Technical Information

YS150, YS170 Single-Loop Controller Control Functions Manual

YS100 SERIES

CONTENTS

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Applicable Products:

- **YS100 SERIES Controllers**
  Models : YS150 Multifunction Single-Loop Controller
  YS170 Programmable Single-Loop Controller
  January, 1992

Revision History:

Date	Edition	Contents	Applicable Model
December, 1991	First Edition	New Publication	YS150-□0□ YS170-□0□
July, 1992	2nd Edition	Appendixes were added. The description of supervisory communication function was moved to separate volume (TI 1B7C8-03E).	YS150-□0□ YS170-□0□
November, 1994	3rd Edition	Items on enhanced functions added.	YS150-□0□ YS170-□0□
July, 1995	4th Edition	Layout alteration, Appendix removed	The models above and YS150-□1□ YS170-□1□
Feb, 1997	5th Edition	Items on enhanced functions added.	The same as above

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Table 0.1 YS100 Series Document Map

Document Class	Document No.	Title	Usage (◎: Essential, ○: For Reference)				
			Progra-mming for YS170	Engineering for Function Selections and Parameter Settings	Tuning	Normal Operation	Installation and Maintenance
Technical Information	TI 1B7A1 - 01E	YS100 SERIES Information	○	○		○	
	TI 1B7C0 - 01E Note 2	YS100 SERIES Intelligent Self-tuning Controllers			◎		◎
	TI 1B7C1 - 01E	YS150, YS170 Single-loop Controller Control Functions	◎	◎	◎	◎	
	TI 1B7C2 - 03E Note 3	YS170 Programmable Functions	◎		○		
	TI 1B7C8 - 03E Note 1	YS100 SERIES Communication Functions		◎		◎	
	TI 1B7C8 - 04E Note 5	YS-net Peer-to-peer Communication Functions		◎			
	TI 1B7C8 - 05E Note 5	YS-net Personal Computer Communication Functions		◎		◎	
Instruction Manual	IM 1B7C1 - 01E	YS150 Single-loop Multi-function Controller YS170 Single-loop Programmable Controller	○	◎	◎	◎	◎
	IM 1B7C8 - 01E	YSS10 YS100 SERIES Programmaing Package	◎				
	IM 1B7C8 - 03E Note 1	YS100 SERIES RS-485 Communication Function (/A31) DCS-LCS Communication Function (/A32)		◎		◎	◎
	IM 1B7C8 - 04E Note 5	YSS50 YS-net Parameter Definition File		◎			◎
	IM 1B7D2 - 01E	YS131 Indicator with Alarm		◎	◎	◎	◎
	IM 1B7D3 - 01E	YS135 Auto/Manual Station for SV Setting		◎	◎	◎	◎
	IM 1B7D4 - 01E	YS136 Auto/Manual Station for MV Setting		◎	◎	◎	◎
	IM 1B7D5 - 01E Note 4	YS110 Standby Manual Station				◎	

Note 1 : Only when used with supervisory communication functions.
Note 2 : Only when using self-tuning functions.
Note 3 : Only for YS170 programmable controller.
Note 4 : The YS110 can be a standby station only for the YS150, YS170, or YS136.
Note 5 : Only when using YS-net communication functions.

1. INTRODUCTION

YS100 SERIES controllers are new single-loop controllers which have various display panels. The display panel adopts a bit-map liquid crystal display for easy panel reading and easy operation, in order to meet a wide range of customer's requirements. The control functions of the YS100 SERIES controller are similar to those used for YewSeries 80 controllers which went on sale in 1980. The YS100 SERIES single-loop controllers are available in two types; one is the YS150 multifunction controller and the other the YS170 programmable controller.

This technical information manual describes the display and control functions which are available on the YS150 and YS170 controllers. Refer to the separately supplied Technical Manuals TI 1B7C2-03E for "Programming Functions" of the YS170 controller, and TI 1B7C8-03E for "Communication Functions" for communication between YS100 and Distributed Control Systems µXL and CENTUM-XL, or the communication functions with supervisory calculators or personal computers.

Refer to the separately supplied Technical Manuals for the new communication function YS-net.

TI 1B7C8-04E "YS-net Peer-to-Peer Communication Functions" and TI 1B7C8-05E "YS-net Personal Computer Communication Functions."

1.1 Features of YS100 SERIES Controllers

① Various panels (operation panels group, tuning panel groups, and engineering panel groups) can be displayed with the bit-map LCD displays.

② All operations such as setpoint change, manual output change, control mode switching, PID parameters setting can be performed from the front panel of the controller.

③ Direct signals such as mV, thermocouple, resistance thermometer detector, slidewire, two-wire transmitter, or frequency can be entered in an analog input terminal .

④ The unit is small in size (DIN standard 72 mm width by 144 mm height and the depth is 320 mm) and light in weight (2.6kg).

⑤ The YS150 controller is equipped with a selector control and cascade control functions in addition to the single-loop control function.

⑥ Self-tuning functions used to adjust PID parameters to optimum values are available.

⑦ One YS170 programmable controller can control two loops independently (an independent current output is available for each loop).

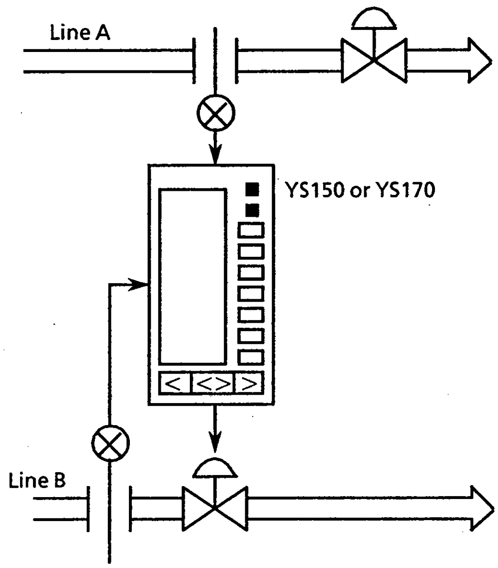
⑧ The YS170 programmable controller is available now with a "high-speed" control period of 0.05 seconds (the standard control period is 0.1 seconds).

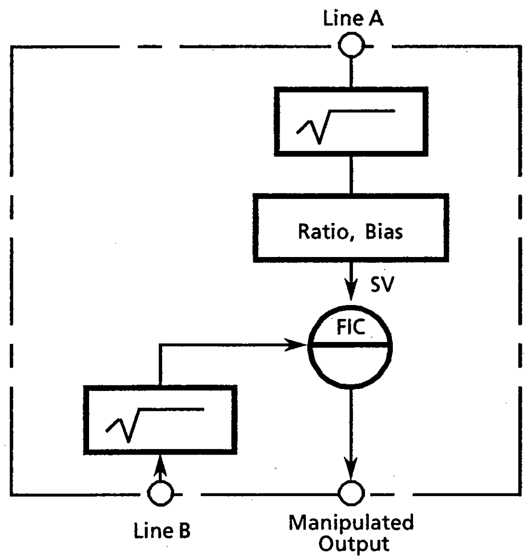
⑨ The YS170 programmable controller has powerful computating functions and a program area for up to 400 program sequence steps so that it can realize a variety of correction computations and advanced controls.

1.2 YS100 Controller Applications–Some Representative Examples

The following application examples illustrate the functional versatility of the YS100 controllers. Use these to grasp an understanding of YS150 and YS170.

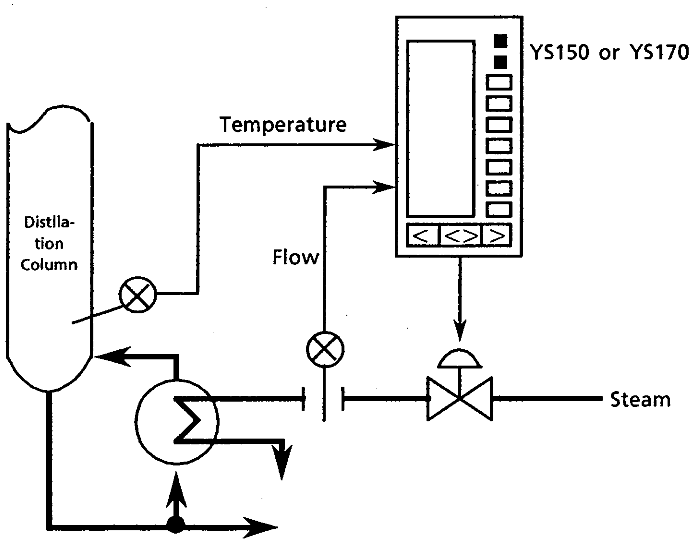
(1) Flow Ratio Control

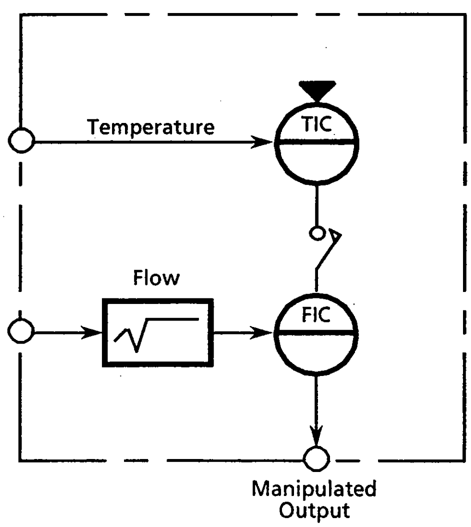




To control the flow in line B so as to keep the ratio between the flows in lines A and B constant at a preset ratio, the flow (differential pressure) in line A is measured, its square root taken, this is multiplied by the flow ratio and a bias added, and the result is used as the setpoint for a controller controlling the flow in line B.

