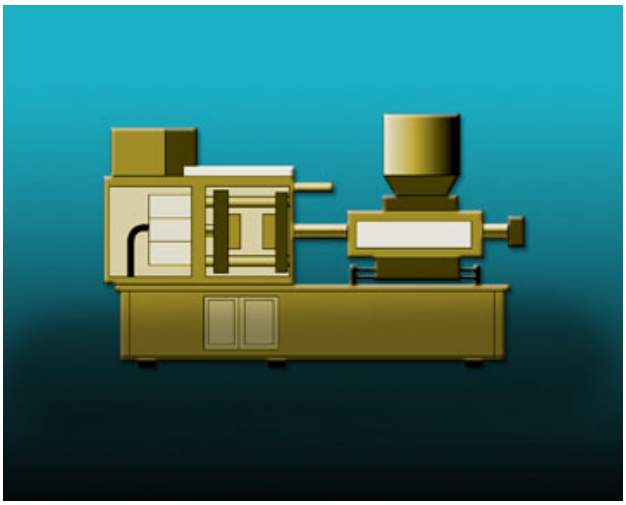
Creating a Plastics Injection Molding Machine Control Solution Using the Logix Platform, DeviceNet and Bosch-Rexroth High-Speed Closed-Loop Controllers



Purpose of this Document: This document will provide useful information for helping a Rockwell Automation customer with understanding the plastics injection molding solution using Logix-based hardware in conjunction with Bosch-Rexroth high speed, closed-loop controllers. It is recommended that the user be familiar with RSLogix5000 and Logix hardware, understand the injection molding process, have basic hydraulic knowledge, and be able to write and interpret ladder and function block code. Additionally, it would be beneficial to have some experience with DeviceNet. This document should be used together with the appropriate Logix User Manual and DeviceNet interface module User Manual, the DN-6.7.2 DeviceNet Cable Installation and Wiring Guide, and the Bosch-Rexroth Manuals for the specified hydraulic controllers.

Application Description: Rockwell Automation has delivered injection molding control solutions based on the SLC and PLC-5 PLC™ product lines for many years. This document will provide the injection molding machine user with a Logix-based solution based on Rockwell Automation's newest control platform. This document was developed in conjunction with Bosch-Rexroth to provide a similar solution for new customers as well as existing customers who want to migrate their plastics applications to Logix-based control. The power of the solution lies in the open network architecture and the various SLC, PLC-5, and Logix hardware products available for control, making the new solution very scaleable in terms of memory, I/O, control, and communications.

Control System Product Requirements: The following list of hardware and software products is required for implementing the solution as described in this application note:

- Any Logix controller
- DeviceNet interface module
- Various Logix input and output modules
- Bosch Rexroth Inject Controller (DPQ-2X)
- Bosch Rexroth Clamp Controller (DPC-1X)
- RSLogix 5000 software with Function Block activation
- RSLinx software
- RSNetworx for DeviceNet software
- Any Front-End HMI software (i.e. RSView32, ME, or SE)

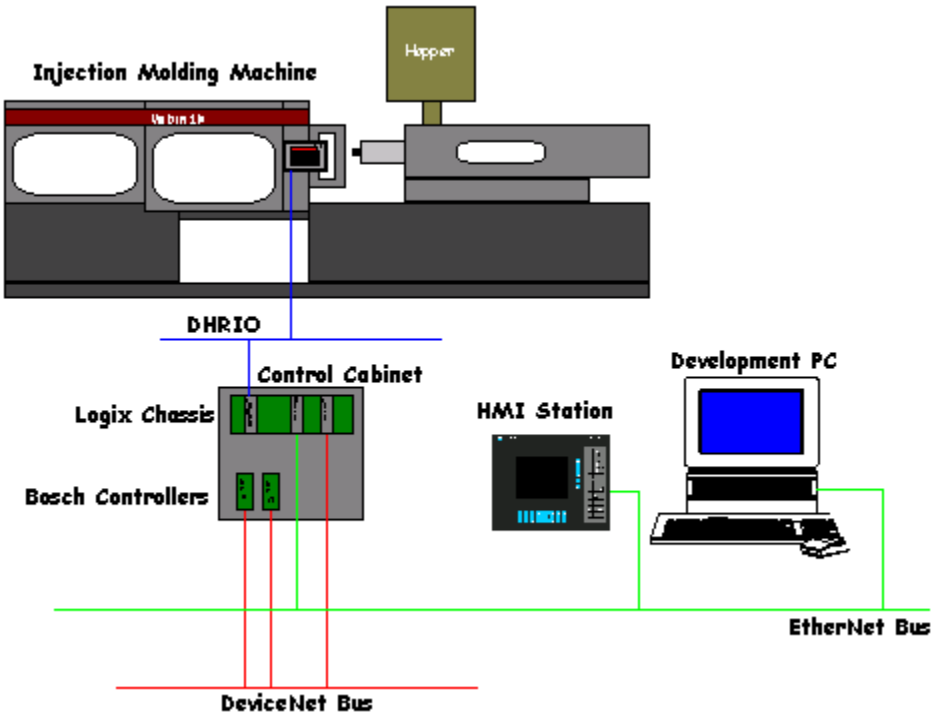
Control Challenges:

- Reduce overall cycle time of injection molding process
- Improve process repeatability and flexibility
- Reduce vibration
- Reduce scrap and regrinds
- Simplify recipe changes
- Simplify reusing this control strategy when integrating it into larger or smaller machines
- Create a solution that can be used in Logix based injection molding applications as well as MicroLogix 1500, SLC, and PLC-5.

