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Procidia Control Solutions
SAMA Diagrams for Boiler Controls

Functional control diagrams for the power industry are often referred to as SAMA[1] diagrams. Based on symbols and diagramming conventions developed by the Scientific Apparatus Makers Association, SAMA diagrams are used to describe and document control strategies and systems designed for industrial and utility boiler applications. Although similar in concept to ISA diagrams, there are significant differences between the two methods of diagramming control systems. Figure 1 shows an ISA diagram and a SAMA diagram for a simple flow control loop. The differing symbology will be discussed later.

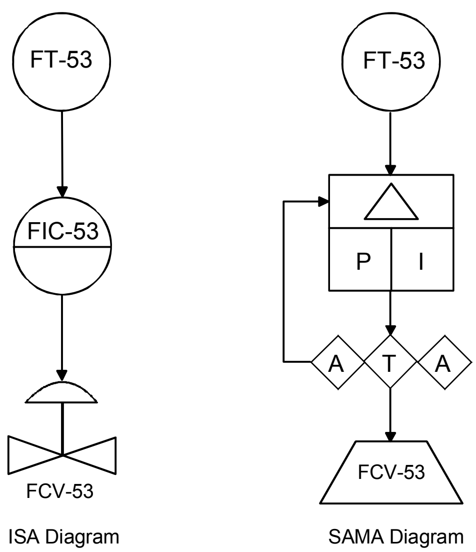


Figure 1 ISA vs. SAMA Diagrams

Although SAMA Standard PMC 22.1-1981 Functional Diagramming of Instrument and Control Systems is no longer supported by SAMA or any other standardization committee, it is anticipated that the symbols and conventions contained in this standard will continue to be used into the foreseeable future. The purpose of this publication is to describe the basic terminology and symbols.

Since SAMA diagrams appear in Siemens 353 Application Data sheets relating to boiler control applications, a general understanding of the diagrams is helpful to effectively use the provided information.

SAMA diagrams represent the language of choice throughout the power industry for instrumentation and control systems. This publication illustrates and explains the following types of symbols, including variations, and provides application examples.

- Enclosure symbols
- Signal continuation symbols
- Signal processing symbols

STANDARD SYMBOLS

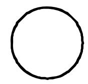
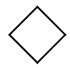
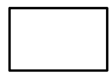
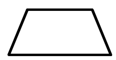
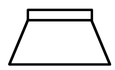
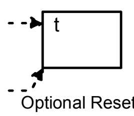
Figure 1 shows a simple flow control loop using both ISA and SAMA diagrams. Only the symbol for the flow transmitter (FT-xxx) is identical in both cases. The ISA diagram shows only a symbolic representation of the flow indicating controller (FIC-xxx). The SAMA diagram provides a more detailed block diagram of the proportional plus integral (PI) controller with setpoint and manual adjustments and auto/manual transfer switch. The SAMA and ISA versions also use different symbols to represent the flow control valve (FCV-xxx).

A SAMA diagram uses various types of enclosure symbols to represent the various elements or functions of the control system, see Table 1. Enclosure symbols are tied together by continuation symbols, see Table 2. Table 3 shows the many signal processing symbols used to describe the functions within each enclosure.

The use of most symbols will be fairly obvious after reading a few SAMA diagrams. It is important to realize, however, that very few designers adhere strictly to the SAMA standard, and it is not uncommon to see slight variations in the symbols shown here.

[1] Scientific Apparatus Makers Association

Table 1 Enclosure Symbols

Function	Symbol
Measuring or Readout	
Manual Signal Processing	
Automatic Signal Processing	
Final Controlling	
Final Controlling with Positioner	
Time Delay or Pulse Duration	

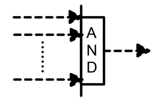
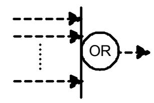
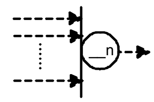
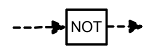
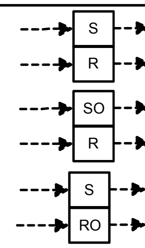
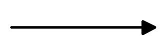
Function	Symbol
Logical **AND**	
Logical **OR**	
Qualified Logical **OR**	
Logical **NOT**	
Maintained Memory	

Table 2 Processed Signal Continuation Symbols

Signal	Symbol
Continuously Variable Signal	
Incremental Change or Rate of Change of a Continuously Variable Signal	
On-Off Signal *	

* The on-off signal symbol may be a solid line if on a separate digital logic diagram or if on an inset detail on a functional diagram.