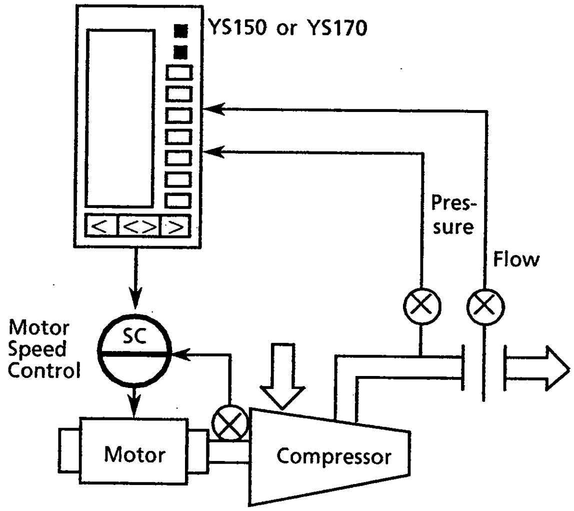
(2) Flow-Temperature Cascade Control Loop

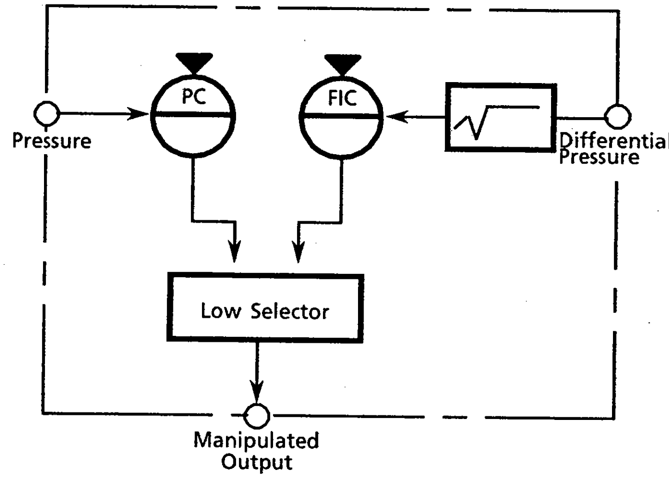




YS150 (or YS170) provides cascade controllers which change the setpoint of flow control based on the temperature at the bottom of the distillation cloumn or independently controls the steam flow for heating.

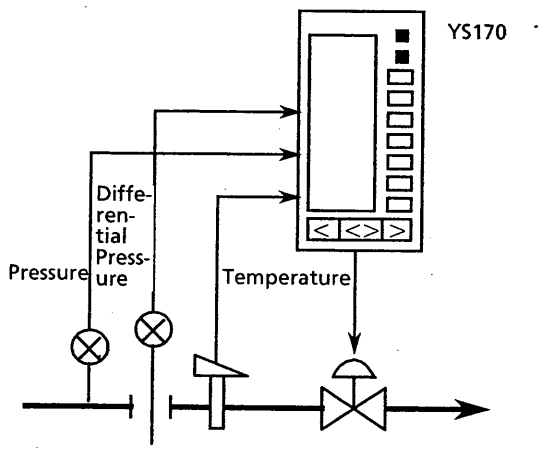
(3) Compressor Anti-surge Control (Autoselector Control)

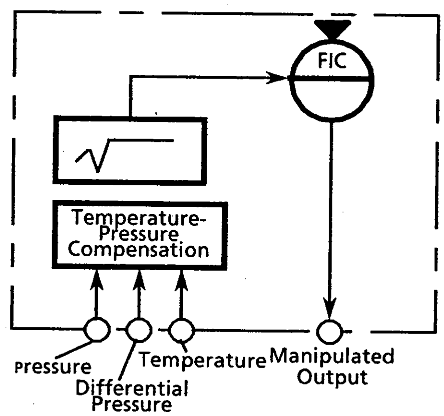




YS150(YS170) normally controls compressor delivery flow within the delivery pressure limits by controlling motor speed. Two controllers incorporated in the YS150(YS170) control pressure and flow respectively and the smaller manipulated variable of them is selected.

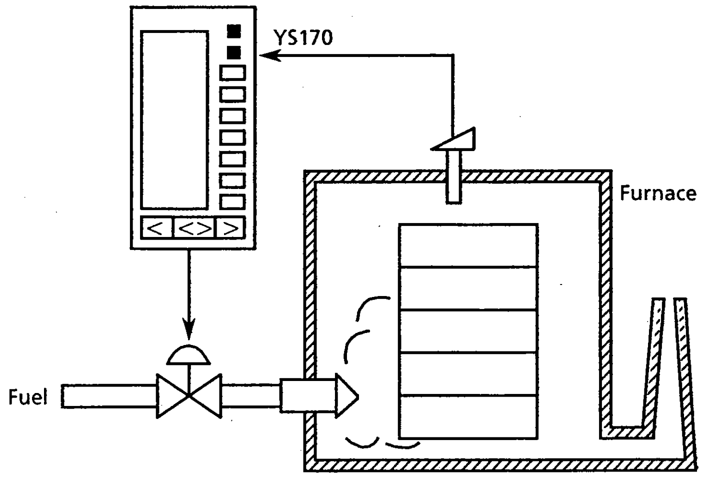
(4) Flow Control with Temperature-Pressure Compensation

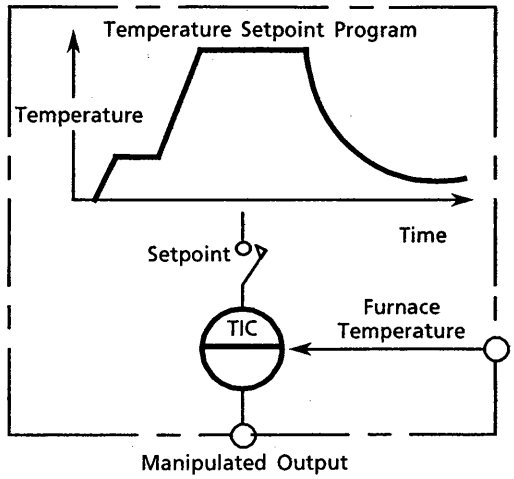




YS170 can measure the pressure and temperature of the gas in the flow line, and perform complex density compensation calculations (to computate the effective flow at reference conditions).

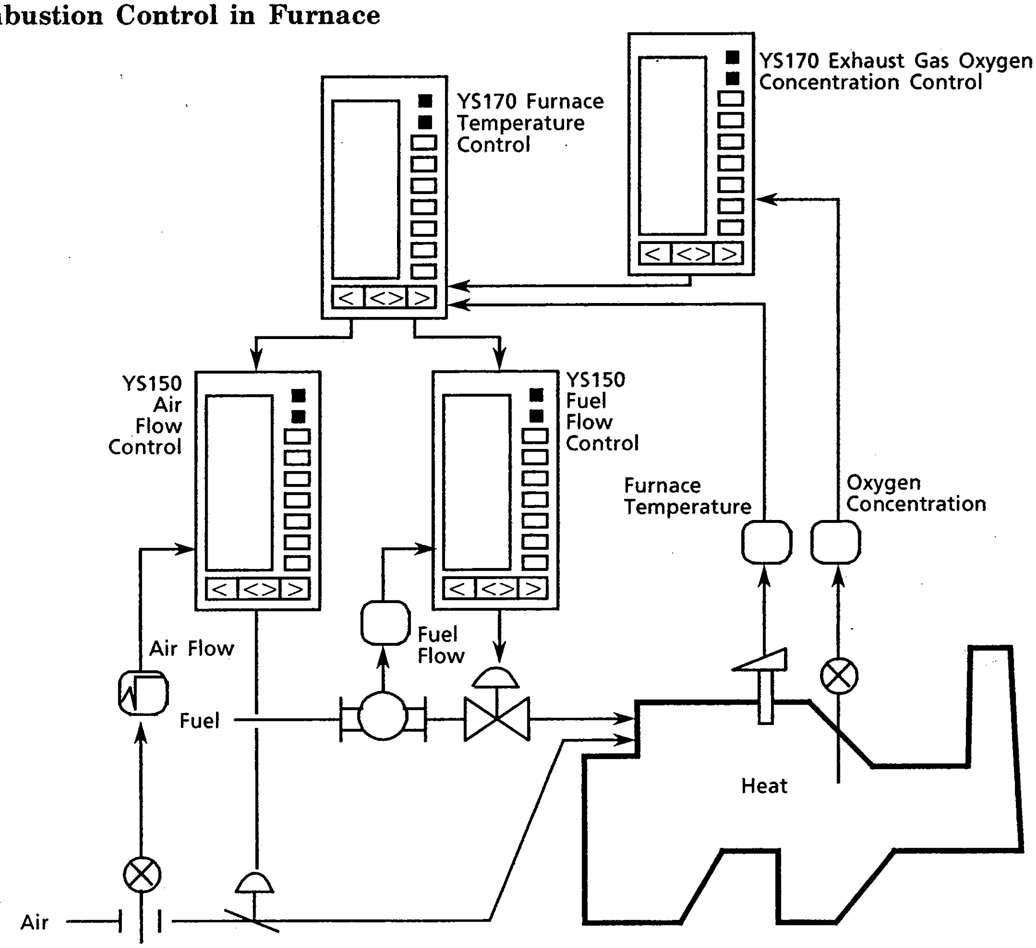
(5) Temperature Control of Heat Treatment Furnace





YS170 automatically controls temperature in a heat treatment furnace according to the temperature setting pattern program with time.