System Overview

For the purposes of this application note, we'll use a specific example that was implemented and installed on a machine in Rockwell Automation's development lab. Keep in mind, however, that this solution is not limited to Logix-based controllers alone; it has also been successfully implemented with SLC and PLC-5-based controllers as well.

The following is a representation of the injection molding system :



The configuration for the System consists of the following:

DeviceNet Network

DeviceNet Scanner

DPC-1X (Bosch-Rexroth clamp controller)

DPQ-2X (Bosch-Rexroth inject/eject controller)

EtherNet Network

Ethernet Module

HMI Station

Development PC (whatever quantity is required during integration process)

RIO Network

DHRIO Module

Redi_Panel Operator Interface/Control

Miscellaneous

Various I/O modules wired to field devices

DPC and DPQ hydraulic controllers are wired to physical valves and sensors to control and read valve outputs, pressures, and positions within the hydraulic circuit

Note: This configuration was chosen for a number of reasons (i.e. quickest integration with the existing set of hardware); however, the network could be re-arranged to suit your application. Your Operator Interface/Control could be on DeviceNet, ControlNet, or EtherNet. Your high-level data acquisition system could be connected to the Ethernet backbone to gather and analyze real-time data.

Now that you have an idea of what a typical injection molding system looks like, let's get into some specifics relating to this particular application.

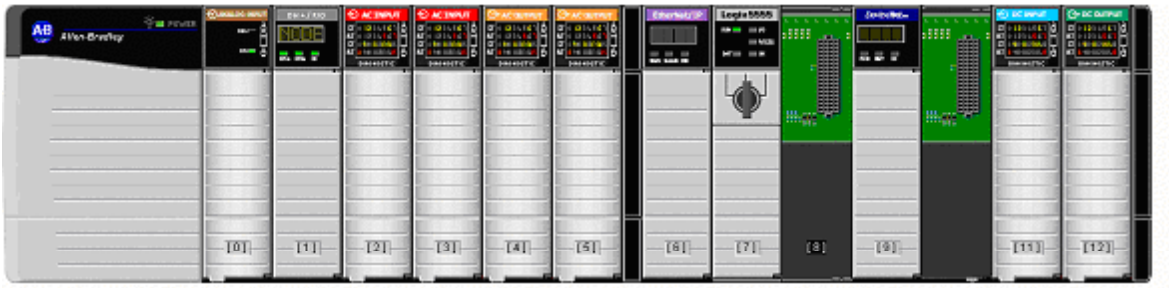
Let's Talk About Our Hardware and Network Components

The following are the key components we utilized to build the control hardware/network configuration of this system:

1) ControlLogix

The core of our system in this example is the ControlLogix chassis. Within this chassis are all the modules required for sequential and process control, network connectivity, and I/O interfaces to field devices. As shown below, a 13-slot ControlLogix chassis was used for this application (other chassis sizes available: 4, 7, 10, and 17 slot versions). Scaleability of the Logix platform is a key feature for this solution; therefore, the spare slot shown below provides a buffer for potential future expansion with processing, networking, motion, or I/O capabilities.

ControlLogix Chassis



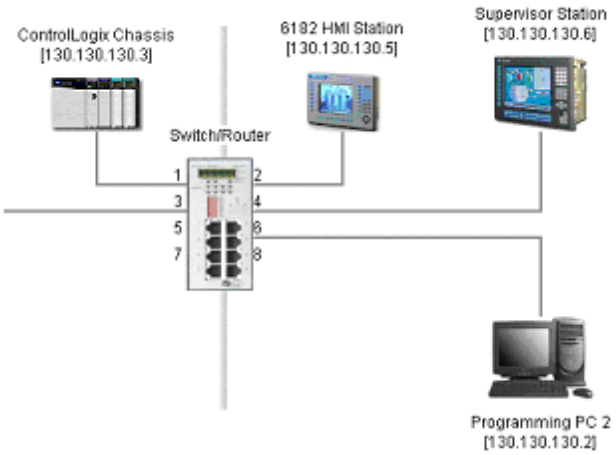
The contents of the ControlLogix chassis used for our specific test case are described in the following table:

