Fundamentals of DDC

Application Requirements

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Objectives

- Understand the process for writing control sequences
- Describe the components of an HVAC application as they relate to DDC systems.
- Describe the 7 step approach to defining process control requirements.

Application Requirements

- Importance of Design
  - There is a lot of variance in both the hardware and software offerings of the DDC industry.
  - Decisions made by a controls contractor at the installation phase will most likely focus on their profitability rather than the underlying quality of what is being delivered.
  - Critical factors must be defined up front as part of the design process.

Importance of Design

- The type of controller is important.
  - Primary/secondary
- One controller or multiple controllers
  - Do not rely excessively on network data
- Network traffic in support of applications
  - What data does a particular application require?
  - Is the data sourced in the controller where the application resides?
  - If the data is sourced elsewhere, what are the network traffic issues?

Importance of Design

- Once we have the architecture defined and each aspect of control is assigned to specific devices within the architecture we can move to the steps involved in specifying the specifics of the applications.
- Controller/Network Components
  - Process controllers
  - Supervisory logic controllers
  - Application specific controllers
  - Network controllers

Importance of Design

- As we look at the control logic for a complete system, it can be broken into multiple elements.
  - Process level control
  - Supervisory logic control
  - Time based control
  - Alarm handling
  - Data collection
  - Dynamic data reporting to the operators
  - Operator adjustable parameters

Importance of Design

- Process level control is the instantaneous measurement of process variables, execution of basic logic and delivery of commands to end devices.
  - Sensors are required
  - End devices are required
  - There is control logic between the process variable and the end device
  - We have a well defined process for defining process control

Importance of Design

- Supervisory Logic Control is similar to process control.
  - Inputs can be one or more pieces of data from one or more controllers
  - Outputs are commands to process control loops
  - The is logic between the inputs and outputs
- In many cases supervisory logic control is accomplished in a separate device and not the process controller…but not necessarily.

Importance of Design

- Time Based Control
  - Time Schedules
  - Binary commands (occupied, unoccupied; off, on; etc.)
  - Hierarchal relationships
- May reside in the process controller, the supervisory logic controller or a network controller.

Importance of Design

- Alarm Handling: A three part process
  - Creation of a binary alarm indicator within control logic
  - Attachment of a text message
  - Dispatch of the text message to one or more operator work stations
- All three parts can be accomplished in one device or divided between multiple devices.
  - Process controller generates the binary indicator
  - A SLC attaches the message and dispatches it to the operator work stations.

Importance of Design

- Dynamic Data Reporting
  - A very important value of DDC systems is the ability to see what is going on from the operator work stations.
  - With single vendor systems, the issue of specifying what data is visible at the OWS is not as critical as when you are attempting to glue together a multi-vendor system.
  - To be safe, you should identify what variables, both external and internal that must be presented.

Importance of Design

- Operator Adjustable Parameters
  - Within any application it may be necessary to periodically adjust a parameter within the application
  - Reset schedule values, timing parameters, calibration offsets, tuning parameters, etc.
  - It is also important for the operator to be able to execute manual control of output points and manual overrides of physical sensor values or states.
- Your specification/sequence of control should define these requirements.

The Design Process-Process Control

- The process of developing the control logic for an HVAC system consists of several sequential steps.
  - Identify the devices to be controlled within each system
  - Select the process variable for each process
  - Define the relationship between the process variable and the controlled device
  - Identify all parameters required for the relationship
  - Define the logic required to produce the parameters
  - Determine limits/conditions which apply to each process
  - Define the logic for these limits/conditions

Process Control Getting Organized

- Identify the devices to be controlled within each system
- An air handling unit may consist of:
  - Fan start stop
  - Fan VSD
  - Mixed air dampers
  - Cooling coil
  - Heating coil
- For each controlled device follow the steps described next.

Process Control Step 1

- Document the type of controlled device and the nature of the control signal required.
  - Fan Start Stop: Starter Circuit, DO Point
  - Mixed Air Damper: 0 to 10 VDC, AO
  - VSD: 0 to 10 VDC, AO

Process Control Step 2

- Select the process variable
- Define the characteristics of the measurement device
- Examples
  - Fan Start Stop: Pv = Time, Internal Time Clock
  - Mixed Air Damper: Pv = Mixed Air Temperature, 10KOhm Thermistor
  - Fan VSD: Pv = Static Pressure, 0 to 2 in, 4 to 20 ma

Process Control Step 3

- Define the relationship between the process variable and the controlled device.
  - Device tracking: When another device is on, this device is on
  - Basic mathematical relationship
    - Lots of choices here
  - Control Loop Response
    - Two Position Control
    - Floating Control
    - P, PI or PID
  - Time Schedule

Process Control Step 4

- Define all of the parameters required by the relationship identified in step 3.
- For each parameter specify whether the value is fixed, fixed but adjustable from the OWS, or variable.
- If the parameter is variable specify if the value is determined by:
  - Secondary control logic within the process controller or,
  - A command from supervisory logic in another controller.