(6) Combustion Control in Furnace



This furnace combustion control system example uses YS170 and YS150 controllers.

The YS170 exhaust gas oxygen concentration controller provides complex dead time compensation. The YS170 furnace temperature controller monitors oxygen concentration information (from the exhaust gas oxygen concentration controller) and controls fuel / air flow ratio. It also monitors the furnace temperature and provides setpoint for the air and fuel flow controllers. Fuel flow setpoint limits may also be provided. Note how the YS170 controllers handle complex functions that would be difficult to realize with any combination of conventional instruments.

2. NAMES OF COMPONENTS AND DISPLAY PANELS

2.1 Names of Components

Figures 2.1.1, 2.1.2 and 2.1.3 show structure of the YS100 SERIES controller , front panel, and internl front panel respectively. The controller consists of a housing and internal unit which are connected to each other with connectors. The internal unit consists of the main circuit board, the power supply circuits, the communication circuits, the signal converter circuits and the display part. The terminal board is located at the rear of the casing. Provided inside the front panel are the backup wheel for manual operation, output balance lamp, lever for pulling out the internal unit, standby manual station connection, and RS-233C connection (for YS170) for a personal computer.

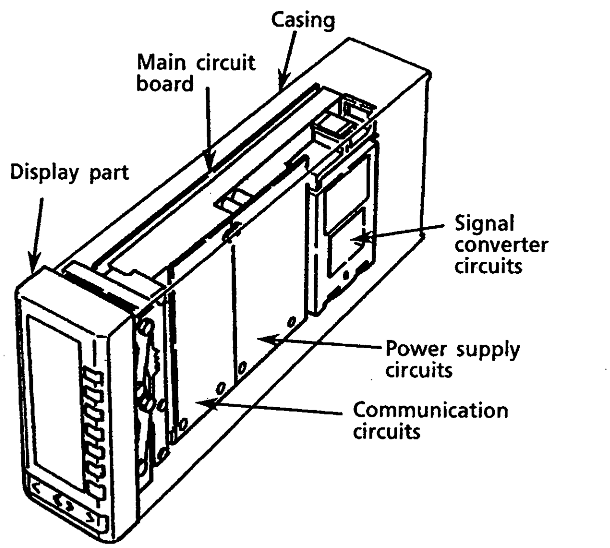


Figure 2.1.1 Structure of the YS100 SERIES Controller

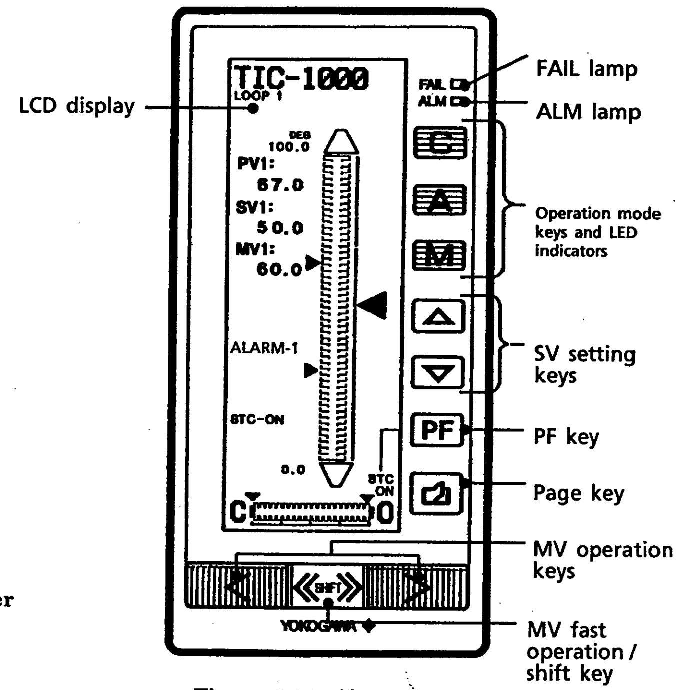


Figure 2.1.2 Front Panel

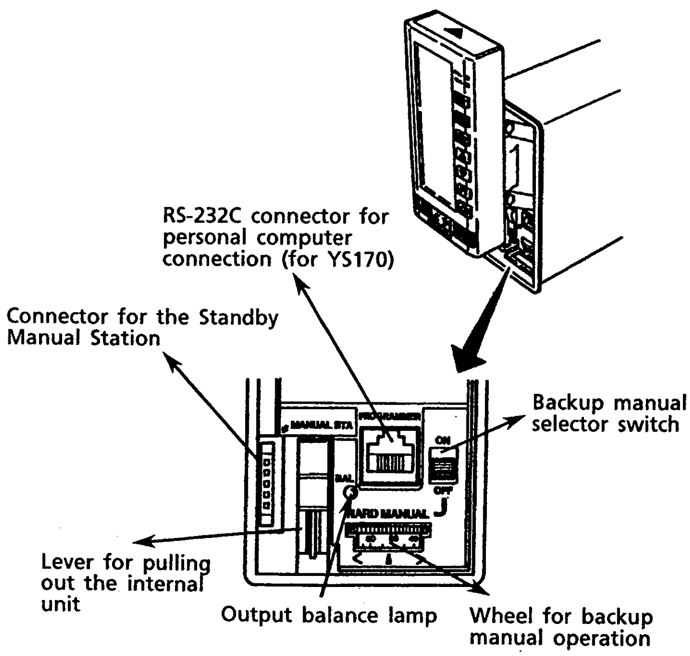


Figure 2.1.3 Internal Front Panel

2.2 Display Panel Overview

The YS100 SERIES controller can display a variety of panels using the bit-map LCD displays. These panels are divided into three groups: operation panel groups; tuning panel groups; and engineering panel groups. The YS150 controller has 21 panels, and the YS170 controller has 27 panels. Figure 2.2.1 shows configuration and panel switching..

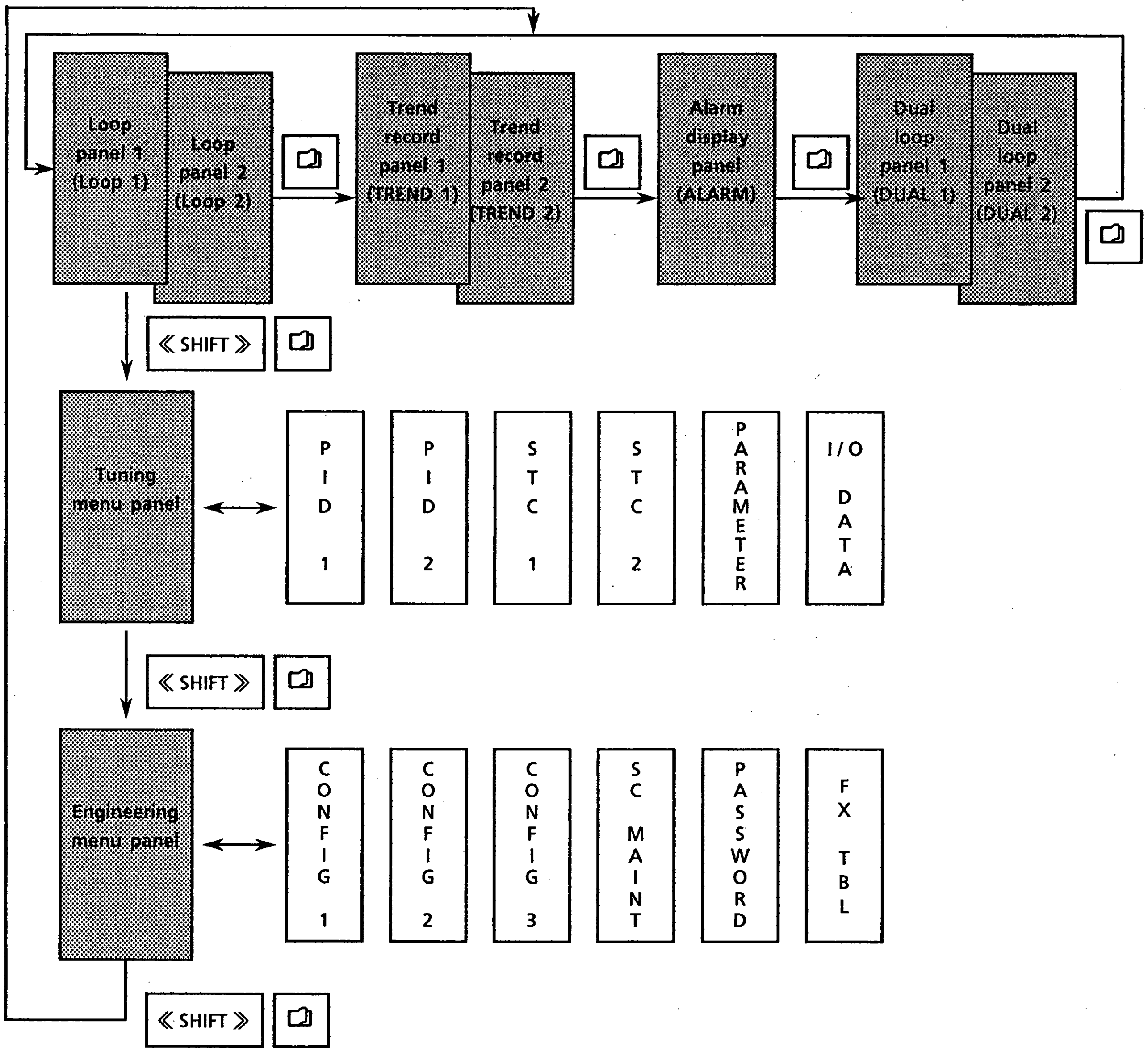


Figure 2.2.1 Configuration of Display Panel

The operation panel group consists of loop panels, trend record panels, an alarm display panel, and dual loop panels used for daily operation. Two loop panels, two trend record panels, and two dual loop panels are available to accomodate 2-loop control. One of the dual loop panels is for the first loop operation and the other for the second loop operatrion. These panels in the operation panel group can be set to be displayed or not to be displayed respectively. Also, it is selectable for each panel to display in the LCD with blue background or white background. The tunig panel group is a gathering of panels for adjusting control parameters. The engineering panel group is a panel group which has the initial setting items for when the controller is first used.