Slot #	*Module*	*Description*	*Function*
0	1756-IT6I	6 Point Thermocouple Input Module	Returns temperature data from 4 J-type T/C on different barrel locations as well as oil temperature
1	1756-DHRIO	Data Highway Plus/Remote I/O Communication Interface Module	Interfaces to RediPanel on molding machine
2	1756-IA16	16 point, 120V AC Input Module	Wired to limit switches on molding machine
3	1756-IA16	16 point, 120V AC Input Module	Wired to limit switches on molding machine
4	1756-OA16	16 point, 120/240V AC Output Module	Wired to solenoids on molding machine
5	1756-OA16	17 point, 120/240V AC Output Module	Wired to solenoids and temperature outputs
6	1756-ENET	Ethernet Communication Interface Module	Interfaces to HMI, programming terminals, and upper level systems
7	1756-L63	ControlLogix Controller	Provides system controls
8	spare	----	----
9	1756-DNB	DeviceNet Interface Module	Interfaces to Bosch Rexroth Clamp and Inject Controllers
	spare	--	--
11	1756-IB16	16 point, 12/24V DC Input Module	Hardwires to Inject/Eject and Clamp Cards
12	OB16I	16 point, DC Isolated Output Module	Hardwires to Inject/Eject and Clamp Card Enables and Autos

Remember, we're providing the above list of specific hardware and software products to help our customers understand this application solution; but, you are NOT limited to these hardware products. One of the powers of this solution lies in its hardware independent nature. Customers may pick and choose their hardware based on their particular application needs (as well as their budget).

2) EtherNet Network

Ethernet networking was chosen to support communications between the HMI, programming terminal(s), and upper level management systems. For this application solution, a small, isolated Ethernet network was created as shown below:



3) DeviceNet Network

DeviceNet is the interface between the Logix system and the Bosch-Rexroth Clamp and Inject/Eject controllers. DeviceNet triggers are sent to the inject/eject and clamp cards predicated on the following:
a) events and conditions programmed through ladder code
b) status from the hydraulic controllers.
These triggers indicate the sequence of block number(s) in the inject/eject and/or clamp hydraulic controller card.
Additional DeviceNet-based hardware (such as PanelViews, Stacklights, sensors, etc.) could be placed on the DeviceNet network as well; however, keep in mind that since time-critical triggers to the hydraulic controllers are sent via DeviceNet, you want to maximize network and machine performance. To that end, it is not recommended that you place any device on the same DeviceNet network that will be *continually* polling the devices for large amounts of data.

4) Injection Molding Machine

This specific injection molding machine solution was integrated onto a Van Dorn 170 HT, with a typical Van Dorn hydraulic circuit with 2 manifolds (1 of these supports both inject and eject) and 3 proportional valves (1 pressure and 2 flow). However, the solution is not limited to this particular hydraulic circuit, to this type or size of machine, or by size of the application. Rockwell Automation recommends you consult your local hydraulics expert or system integrator to review your hydraulic diagrams to ensure optimal performance of your system. (i.e. you want to make sure the hydraulics components have been properly sized for your application).

5) Operator Interface Panel

The existing universal RIO (remote I/O) network and RediPanel used with the previously installed control system solutions (SLC and PLC-5) were also used in this solution. Although universal RIO is supported by the Logix platform, RA recommends that you consider using a PanelView on EtherNet or DeviceNet for operator machine controls. This provides you with a more open solution based on the NetLinx Integrated Architecture (for more information on this topic, contact your local RA distributor or Sales Representative).

6) Machine HMI Interface

For the purposes of this application, the RSView32 project was developed on an Allen Bradley 6181 Industrial Computer in a Windows 2000 environment. The data is served up to the RSView application through an OPC Server (RSLinx). Data is transmitted from the ControlLogix L63 controller over EtherNet and from the Bosch-Rexroth Inject/Eject and Clamp controllers via the DeviceNet scanner, across the backplane to the EtherNet module, out the EtherNet port to the HMI. This demonstrates one of the key strengths of Rockwell Automation's Integrated Architecture: Seamless bridging and routing. Because the Bosch-Rexroth hydraulic controllers sit

on DeviceNet (one of Rockwell's core networks), the user has the ability to explicit message to and from the devices directly from the HMI, which bypasses the ControlLogix L63 controller altogether. This greatly reduces the overhead in the controller, allowing for faster scan times and more communication bandwidth; additionally, it reduces the time commitment of the programmer.
Because a molding machine can be used to mold numerous parts, the ability to store recipe information is critical. To support this function, an RSView32 extension called RecipePro is utilized. This is a simple add-on to the basic RSView32 package and makes the download and storage functions very easy. Another advantage of using this utility to store your recipes is the conservation of memory space in your sequential controller. For more information on how to use this RSView extension, please refer to the following Rockwell Software manual: *9399-RSVPROGR: RecipePro Getting Results Guide*

7) Bosch Hydraulic Controllers

Clamp Controller (DPC-1X)
The DPC is a digital platform, industrial clamp controller. It optimizes the control of a hydraulic axis for velocity and pressure control.