Process Control Step 5

- Define the secondary control logic required to produce the parameters defined in step 4.
- Define the measured variables that are the input to the secondary control logic
- Define the relationship between the measured variables and the output parameter.
- Repeat for each parameter

Process Control Step 6

- Determine limits/conditions which apply
- The term condition generally describes a test which must be conducted within the control strategy before an event can take place:
  - Hot water pump must be on before the fan is started
  - System must be in the occupied mode
  - Evaporator fan must be on before starting the condensing unit
- These discrete conditions may require secondary logic to generate it.
- Additional measured variables may be involved.

Process Control Step 6

- Determine analog limits/conditions which apply
- The term limits refers to process decisions which are based on a certain value (or set point) of a continuous variable such as temperature or pressure. For example:
  - Outdoor air temperature greater than 68F, change to minimum position
  - If the water temperature is greater than 215F, turn off the burner
  - If the discharge air humidity rises to 85%, begin closing the steam valve
- The analog limit may require secondary control logic to generate it.
- Additional measured variables may be involved.

Process Control Step 7

- Describe the secondary control logic for each discrete condition that requires logic.

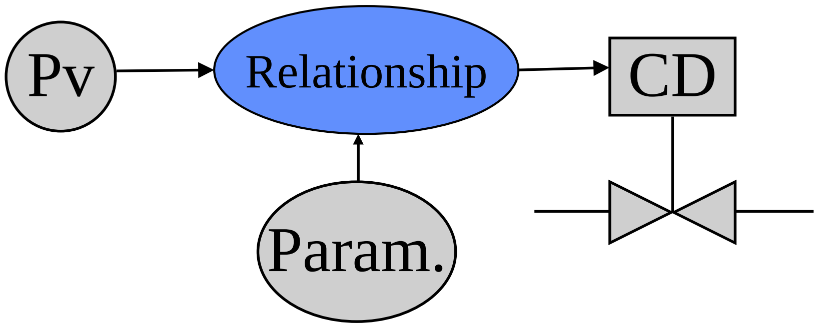
Process Control Comments

- If you have done a good job of identifying discrete conditions, analog limits and parameters the control of the process should be well coordinated with the control of the other processes.
- Example: Do not open the hot water valve unless the fan is on. This condition establishes communication between the fan control process and the hot water coil valve process.
- Example: The mixed air set point shall be two degrees less than the set point for the cooling coil control. This establishes a relationship between the cooling coil process and the mixed air process.

Process Control Comments

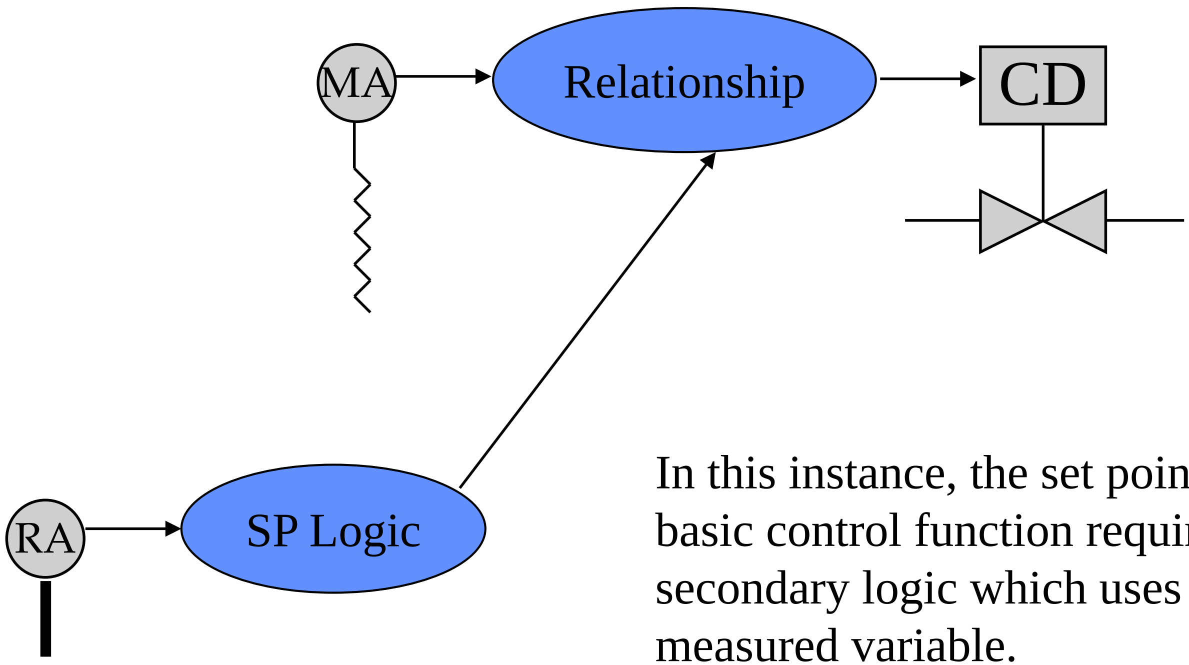
- After you have developed several process control logic diagrams following the previously described steps you should have a better level of appreciation for the detail required in the sequence of control
- In is not unusual to rewrite a process control sequence two or three times (or more) as the logic diagrams are being built.