Pressing the page key selects the desired panel in each panel group. Pressing the page key while pressing the shift key selects the desired panel group.

2.3 Display Pnael Detail

Here are the introduntion of same panels, mainly operation group panels.

2.3.1 Loop Panel

Figure 2.3.1 shows the controller panel which is called "loop panel". The main data are displayed with analog type display and with numerics and characters.

(Note) The register display in the upper part applies only to the YS170 programmable controller. It is enabled on the Function Setting Panel 1 and available for both Loop Panel 1 and Loop Panel 2 independently. As the value of the internal register used in the program is displayed in any 3 character parameter names, it can be used in the ratio displays in ratio control.

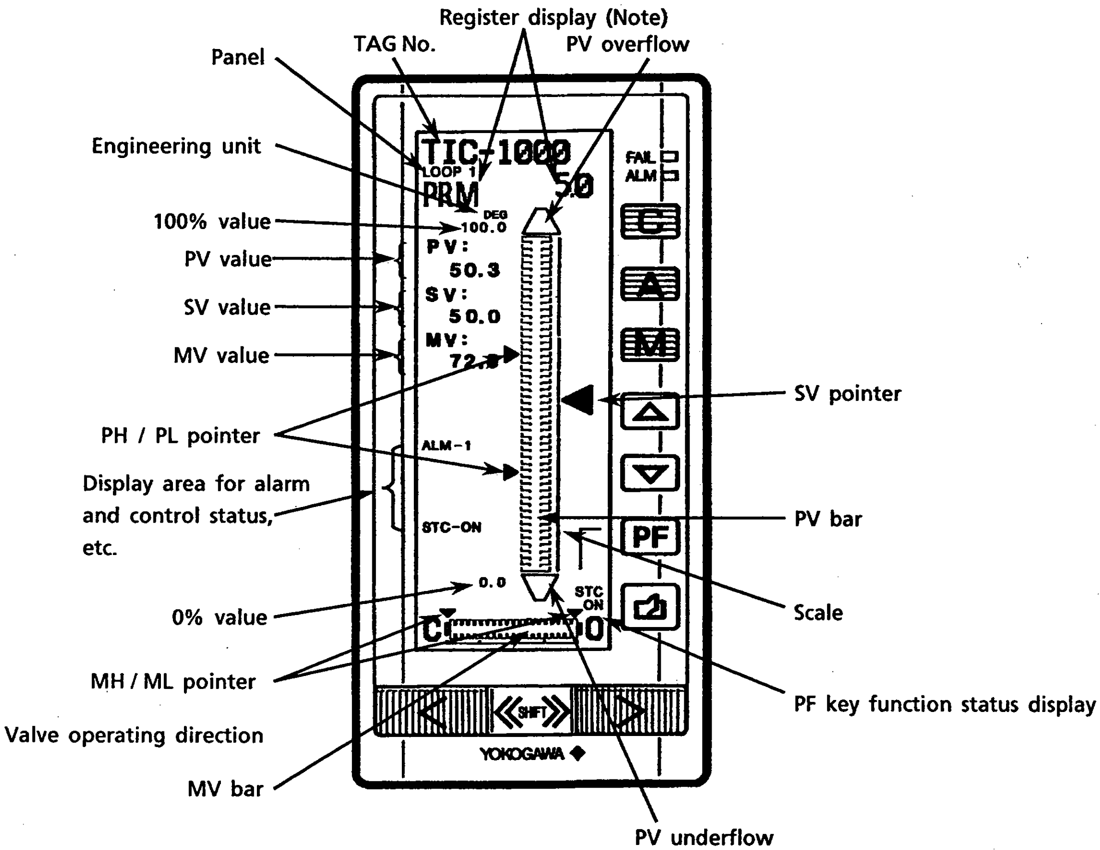


Figure 2.3.1 Loop Panel

2.3.2 Trend Record Panel

Figure 2.3.2 shows the trend record panel for displaying process variables. This panel is used to monitor change of process at startup operation and at normal operation. You can use the trend record panel to check the operation status the night before, or the morning after a weekend, after automatic operation.

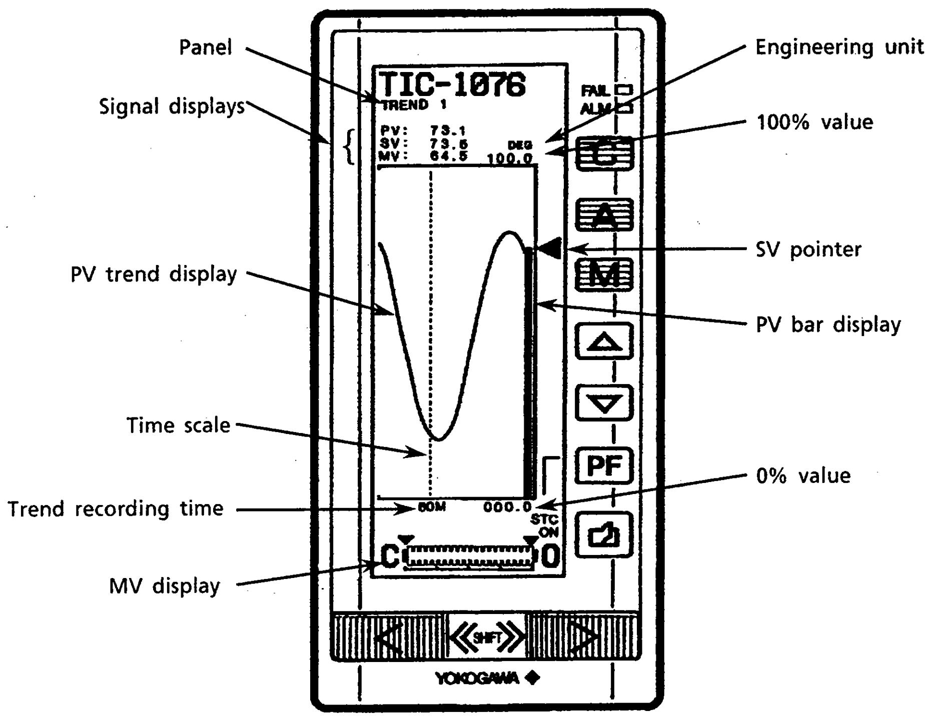


Figure 2.3.2 Trend Record Panel

Display of the recording span can be set from 1.5 minutes to 45 hours. The table below shows the relationship between the recording span and the sampling intervals.

Recording Span	1.5 minutes	7.5 minutes	15 minutes	45 minutes	1.5 hours	7.5 hours	15 hours	45 hours
Sampling Interval	1 second	5 seconds	10 seconds	30 seconds	1 minute	5 minutes	10 minutes	30 minutes

2.3.3 Alarm Display Panel

Figure 2.3.3 shows the alarm display panel. The displays consist of the alarm status display of process signals (process alarm), the alarm display of self-tuning functions, and the self-diagnostic display of the controller. Generated alarms are displayed in inverse display. Alarms displayed by normal display and not inverse display indicate that the alarm had previously been generated, but that it has revocered into the normal state. Mark * at the head of an alarm is an unacknowledged mark which means that the alarm status has not been acknowledged yet by the operator. When the operator acknowledges the alarm status by pressing the [CLR] key, the * mark and past alarm indications will disappear.

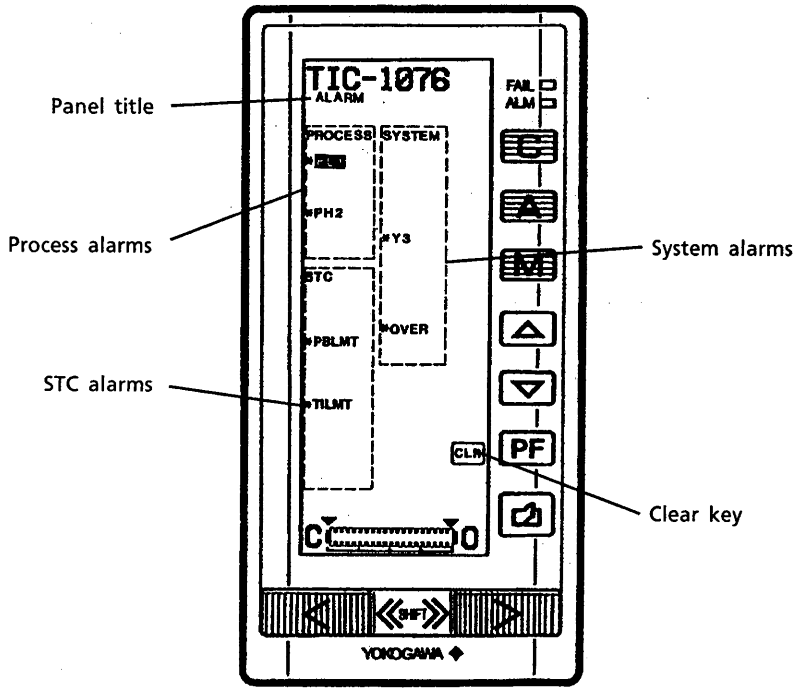


Figure 2.3.3 Alarm Display Panel

2.3.4 Dual Loop Panel

Figure 2.3.4 shows the dual loop panel. In this panel the information on both loops is displayed (loop 1 on the left side and loop 2 on the right side). There are two dual loop panels. One is for loop 1 operation and the other for loop 2 operation, and changing operation mode, SV setting, or MV output is possible for each loop. To make it easy to differentiate two dual loop panels the PV and SV digital value for operatable loop is displayed in the inverse mode. The function of each key is the same as that of the "single" loop panels.