- Velocity profiles are controlled completely by use of closed loop position control. An advanced position command profile is calculated automatically based on the operator input velocity profile.
- Because the DPC is a position control device it requires a position feedback transducer. Both 0 to 10 VDC analog and SSI digital types are supported.
- The DPC uses constant acceleration type ramping to allow smooth acceleration of the clamp.
- Position dependant braking technology is used so that even the most demanding systems can be decelerated in the shortest time possible, smoothly and with superb repeatability.
- The DPC includes pressure-limiting control that can be configured to work with 1 or 2 pressure transducers or a load cell.
- Advanced control techniques like Active Damping allow precise closed loop control of the most demanding low-natural-frequency systems.
- The velocity profile and pressure profiles may be controlled with one proportional directional type hydraulic flow control valve, or using separate valves for flow and pressure.
- The DPC includes DeviceNet communications capability that allows access to all parameters directly from a PLC or computer. All sequence triggers are transmitted to the DPC over DeviceNet .

Motion profile set points are normally transferred into the DPC from a PLC or computer. The profile set points may also be entered into the card using RSNetworx for DeviceNet or Bosch Rexroth BODAC software.

The DPC is configured to control clamp type applications and all parameters are labeled to be recognizable in clamp applications. There are, however, many other applications that could benefit from the quality of control afforded by the DPC.
Typical applications include:

- Mechanical handling devices
- Lift and Transfer machines
- Powder metal presses
- Angular position for rotary axis
- Shuttle and Transport axis

Inject Controller (DPQ-2X)
The DPQ is a digital platform, industrial injection molding controller. It optimizes the control of a hydraulic injection axis and/or a hydraulic ejector axis.

- Injection velocity profiles are controlled completely by use of closed loop position control. An advanced position command profile is calculated automatically based on the operator input velocity profile.
- Ejector profiles are controlled either open or closed loop depending on the hydraulic configuration.
- Because the DPQ is a position control device it requires a position feedback transducer. Both 0 to 10 VDC analog and SSI digital types are supported for the injection axis.
- The DPQ includes injection pressure-limiting control that can be configured to work with 1 or 2 pressure transducers or a load cell.
- The injection velocity and pressure profiles may be controlled with one proportional directional type hydraulic flow control valve, or using separate valves for flow and pressure.
- The DPQ includes DeviceNet communications capability that allows access to all parameters directly from a PLC or computer. All sequence triggers are transmitted to the DPQ over DeviceNet.

Motion profile set points are normally transferred into the DPQ from a PLC or computer. The profile set points may also be entered into the card using RSNetworx for DeviceNet or Bosch Rexroth BODAC software.

The DPQ is configured to control injection molding type applications and all parameters are labeled to be recognizable in injection molding applications. There are, however, many other applications that could benefit from the quality of control afforded by the DPQ.

Typical applications include:

- Transfer molding
- Extrusion
- Broaching
- Rubber molding
- Accumulator head blow molding

Software Components

There are 4 Rockwell Automation (RA) software packages that were utilized for this project:

- RSLogix5000 – software package used to program all sequential logic for stepping through the molding process and function block logic for temperature control.
- RSNetworx for DeviceNet – software that lets you configure and monitor devices on DeviceNet networks.
- RSLinx - a 32-bit product that links RA networks and devices to Microsoft Windows applications. These range from device programming and configuration applications such as RSLogix and RSNetWorx, to HMI applications such as RSView32, to your own data acquisition applications using Microsoft Office, Web pages, or Visual Basic.
- RSView 32 – RA HMI package

In addition to these products, Bosch-Rexroth provides their own proprietary Windows-based software (BODAC) for the clamp, inject, and eject hydraulic control of the injection molding process. This software provides another path to get online with the inject and clamp controllers in a quick and easy way through the serial ports located on the faceplate of the hardware.
The software (which can be obtained directly from Bosch-Rexroth Industrial Hydraulics Division) has the following functionality: setup, troubleshooting, upload and download parameters, tuning, parameter monitoring, real time graphing, and module diagnostics.

Ladder Code Setup

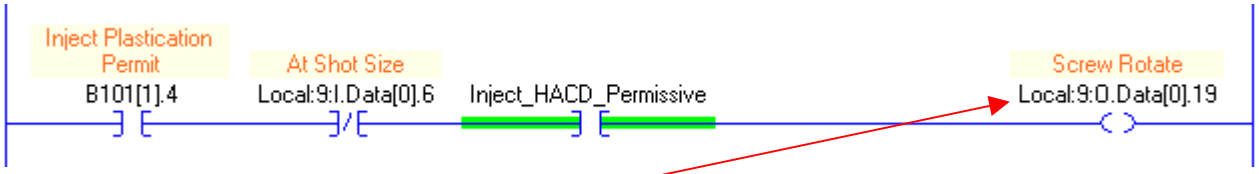
The code that was developed for this application was designed to control the most “standard” injection molding sequences. The code interfaces with the Bosch-Rexroth clamp and inject/eject controllers through DeviceNet triggers and hardwired connections. Additionally, it includes barrel temperature control, machine modes, standard clamp/inject/eject sequences, alarms, etc.
For this specific application, the ladder code was developed in conjunction with clamp and inject/eject sequence charts (provided through Bosch-Rexroth technical manuals for DPQ-2X and DPC-1X) which follow the four main phases of the injection molding process:

- Clamp close – During this phase, the clamping cylinder pushes the moving platen towards the stationery platen
- Inject – During this phase, the injection ram advances to shoot molten plastic into the mold cavity, pressurizes it to fill any voids (pack), and holds that pressure as the part cools; the injection ram (screw) then rotates to reload plastic for the next shot. The screw forces the plastic down the screw flights in front of the screw tip. As this occurs, the ram is forced to retract (Plastication). The distance the ram retracts designates the shot size.
- Clamp open – During this phase, the clamping cylinder pulls the moving platen from the stationery platen to open the mold.
- Eject – During this phase, the ejector plate in the mold advances the ejector pins to eject the part from the mold.