Table 3 Signal Processing Symbols

Function	Symbol
Summing	Σ or +
Averaging	Σ / n
Difference	Δ or -
Proportional	K or P
Integral	∫ or |
Derivative	d/dt or D
Multiplying	X
Dividing	÷
Root Extraction	$\sqrt[n]{\ }$
Exponential	X^n
Non-Linear Function	f(x)
Tri-State Signal (Raise, Hold, Lower)	↕
Integrate or Totalize	Q
High Selecting	>
Low Selecting	<
High Limiting	≯
Low Limiting	≮
Reverse Proportional	-K or -P
Velocity Limiting	V ≯
Bias	+/-
Time Function	f(t)
Variable Sig. Gen.	A
Transfer	T
Signal Monitor	H/, H/L, /L

Function		Symbol
Logical Sig. Gen.		B
Logical AND		AND
Logical OR		OR
Qualified Logical OR n= integer	> n	GTn
	< n	LTn
	= n	EQn
Logical NOT		NOT
Set Memory		S, SO
Reset Memory		R, RO
Pulse Duration		PD
Pulse Dur. Lesser Time		LT
Time Delay on Initiation		DI or GT
Time Delay on Termination		DT
Input/ Output Signal Converter Examples: D/A I/P	Analog	A
	Digital	D
	Voltage	E
	Frequency	F
	Hydraulic	H
	Current	I
	Electromag or Sonic	O
	Pneumatic	P
	Resistance	R

SYMBOL VARIATIONS

PID Controller

The control function underlying most loops is the PID controller. PID stands for Proportional plus Integral plus Derivative control algorithm. Figure 2 shows four variations of the symbols used to describe this algorithm in SAMA diagrams.

The PID controller generally has two inputs representing the process variable (PV) to be controlled and the setpoint (SP) value at which it is desired to maintain the PV. The controller calculates the difference (Δ), or control error, between the two signals and generates an output to drive the PV to SP. Depending on the number of control modes specified, the controller output is proportional (P) to the magnitude of the error, the integral (I) of the error, the derivative (D) of the error, or various combinations of these three functions.

Figure 2A shows the classic SAMA symbol for a PID controller using the standard mathematical symbols for these functions. The rectangular enclosures indicate that these signals and functions are processed automatically. Figure 2B simply substitutes P, I, and D for the standard mathematical symbols. Figure 2C simplifies the drawing of the symbol by combining the P, I, and D functions within a single rectangle.

Figure 2D shows the actual structure of the standard Siemens 353 implementation of the PID algorithm. In this form, the derivative mode is a function of a change in the process variable instead of a change in the control error. This avoids a derivative "kick" on changes in setpoint. In most cases, however, it is not necessary to make this distinction when drawing a SAMA diagram.

Single Loop Control

The fundamental single loop control diagram includes a process measurement, a PID controller with adjustable setpoint and auto/manual transfer, and a final control element such as a control valve or drive mechanism. Figure 3 shows three variations of the collection of symbols used to describe single loop control on SAMA diagrams.