(Note) This panel is set not to be displayed at the factory.
To display it set parameters "DUAL 1" or "DUAL 2" in the CONFIG 1 panel to other than 0.

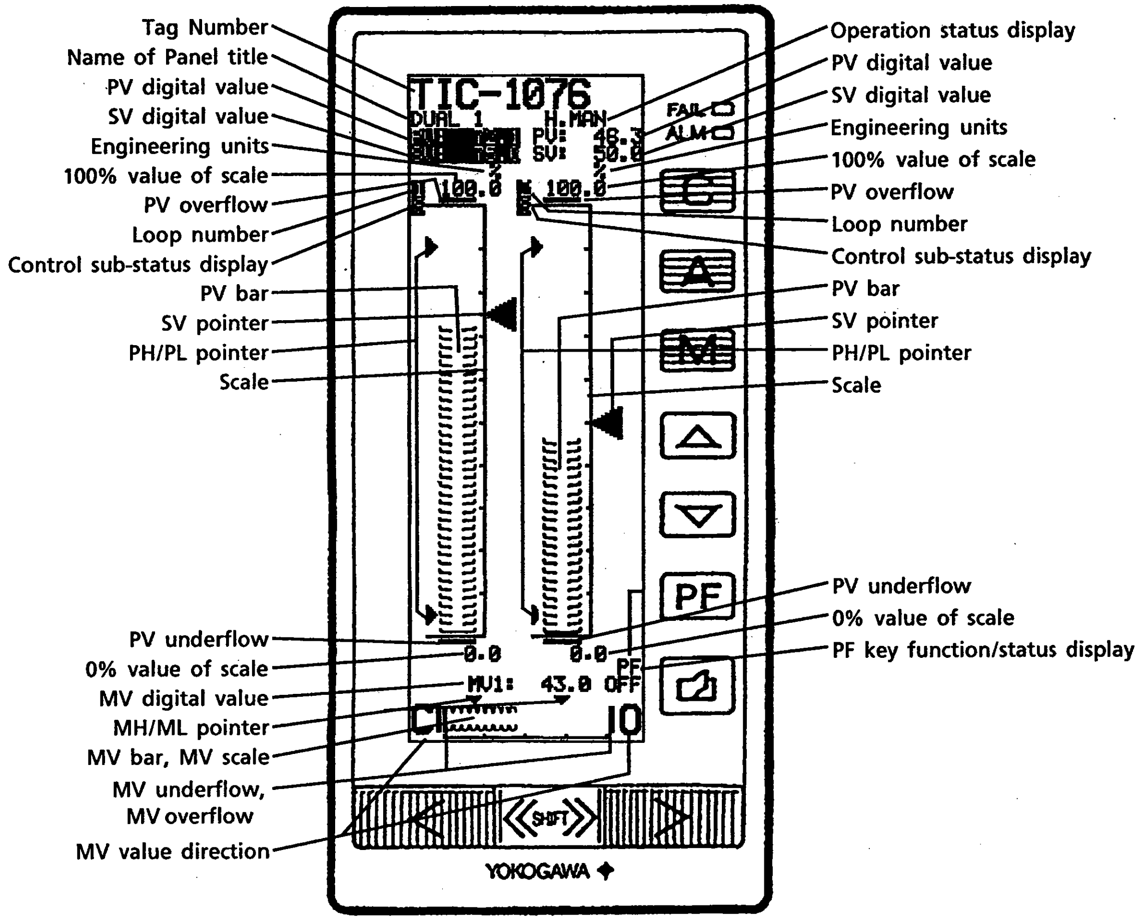


Figure 2.3.4 Dual Loop Panel

2.3.5 Tuning Panel Group

Table 2.3.1 shows types and functions of tuning panels. For the tuning panel group, the function of the keys on the front-right are not as they are marked on the keytops. They function as they are displayed on the right of the panel display. The output control keys at the bottom can be operated in the MAN mode in the PIDn or STCn panel.

To switch from the tuning menu panel to the desired tuning panel, press the key to the right of the individual panel titles.

Table 2.3.1 List of Tuning Panels

Name of Panel	Description
Menu	Displays names of the tuning panels
PID 1	Sets PID parameters, alarm setpoints, and output limit values of primary loop
PID 2	Sets the same items as above of secondary loop
STC 1	Displays and sets the self-tuning parameters of primary loop
STC 2	Displays and sets the same items as above of secondary loop
PARAMETER (Only for YS150)	Sets the parameters and time constants of primary and secondary loops for setpoint computation, process variable computation, and feed-forward computation
P & T REG (Only for YS170)	Displays and sets values of parameters Pn and temporary registers Tn
I/O DATA	Displays raw data of analog input/output signals and status input/output signals

Tuning menu panel

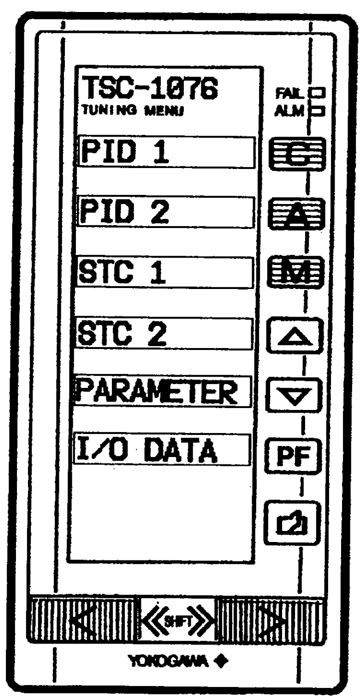


Figure 2.3.5 Tuning Menu Panel

2.3.6 PID Setting Panel

Figure 2.3.6 shows the PID setting panel. The principle data is displayed at the top part of the panel, and the parameters for PID tuning are displayed below that data. As parameters can be group-displayed, parameters can be set while gaining an understanding of the interrelationships of all the parameters. The selected data can be expanded and displayed at the top of the panel.

The [SAV] key saves the optimum parameters set and stored in the main memory in the non-volatile memory (EEPROM). This function is most effective for using the saved parameters as a back-up when power failure over a long period has destroyed the contents in the main memory.

The operation panel is displayed while the [CHG] key is pressed. When you release the key, the tuning panel is displayed. Pressing this key, PID tuning can be carried out while monitoring the trend record panel, or setpoints can be changed from the loop panel during tuning.

In this case, note that the operation panel displayed prior to changing the panel (loop panel, trend panel, or dual loop panel) to tuning panels is displayed.

PID setting panel

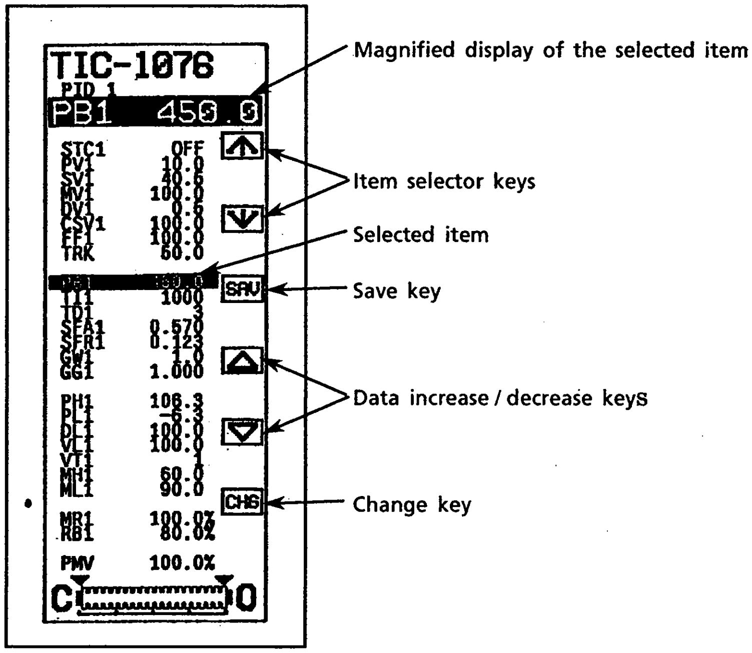


Figure 2.3.6 PID Setting Panel

2.3.7 Engineering Panel Group

Table 2.3.2 shows the types and functions of the engineering panel group.