To understand more about how DeviceNet triggers to the inject/eject and clamp hydraulic controllers are utilized to move through the process stages listed above, reference the sequence charts provided in the Bosch-Rexroth documentation for the DPQ-2X and DPC-1X products.

DeviceNet Interface to the Bosch-Rexroth Hydraulic Controllers

Rockwell Automation recognizes the strengths and benefits of DeviceNet as one of our core networks. Because of this, when we initiated a relationship with Bosch-Rexroth in this development effort, we mutually agreed to take their existing hydraulic controller technology and design next generation hydraulic controllers whose communications would be based on DeviceNet. Today, the resulting products (DPC-1X clamp controller and DPQ-2X inject/eject controller) are nearing final compliancy approval from ODVA and are marketed through their Sales and Distribution network with DeviceNet connectivity.
The trigger as discussed in previous sections of this document simply refers to an energized bit that is scanned in the ladder logic and sends a command to the specified DeviceNet target. Let’s look at an example to help you understand this a little better:



In the ladder rung shown above you can see that the OTE instruction is mapped to the output Local:9:O.Data[0].19 and has a description of Screw Rotate. This is a trigger to the DPQ-2X Bosch-Rexroth Inject/Eject controller to instruct the card to rotate the screw for recovery after a shot was fired. This particular DPQ-2X DeviceNet product has 16 bytes of input data and 4 bytes of output data as shown in the following table.

I/O from Bosch-Rexroth Inject Controller

Descriptor	I/O Type	Byte	Bit
Transfer Achieved	input	1	0
Inject Card OK	input	1	1
Ejector Fully Retracted	input	1	2
Select Ejector Retract Position	input	1	3
End of Pressure Profile	input	1	4
End of Decompress	input	1	5
At Shot Size	input	1	6
At Ejector Extend	input	1	7
Inject Card Enable	input	2	0
Inject Cylinder Position Feedack	input	3-6	
System/Injection Pressure	input	7-10	
Ejector Position Feedback	input	11-14	
Active Block in Inject Card	input	15-16	

Descriptor	I/O Type	Byte	Bit
Inject Start	output	1	0
Eject Retract Manual	output	1	6
Manual Post Decompress	output	1	7
Clamp Movement	output	2	8
Eject Extend	output	2	9
Jog Forward	output	3	17
Jog Reverse	output	3	18
Screw Rotate	output	3	19
Pre-Decompress	output	3	22
Post-Decompress	output	3	23
Eject Forward Manual	output	4	25
Eject Retract Manual	output	4	26
Ejector Auto Full retract	output	4	27
Ejector Auto Retract to Tip Stroke	output	4	28
Inject Card Initialize	output	4	31

The same trigger mechanism is applicable to the Bosch-Rexroth clamp controller. As shown in the table below, the Bosch-Rexroth clamp controller supports 12 bytes of input data and 4 bytes of output data, all of which are utilized in the sequencing of the injection molding process.

I/O from Bosch-Rexroth Clamp Controller

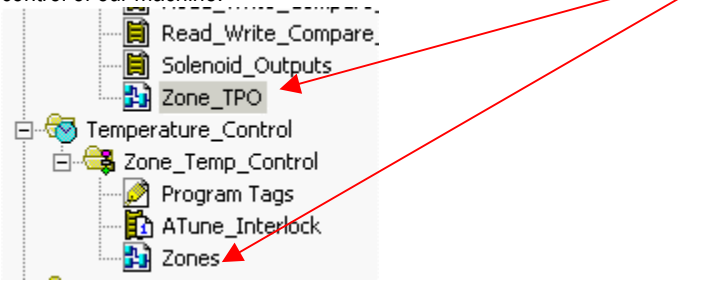
Input Descriptor	I/O Type	Byte	Bit
Transfer Achieved	input	1	0
Clamp Card OK	input	1	1
At Open Position	input	1	3
At Tonnage	input	1	4
At Closing Force	input	1	5
At Decompress Pressure	input	1	6
Clamp Permissive for Ejector	input	1	7
Clamp Card Enable	input	2	0
Clamp Position Feedback	input	3-6	
Clamp Pressure	input	7-10	
Active Block in Clamp	input	11-12	