Basic Control Loop (DDC)



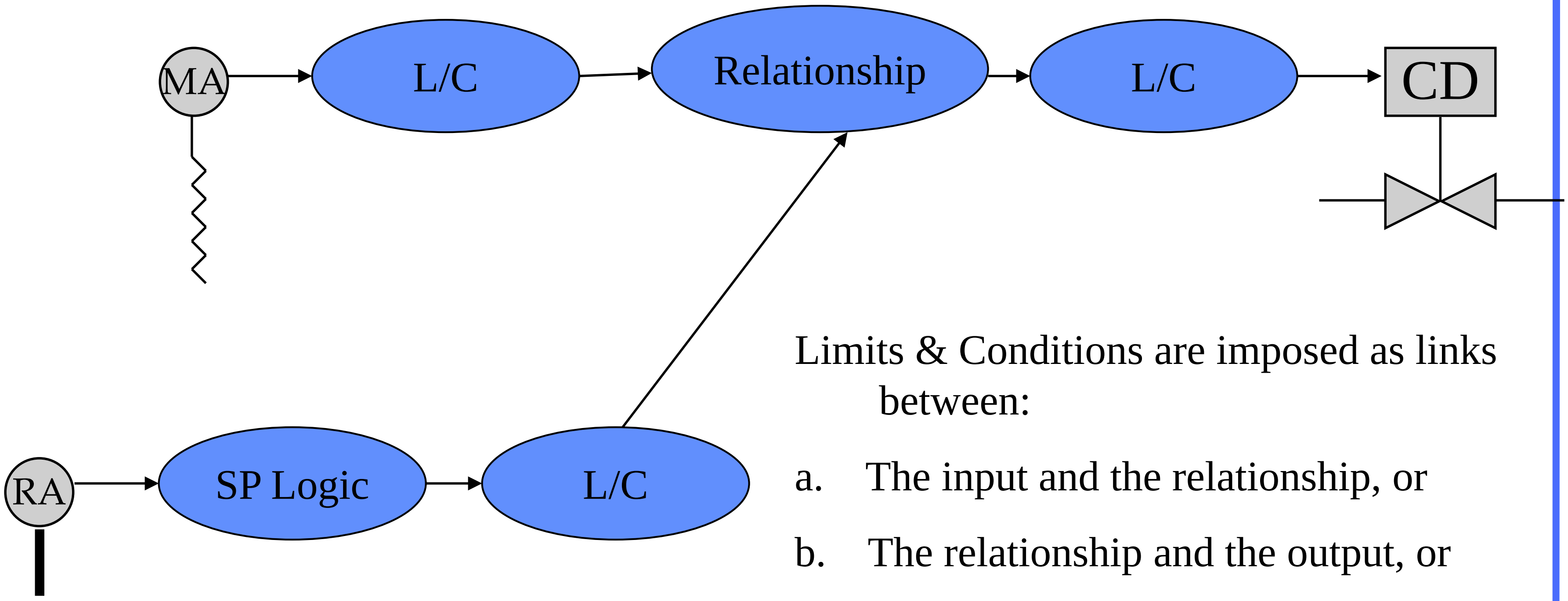
A basic control loop will consist of a sensor, a single “link” that holds the control loop relationship function, parameters and a controlled device.