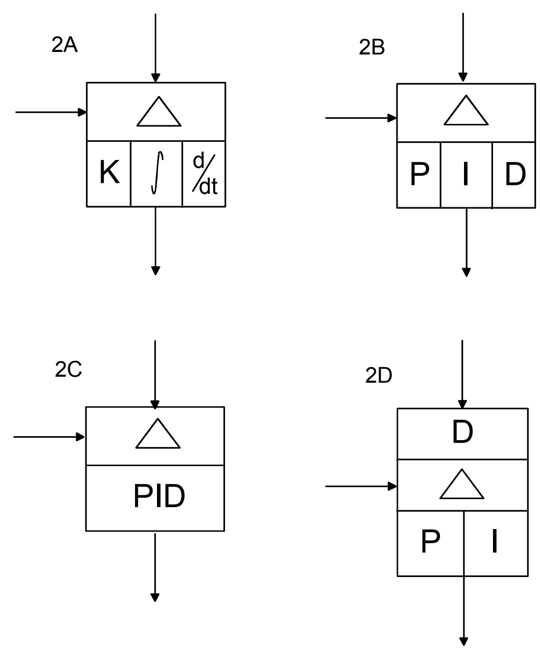


Figure 2 PID Controller Symbol Variations

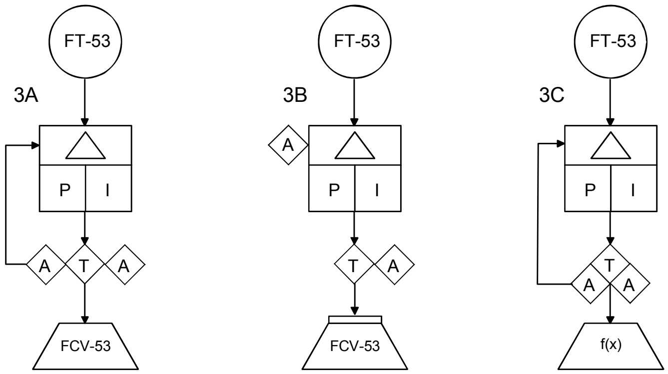


Figure 3 Single Loop Control Variations

Figure 3A shows a classic SAMA diagram for single loop control using the PI controller. The three diamonds ganged together represent the adjustable setpoint (left A), the adjustable manual output (right A), and the auto/manual transfer switch (T). The diamond shaped enclosures indicate that these are all manual functions performed by the operator. The location of these functions on the diagram is probably symbolic of the equipment designs in use when the standard was originally developed. These adjustments were typically provided by separate components mounted within the control station.

Figure 3B simply relocates the setpoint adjustment directly on the symbol for the PI controller. It also shows the FCV equipped with a valve positioner. It should be noted, however, that many diagrams omit the positioner symbol for simplicity, and the drawing should not be considered as the final authority regarding the presence or absence of a valve positioner.

Figure 3C shows another variation of the classic arrangement of the three diamonds. Note the non-linear function symbol [f(x)] instead of FCV. This may be used to represent an inherently non-linear valve characteristic (e.g. equal percentage), or it may represent the use of a positioner that includes a characterizer function (even though the positioner symbol is not shown). Also be aware that some SAMA diagrams routinely show the f(x) symbol on all final control elements without regard for the actual characteristics of the valve or positioner.

Equipment Detail

SAMA diagrams are used to describe the functional elements of a control strategy. The symbols are generic and are not specific to the control hardware manufactured by any particular vendor. There are instances, however, when it may be necessary to show equipment details to fully document the control strategy. Figure 4 shows two variations of the single loop control diagram showing equipment details. In general, this level of detail should be avoided since it obscures the basic control strategy and makes the diagram less generic.

Figure 4A shows one of the single loop variations with the addition of three separate indicators for monitoring and manipulating the loop. The indicators are shown as circular enclosure symbols with the ISA indicator symbol (I). They display the three key variables of the control loop (process, setpoint, and valve). The operator needs to see these variables to determine the state of the control loop. In addition, the operator must be able to see the value of the setpoint and the valve loading to adjust these variables in auto and manual modes, respectively. Since it is standard practice to provide these readouts on every control loop, it is generally not necessary to show them explicitly on the SAMA diagram.