Table 2.3.2 List of Engineering Panels

Name of Panel		Description
CONFIG1		Selects the controller mode, the start mode, the communication function, selection of display / no display of operation panel, and selection of loop panel register display *1
CONFIG2		Specifies the control and display specifications such as control expressions, tag number, trend recording span, and scale.
CONFIG3		Selects the desired PF key function, contact input function, and signal computations.
SC MAINT*2		Specifies the desired range for the direct input signals.
PASSWORD		Sets the desired password. The password is used for ensuring security. Once a password is set, display of panels is freely done, however, data setting using a tuning panel or an engineering panel is prohibited. In this case, you can release the inhibition of the data setting by entering the set password. A 4-digits number is used as a password.
FX TABLE		Sets the desired two characteristics of 10 segment-line functions.
Only for YS170	SMPL & BATCH	Sets the desired parameters for sample-and-hold PI control and the batch PID control.
	GX1 TABLE	Sets the desired characteristics of 10 segment-line function GX1.
	GX2 TABLE	Sets the desired characteristics of 10 segment-line function GX2.
	PGM SET	Sets the desired program setting function PGM.
	PID TABLE	Sets the eight desired sets of preset PID parameters.
	K CONSTANT	Displays fixed constant register Kn.

*1 : Applies only to the YS170 programmable mode
*2 : Not applies to the YS170 programmable mode

The display type and the ways of setting are the same as those of a tuning panel. Set the parameters of the configuration panels 1, 2, and 3 (CONFIG 1, 2, and 3) and the input specification setting panel (SC MAINT) after deactivating the control computation function.

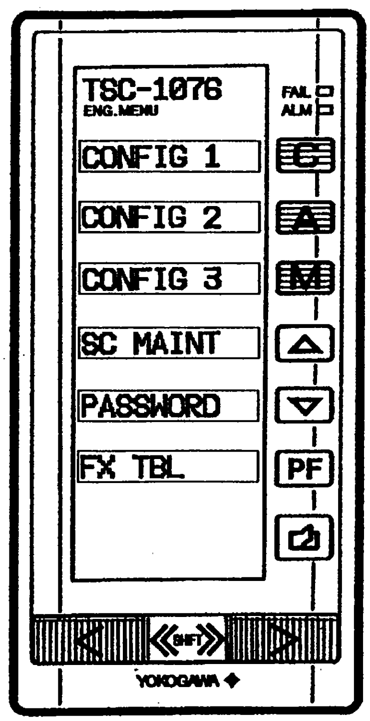
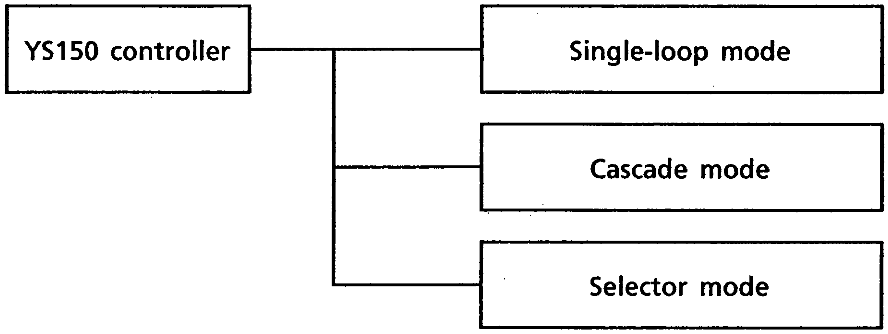


Figure 2.3.7 The YS150 Controller Engineering Menu Panel

3. CONTROL FUNCTIONS

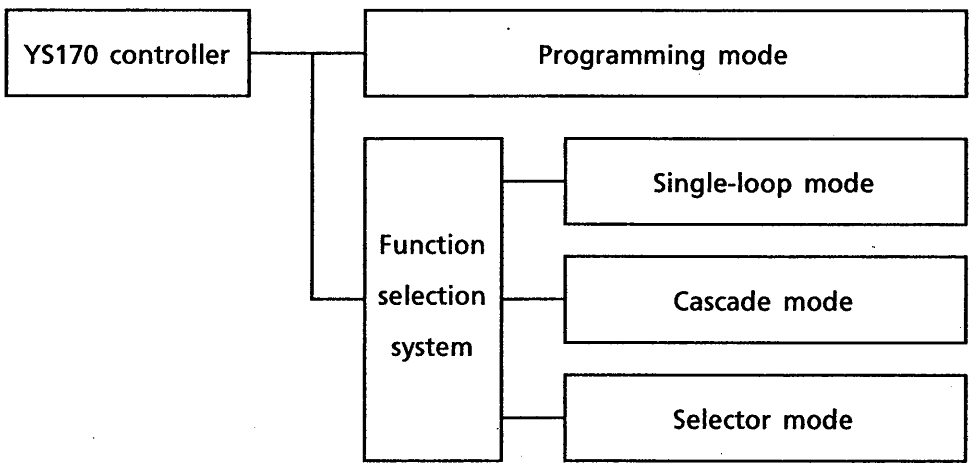
3.1 Control Mode Configuration

The three following control modes are available on the YS150 controller.



To use the controller as a single-loop controller, a cascade controller, or a selector controller, set the relevant control mode on the configuration panel.

The YS170 controller is a programmable type controller with which the desired computation and control functions can be created. The three following control modes (the same as the YS150 controller) are also available on the YS170 controller. If these modes are selected, there is no need for program generation, and can be used as a YS150.



These modes for YS150 and YS170 are selected by the setting item CTL in the configuration panel 1.

3.2 Control Function of YS150 Controller

This section explains the control specifications and function blocks of the single-loop mode, the cascade mode, and the selector mode, which are available on the YS150 controller.

Each mode consists of signal computation, self-tuning (STC), status change functions, and auxiliary control functions, with the control module at the core. The desired function can be selected from the configuration panel. There are numerous combinations of function settings, and is optimum for a wide range of uses. See Chapter 4 for the signal computation functions and the auxiliary control functions. See Chapter 5 for the self-tuning functions.

3.2.1 Single-loop Mode

The controller functions as a single-loop controller in the single-loop mode. The following shows the control specifications of the single-loop mode (see Section 3.4 to 3.11 and chapter 4 to 5 for details of each specification item).

[Specifications]

Figure 3.2.1 shows the function block diagram.

- Control module : Control elements
  - Control type ; Standard PID or proportional (PD) control
  - Control algorithm ; To be selected from the items below for standard PID control (when using PD control, always select PI-D)
    - PV proportional type PID (I-PD)
    - PV derivative type PID (PI-D)
    - Adjustable setpoint filter (SVF)
- Function of the PF key : Start and stop of the self-tuning function. (The status input has priority over the others when start and stop function of self-tuning is selected by status input.)
- Control period : 100 ms.

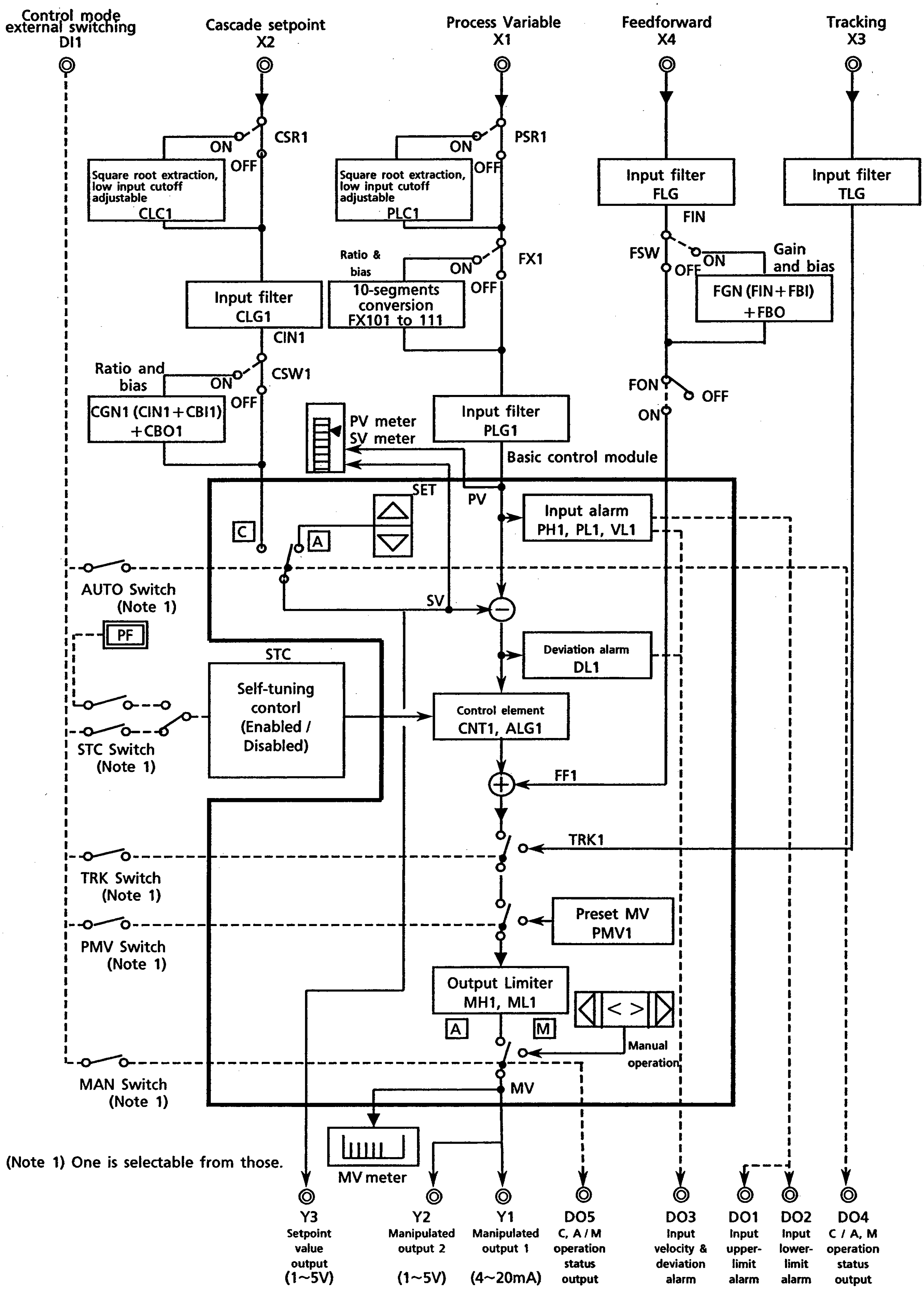


Figure 3.2.1 Function Block Diagram of the Single-Loop Mode

3.2.2 Cascade Mode

In order to execute cascade control, two loops are connected in series (cascade connection). The following shows the specifications of the cascade mode (see Section 3.4 to 3.11 and chapter 4 to 5 for details of each specification item).