Secondary Logic - SP



In this instance, the set point for the basic control function requires secondary logic which uses another measured variable.

Adding the Limits & Conditions



Limits & Conditions are imposed as links between:

a. The input and the relationship, or

b. The relationship and the output, or

c. The SP logic and the relationship.

Writing a Good Sequence for Process Control

- Describe the Basic Control Process
  - Clearly identify the controlled device
  - Identify the process variable
  - Define the relationship
  - Define all parameters, fixed and variable
  - For the variable parameters define how they are created, secondary control logic or supervisory control logic.

Writing a Good Sequence for Process Control

- Describe the Limits and Conditions
  - Include all safeties
  - Specify software versus hard-wired interlocks
  - For switching based on temperature crossing, include differential

The Design Process-SLC

- Supervisory Logic Control
  - Identify the location of the SLC within the architecture
  - List the input variables to the supervisory logic
  - Identify the source of the input variables
  - Define the output of the supervisory logic
    - Static Pressure Set Point
    - Discharge Air Set Point
  - Describe the mathematical relationship between the input variables and the output variable.
  - Identify the recipient of the output variable.

The Design Process-Alarm Handling

- Alarms can be information only for the operators or they can serve as discrete conditions to process control.
- The alarm criteria must be defined for each alarm.
  - A Mixed Air Temperature less than 42 F (adj) shall generate an alarm message.
- The reset characteristics should be defined
  - Self correcting on a change in the measured criteria
  - Latching with operator reset
  - Latching with control logic reset

The Design Process-Alarm Handling

- In larger systems with multiple operator work stations, it may be necessary to define the “where and when” of alarm dispatch.
- “All Central Plant Alarms shall be dispatched to the OWS in the Central Plant and to the central OWS”.
- “All Occupied Space Alarms shall be dispatched to the OWS in the HVAC Maintenance Office and the central OWS”.

The Design Process-Dynamic Data Reporting

- When programming, the application programmer has the opportunity to “expose” both external and internal points such that they are visible at the OWS.
- External points typically are set to be visible.
- Internal points may or may not be.
- In your specification define (rpt) as “value shall be visible at the OWS”
- As you refer to a variable in your sequence add the (rpt) after you name the variable.
- ….the VFD Start Up Mode (rpt) ….

The Design Process-Adjustable Parameters

- Application
  - Application parameters such as set points, timing parameters, calibration offsets, tuning parameters, etc.
  - Manual control of external output points
  - Override of external input points
- Application Parameters
  - In your specification define (adj) in your definition of terms section as “the operator shall be able to adjust the fixed value of the parameter without downloading the program to the controller”
  - As you write your process control sequences, amend each variable with (adj) if you wish for the parameter to be adjustable.

The Design Process-Adjustable Parameters

- **Manual Control of External Output Points**
  - **The concept of manual control of external output points should be defined in your definition of terms section. It is the ability of the operator to interrupt the flow of a command from logic to the external point and to force the state or value of the external point to a specific state or value.**
  - **In the requirements section of your specification it should be stated that the operator shall be able to execute manual control of all external output points.**

The Design Process-Adjustable Parameters

- Manual Control of External Input Points
  - The concept of manual control of external input points should be defined in your definition of terms section. This is sometimes referred to as “Test Mode”. It is the ability of the operator to interrupt the flow of data from the external sensor to the control logic and to force the state or value used by control logic to a specific state or value.
  - In the requirements section of your specification it should be stated that the operator shall be able to execute manual control or test mode of all external input points.

Presentation of Design

- **A written sequence of control is the most common methodology for presenting a system design.**
  - **Most common problems are organization and a lack of detail which is subsequently left to the controls contractor.**
  - **Detail can be added which makes the written sequence of control more complete but the typical consultant does not have the expertise to define the detail.**
  - **Organization by system and then the processes within the system provides the best possible clarity.**
  - **Supervisory logic for each system can be separately defined.**

Presentation of Design

- Control Logic diagrams can be used in concert with a simplified sequence of control.
- The logic diagrams will serve to present a great deal of the detail.
- The logic diagrams will also eliminate confusion due to the lack of standard terminology within the controls industry.
- Control logic diagrams represent the most complete form of communicating a controls design.

Conclusion

- Building the control logic for a system is accomplished on a process by process basis.
- Large systems just have more processes.
- The quality of the final control system performance will depend on the thoroughness of your sequence of control.
  - The correct Pv and the proper relationship for the physical environment
  - Inclusion of all appropriate limits & conditions
  - Appropriate modifications for different modes

Example Drawing with Logic