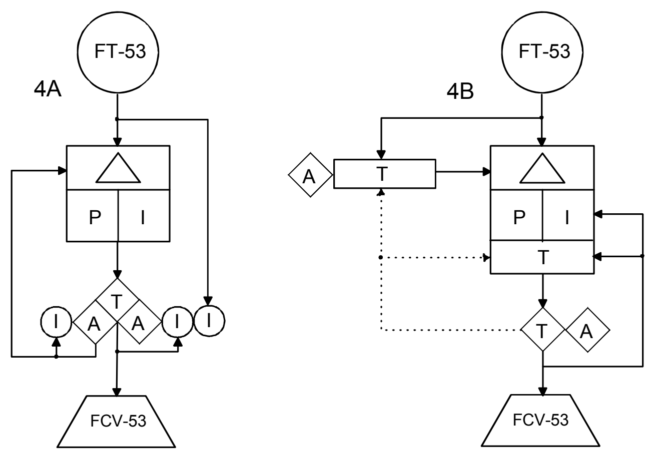


Figure 4 Equipment Detail Variations

Figure 4B shows additional automatic signal processing functions to describe equipment details. The transfer blocks on the setpoint signal and controller output are used to describe setpoint and controller tracking. The rectangular transfer symbols switch automatically based on the state of the discrete input signal represented by the dotted line. This discrete signal indicates the position of the manually operated auto/manual transfer switch. In the manual mode, the setpoint tracks the process variable, and the controller tracks the manually adjusted valve loading signal. This prepares the controller for bumpless transfer back to auto and aligns the setpoint with the present value of the PV.

Another equipment detail shows reset feedback from the valve signal to drive the integral action of the PI controller. These are control hardware implementation details that are not usually needed to convey the overall control strategy. They should be shown only as necessary in the judgment of the designer or end user.

EXAMPLES

Three-Element Drum Level Control

A common application in boiler control is three-element drum level control. Boiler drum level is a critical variable in the safe operation of a boiler. Low drum level risks uncovering the boiler tubes and exposing them to heat stress and damage. High drum level risks water carryover into the steam header and exposing steam turbines to corrosion and damage. The level control problem is complicated by inverse response transients known as shrink and swell.

Figure 5 is a SAMA diagram of the cascade plus feedforward control strategy that is normally used to solve these control problems. See AD353-128 Cascade Control and AD353-129 Feedforward Control for more information on these topics.

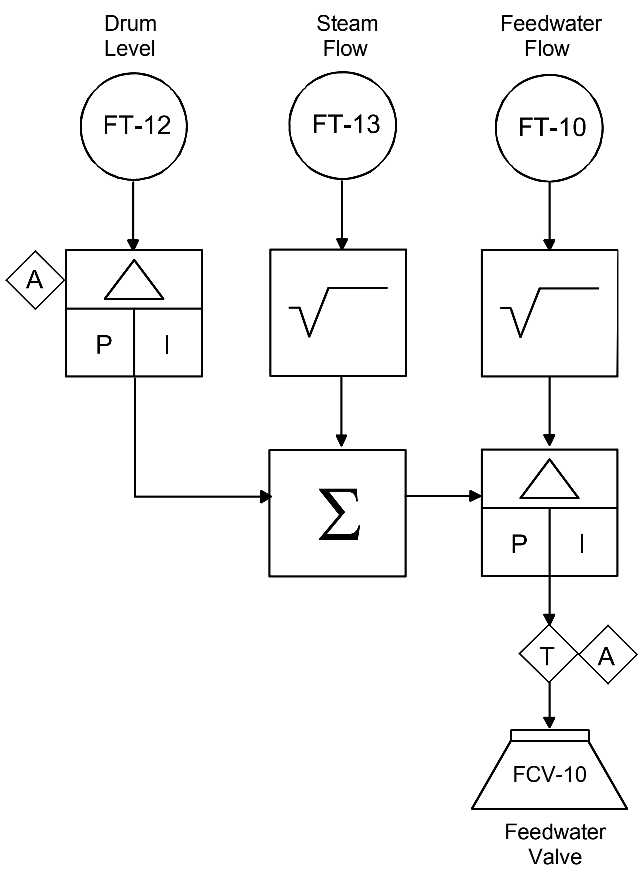


Figure 5 Three-Element Drum Level Control

The three transmitters (FT-10, 12, and 13) are the three elements referred to in the name of the control strategy. Each produces an output signal known as a "process variable." The feedwater flow setpoint is set automatically by the steam flow signal to keep the feedwater supply in balance with the steam demand; this is the feedwater component of the control strategy. The drum level controller trims the feedwater flow setpoint to compensate for errors in the flow measurements or any other unmeasured load disturbances (e.g. blowdown) that may affect the drum level; this is the cascade component of the control strategy. The summing function is used to combine these two components.

The square root functions on the flow transmitters linearize the relationship between flow and differential pressure in head-type flowmeters.

Logic Diagram

To avoid damage to equipment and injury to personnel, boiler control systems include safety systems for combustion control and burner management. These systems provide permissives and interlocks to ensure safe operating conditions and to shutdown or "trip" the unit if safe operating conditions are not maintained.