[Specifications]

Figure 3.2.3 shows the function block diagram.

- Control module : Cascade control module.
  - Control type ; Standard PID control
  - Control algorithm ; To be selected from the items below for primary and secondary loops
- Self-tuning function : Can be specified. It operates in the secondary loop when the internal cascade is set open, and in the primary loop when the internal cascade is close.
- Alarm function : Alarm action ; Upper limit, lower limit, velocity, and absolute value of deviation for primary and secondary loops
  - Output contact ; Alarm outputs for primary and secondary loops. The loop alarm output is the logic OR signal of the upper limit, lower limit, velocity, and deviation alarms.

[Display Operation]

In the cascade mode, display and operation are performed on the instrument front panel as allocated in Figure 3.2.2.

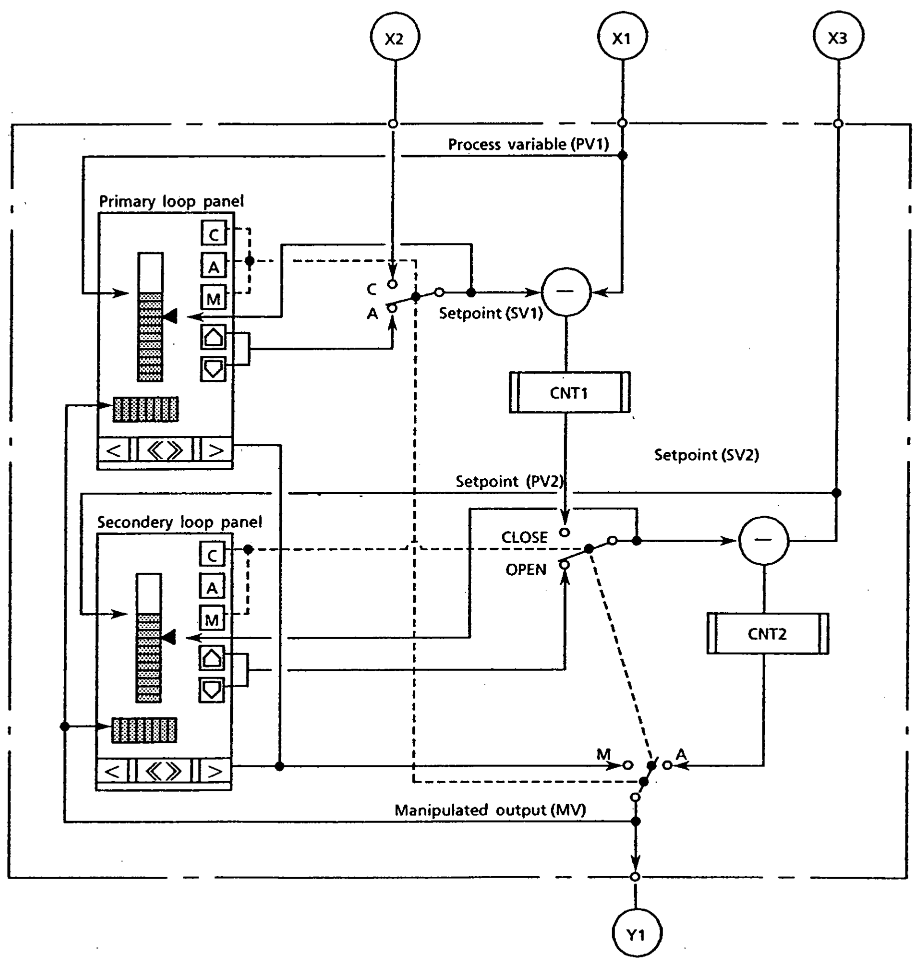


Figure 3.2.2 Display and Operation in Cascade Mode

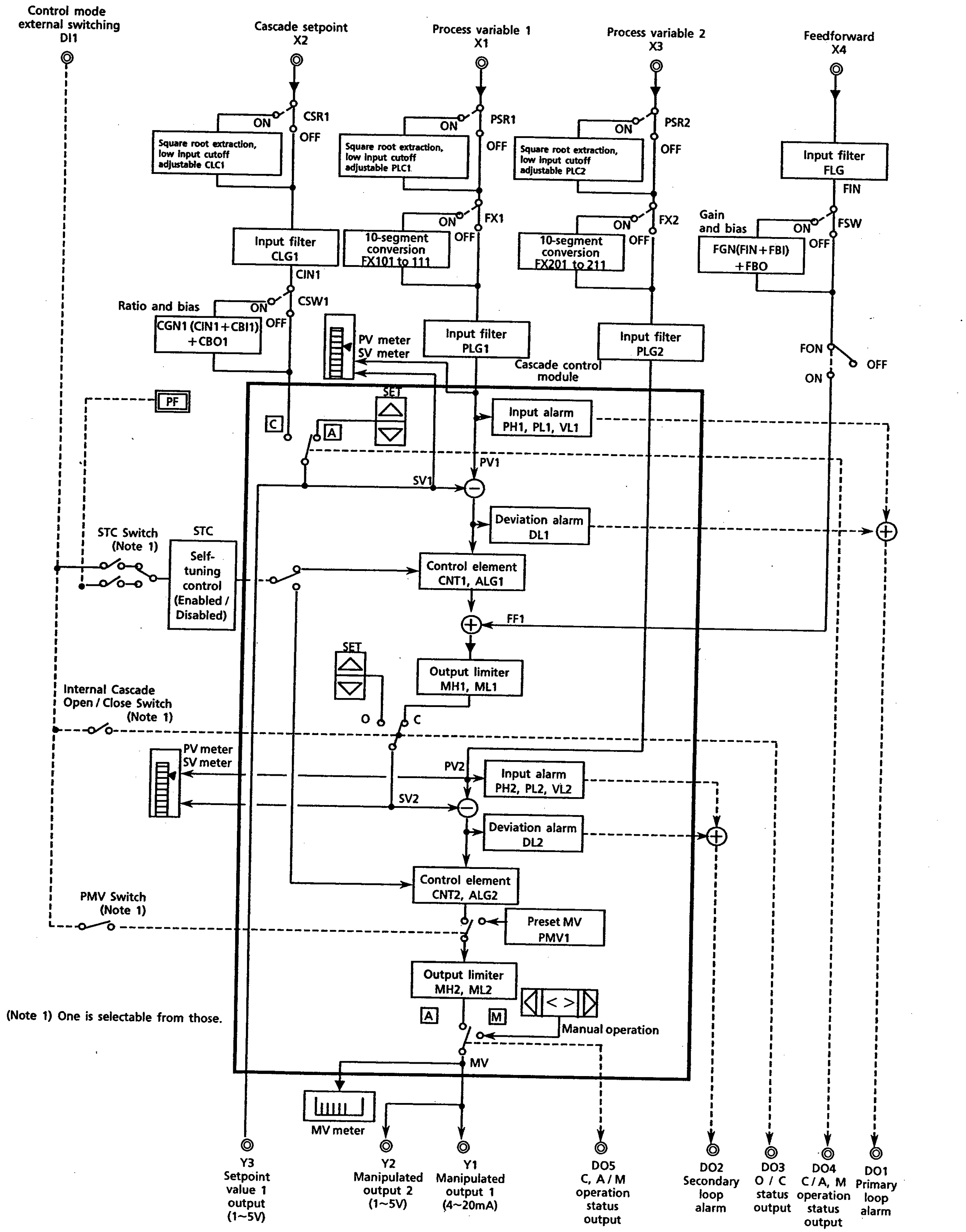


Figure 3.2.3 Function Block Diagram of Cascade Mode

3.2.3 Selector Mode

In the selector mode the controller consists of two control elements and the automatic selector. The following shows the specifications of the selector mode (see Section 3.4 to 3.11 and chapter 4 to 5 for details of each specification item).

[Specifications]

Figure 3.2.5 shows the function block diagram.

● Control module : Selector control module.
  Control type ; Standard PID control
  Control algorithm ; To be selected from I-PD / PI-D / SVF for primary and secondary loops
  Selector function ; Autoselector
   = High selector or low selector is to be designated.
  Manual selector control
   = The output from the designated loop is output regardless of the level of the signals

● Self-tuning function: Can be designated. It operates in the selected loop.

● Alarm function : Alarm action ; Upper limit, lower limit, velocity and absolute value of deviation of primary and secondary loops
  Output contacts ; Alarm outputs for primary and secondary loops. The loop alarm output is the logic OR signal of the upper limit, lower limit, velocity, and deviation alarms.