Input Descriptor	I/O Type	Byte	Bit
Start Close	output	1	0
Decompress	output	1	7
Start Open	output	2	8
Clamp Open	output	3	16
Clamp Close	output	3	17
Clamp Card Initialize	output	4	31

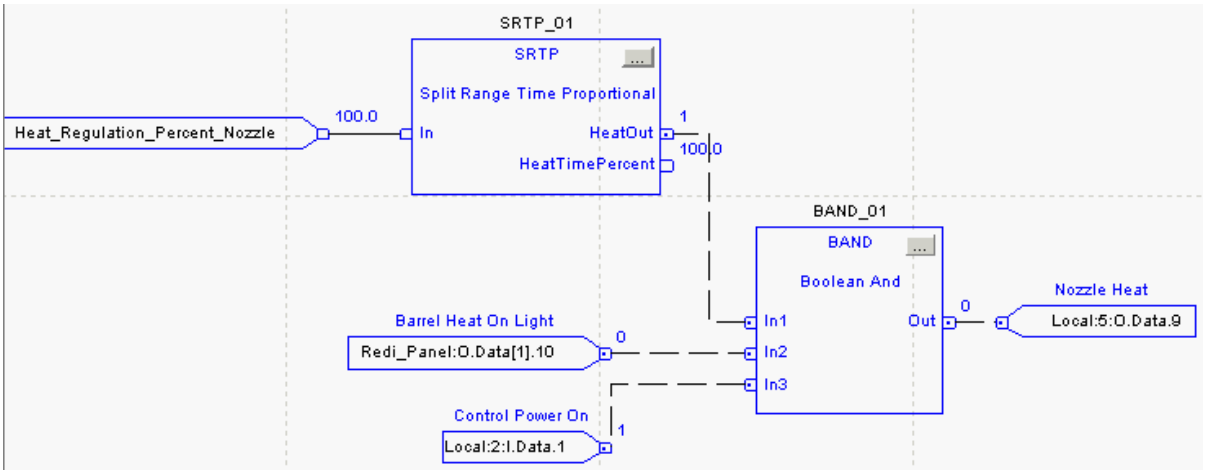
Function Block Setup for Temperature Control

One of the benefits of using the Logix platform as the foundation for this application is the addition of Function Block (FB) programming capability. Along with a discrete output module and 6-channel thermocouple module (1756-IT6I), FB provided the basis for barrel temperature control. For this specific application, heat only zones were utilized, so only 4 outputs were required to drive the heater contactors.

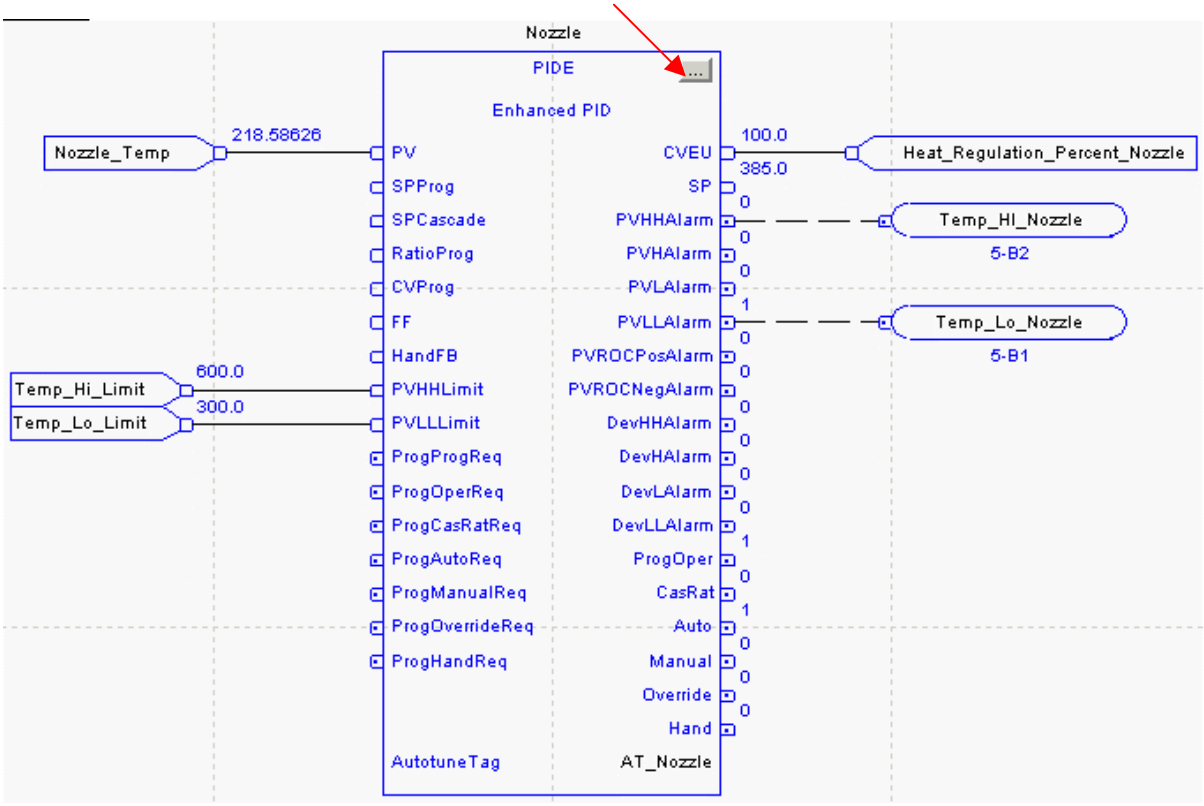
As shown in the Controller Organizer in the example below , there are 2 function block routines that were created for the temperature control of our machine.



