users modifying field settings.

The HMI interface greatly enhances the field diagnostic information available. Rather than relying on go/no-go LED indicators and requiring that analog signals are measured using test meters all pertinent information may be presented on the display, which has the added advantage of ensuring that the signals are in fact correctly applied to the device.

Finally, the extensive library of function blocks available on the APB controller allows enhancements to be easily added to standard 'fixed function' relay requirements. The resulting configuration may be exactly tailored to the application requirements, and often will allow adding significant features at little or no cost.

The APB controller is available with 8 or 14 inputs and either 4 or 8 outputs although expansion units may be added to support up to 130 inputs and 64 outputs. The outputs may be solid state (NPN or PNP) or normally open (NO) relays. Low cost relays may be added to provide NO/NC relay connections if required.

References

AP-1 Liquid Level Control
AP-2 Position Monitoring
AP-3 APB Process Timing
AP-8 Run Time Control
AP-9 Run Time Verification
AP-11 APB Timer Functions
AP-12 Level Monitoring

YouTube Video Training

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