Figure 6 shows a typical logic diagram for a small portion of the safety system. This diagram shows the derivation of a boiler trip command signal and alarm indicators. These are based on a high or low drum level and power failures in the combustion control system (CCS) or burner management system (BMS). For fail-safe operation, the drum level and power switches (LSH, LSL, JS) are the ON for safe conditions and OFF for trip conditions. The NOT functions reverse the logic to accommodate the input convention.

Time delay functions on the drum level switch signals prevent nuisance trips due to brief violations of the level limits that may be caused by noise or transient behavior. As indicated in Table 1, these symbols require a time setting "t" and a two-letter designator for the function type (e.g. PD, DI, DT, etc.). DI stands for "Delay On Initiation"; in this example, the delay time is set for 20 seconds. The input signal must stay ON for at least 20 seconds before the output signal will turn ON.

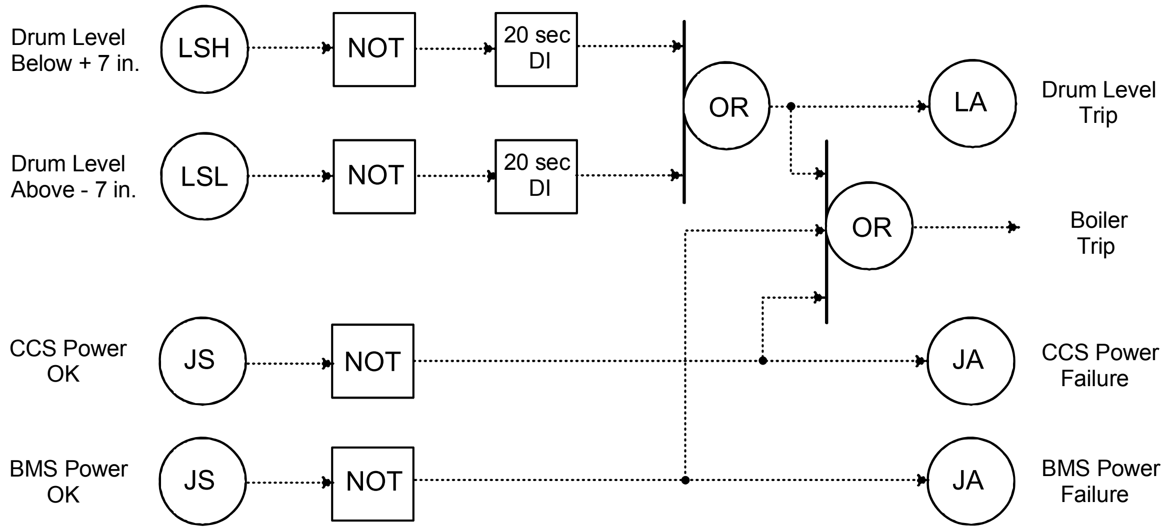


Figure 6 Typical Logic Diagram

One OR function provides a common alarm and trip signal for high and low drum level conditions. The other OR function provides a common boiler trip signal for a level trip, a CCS power failure, or a BMS power failure. This example uses dotted lines to designate discrete logic signals. However, it is also acceptable to use solid lines when the logic diagram is separate from the continuous control diagram.

APPLICATIONS

SAMA diagrams are generally used to describe boiler control systems for the power industry. Although there is no reason they cannot be used to describe control systems in other industries, convention dictates that ISA diagrams are used in those industries. A control engineer should be conversant with both methods of diagramming control systems.

Although SAMA and ISA diagrams document a control strategy, they cannot fully document the actual configuration of the process controller. The Siemens i|config™ Graphical Configuration Utility fully documents the actual configuration of the 353 controller. A large library of standard function blocks are used for both continuous variable and "On-Off" variable designs. Logic blocks are similar to those shown in Figure 6. Logic circuits can also be designed with i|config using the conventional "ladder logic" approach.

Application Support

User manuals for controllers and transmitters, addresses of Siemens sales representatives, and more application data sheets can be found at www.usa.siemens.com/ia. To reach the process controller page, click **Process Instrumentation** and then **Process Controllers and Recorders**. To select the type of assistance desired, click **Support** (in the right-hand column). See AD353-138 for a list of Application Data sheets.