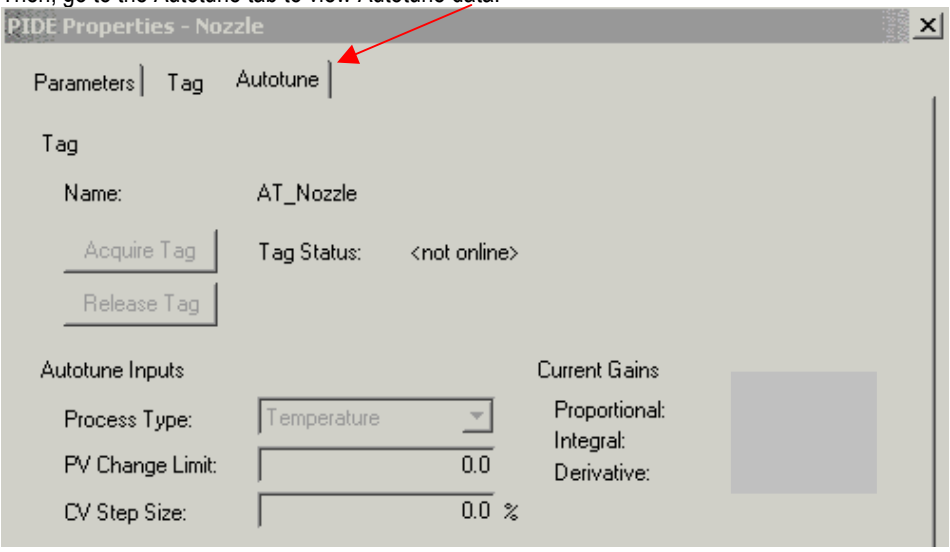
The first (Zone_TPO) is called unconditionally from the MainRoutine. There are 4 sheets in this FB routine (1 for each heating zone of the barrel). The SRTP instruction takes the 0-100% output of a PIDE loop in the Zones FB routine (in the Temperature_Control task) and drives the output contacts via a digital pulse. As shown below in the FBD for the Nozzle heating zone, the contactors are not energized until two additional inputs to a BAND instruction are high as well.



A second FB routine(Zones) is unconditionally called from the Atune_Interlock routine and uses enhanced PID instructions to allow the programmer to set up control, setpoint, and alarming values for each heating zone on the barrel. Additionally, the RSLogix 5000 PIDE provides an open-loop autotuner built into the PIDE instruction. You can autotune from the PanelView terminal or any other operator interface device, as well as RSLogix 5000 software. For this application, the Autotune function has already been performed. To view the PID values for each heating zone, go to the zone-specific sheet in the FB routine and click the ellipsis button on the PIDE instruction.



Then, go to the Autotune tab to view Autotune data.



The application code performs the multi-zone temperature control through function block routines and autotune functions. For a more detailed explanation on how each of these tasks is accomplished, please refer to the following KnowledgeBase Documents located on the www.ab.com website:
A22929290: ControlLogix Multi-zone Temperature Control – Plastics Industry
A20456899: Performing a PIDE Autotune from Logic with the Embedded PIDE Autotune

Summary

To summarize the benefits of the Injection Molding Solution utilizing Logix-based control w/ Bosch-Rexroth hydraulic controllers, let's take a look at how the solution addresses each of the control challenges previously stated in this document:

Control Challenges:

1) Increase overall production speed of the injection molding machine
    - High performance closed-loop velocity and pressure regulation for both the inject and clamp control
    - High response ejector profile with multi-stroke capability

   A comparison to the existing Pro-Set 200 solution shows a marked difference as displayed in the table below:

	Avg. Cycle Time (sec)	*Cycle Time Minimum (sec)*	*Cycle Time Maximum (sec)*	*Cycle Time Standard Deviation*
Pro-Set 200 (SLC-based injection molding control)	42.15	41.59	44.86	0.78
Logix-based Solution w/ Bosch-Rexroth hydraulic controllers	33.17	33.04	33.25	0.05

2) Improve process repeatability and reduce scrap / regrinds
    - High-speed program scan in Logix controller improves control and repeatability
    - Control structure specifically designed for hydraulic axes makes control so repeatable that exact setup of the desired profile is possible without allowance for variation
    - Cutting edge performance of injection and clamp controllers is for both old and new injection molding machines. This performance helps minimize scrap and makes the injection and clamp processes completely repeatable
3) Reduce cost and machine vibration
    - Reduce your hardware investment: the injection/ejection card (DPQ) can control up to 3 proportional valves simultaneously; the clamp card (DPC) can control up to 2 proportional valves simultaneously
    - Eliminate leaks due to hydraulic shock by precisely controlling the hydraulic conditions within the system
    - Eliminate vibration to injection molding machine and any peripherals (such as your HMI) due to smooth transitions in clamp movement, acceleration, deceleration, and breaking functions
4) Increase flexibility and improve efficiency
    - Create a solution that can be used in SLC, PLC-5, and Logix-based injection molding applications
    - Simplify reusing this control strategy when integrating it into larger or smaller injection molding machines
    - Use multi-language support in RSLogix 5000 software for closed-loop temperature control of the injection molding barrel
    - Use of the ControlLogix backplane as a bridge device allows easy access to all control and configuration parameters via on-board DeviceNet communications on both clamp and inject/eject controllers without loading the Logix controller with extensive explicit messaging in ladder code
    - Use off-the-shelf controllers, I/O, and communications products and customize to your application specifications
    - Use off-the-shelf front-end HMI products and customize to your application specifications
    - Simplify recipe changes by utilizing extensions to standard HMI products
    - Configuration options on injection/ejection controller to support any type of proportionally controlled hydraulic circuit including one or two valve injection circuits
    - Configuration options on clamp controller to support any hydraulic circuit that uses directional type of proportional control valve
5) Improve overall process control
    - Setup in both clamp and injection/ejection controllers allow enough profile options for total control of the most demanding application
    - True differential force control in the clamp allows the lowest possible mold protect force without affecting the velocity setting
    - Complete closed-loop multi-step open and close profiles for clamp velocity
    - Position-dependent braking allows repeatable, fast, and smooth deceleration of toggle or hydraulic clamps
    - Multiple options for part ejector profile, mold fill, hold pressure, and recovery pressure

Final Thoughts:
The ease of development for an injection molding application has been greatly improved by using the Logix-based programming environment and hardware in conjunction with Bosch-Rexroth Inject/Eject and Clamp Hydraulic controllers. From setting up the hardware, to sequencing the machine processes, to controlling the barrel temperature, to configuring and integrating the Bosch-Rexroth controllers, the use of software and hardware components from Rockwell Automation, a world-class provider of industrial networks and control systems, and Bosch-Rexroth, a world-class provider of hydraulic control technology provides the molding machine OEMs, integrators, and end user with a world-class injection molding solution that utilizes standard, off-the-shelf hardware and software products.

Appendix A: Major Differences in Logix, PLC-5 and SLC Solutions
The following table provides a comparison of many of the major differences in the Rockwell Automation hardware and software offerings for an injection molding solution:

	ProSet200	ProSet700	Logix
Motion or process Loop Closure location	SLC processor	I/O controller card (QDC)	Bosch-Rexroth Hydraulic Controller Cards
Platform	SLC	PLC-5	All Logix, PLC-5, MicroLogix, and SLC with DNet Comms
Loop Closure time	10 msec	2 msec	2 msec or less
Temperature Control	1746-BTM	1771-TCM	Any Logix standard T/C input
HMI platform	PanelView, RSView	ControlView	Any View solution
Integrated loop and discrete I/O	yes	no	yes
Processor scan time dependant loop closure	yes	no	no
Flash memory setup and parameters	no	no	yes
Actuals Available	yes	yes	must calculate

Appendix B: Application Example and Results
The following is a table displaying the operating parameters of a 700-ton injection molding machine before and after converting to Rockwell hardware in conjunction with the Bosch-Rexroth hydraulic controllers. This information was provided by JVH Engineering, a Rockwell Automation System Solution Provider.
Notes: The Decompression Repeatability measurement spec is dependent upon barrel size and the following information:

- This barrel had a shot capacity of 165 oz. and 10.31cc/mm of stroke
- This measurement was taken at 75% decompress speed

Characteristic	700-Ton Before Rebuild	World-Class Machine	700-Ton After Rebuild
Hydraulic Response (sec/1000 psi)	Failed - Pressure never settled	0.200	0.145
Speed Linearity	28.28%	10.00%	8.41%
Load Compensation (%kpsi)	88.10	<3	0.610
Clamp Repeatability (mm) (Clamp Speed Control)	7.188	2.540	1.676
3 Stage Capability (Velocity Pack, Cavity Pressure Transfer)	Not capable	Capable	Capable
Ejector Repeatability (mm)	1.78	2.54	0.254
* Decompression Repeatability (cc)	Not repeatable	<25cc	9.940
Injection Speed (cc/sec)	700	n/a	900

Important User Information

Solid state equipment has operational characteristics differing from those of electromechanical equipment. Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls (Publication SGI-1.1 available from your local Rockwell Automation sales office or online at http://www.ab.com/manuals/gi) describes some important differences between solid state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.

In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this document are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

No patent liability is assumed by Rockwell Automation, Inc. with respect to use of information, circuits, equipment, or software described in this document.

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