[Display / Operation]

In the selector mode, display and operation are performed on the instrument front panel as allocated in Figure 3.2.4.

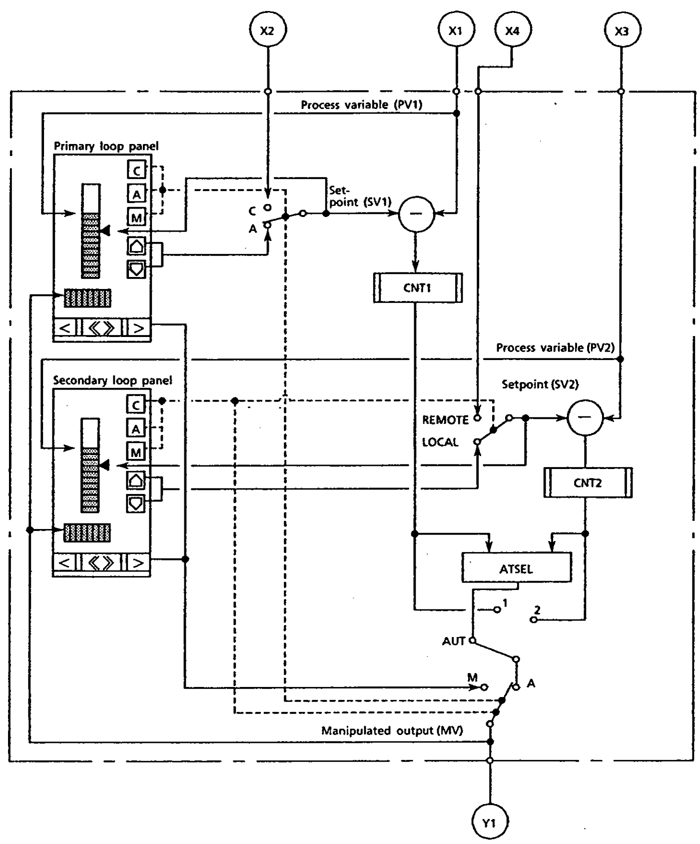


Figure 3.2.4 Display and Operation in Selecter Mode

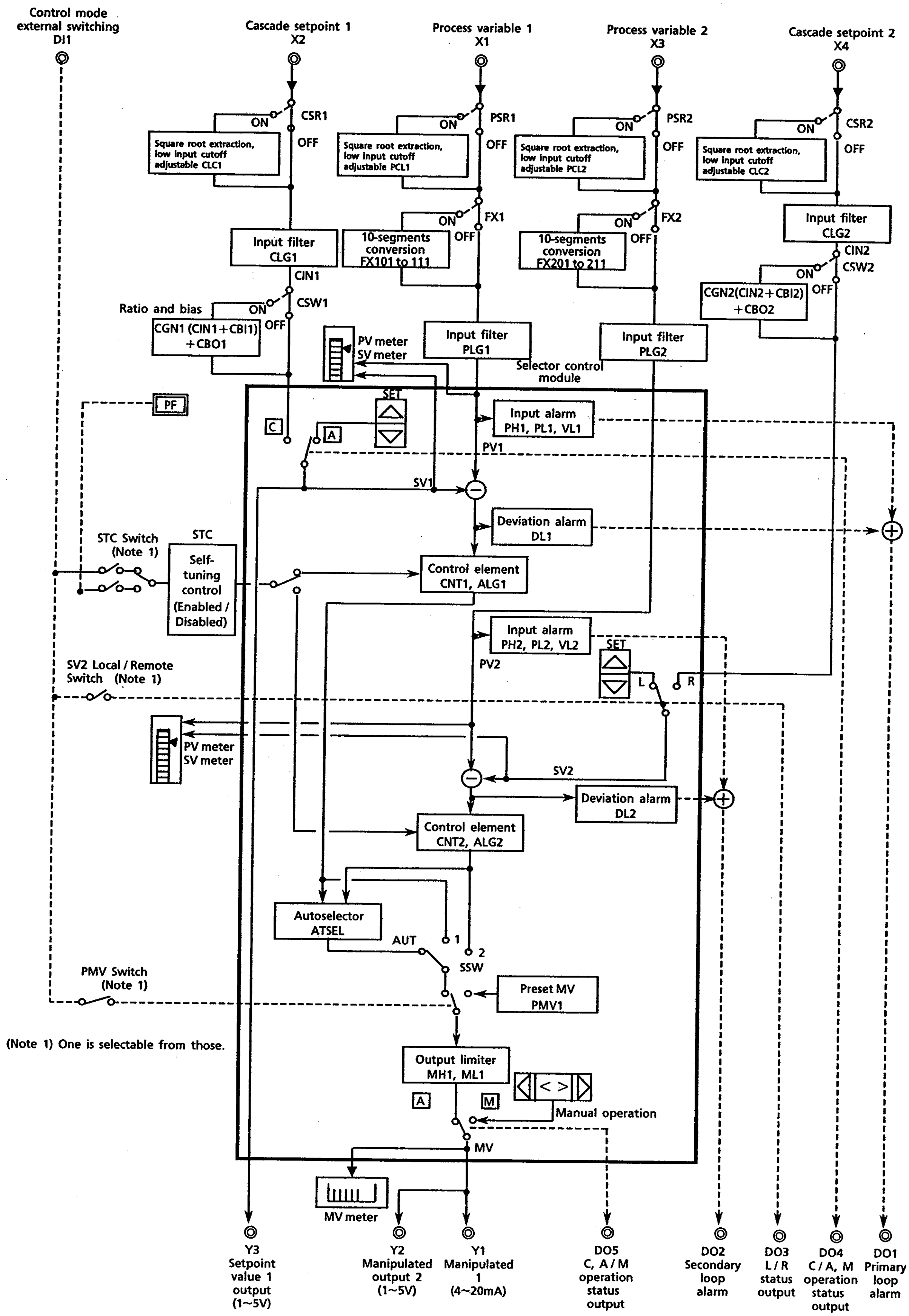


Figure 3.2.5 Function Block Diagram of Selector Mode

3.2.4 Configuration of Control Module

The following describes the control module which is the central part of each controller mode.

(1) Control Elements

As shown in Figure 3.2.6, the control module consists of one or two control elements.

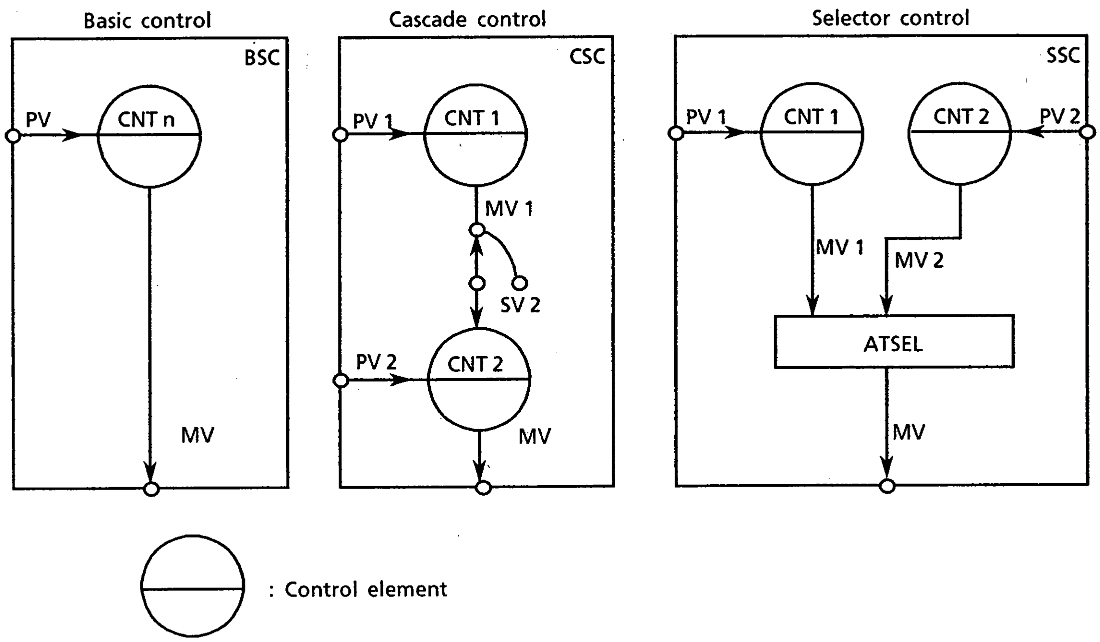


Figure 3.2.6 Relationship between Control Module and Control Element

(2) Control Type

The desired control type is selected and set from "Standard PID control" and "Proportional (PD) control" for each control element. As shown in Table 3.2.1, "Proportional (PD) control" can be designated only in the control element of the single-loop mode.

"Non-linear PID control" and "PID control with reset bias" are included in "Standard PID control". "Proportional (PD) control" also has "Non-linear control" functions (see Sections 3.4 and 3.5 for control actions of each control type).

Table 3.2.1 Combination of Control Types and Control Element

Control Element / Control Type	Single-Loop	Cascade		Selector	
		Loop 1	Loop 2	Loop 1	Loop 2
Standard PID control	×	×	×	×	×
Proportional (PD) control	×	—	—	—	—

(3) Control Computation

When selecting "Standard PID control" as the desired control type, select the desired control algorithm from "PV proportional PID control" (I-PD type), "PV derivative PID control" (PI-D type) and "Adjustable setpoint filter function" (SVF) (see Sections 3.4 and 3.8 for details of the control algorithm).

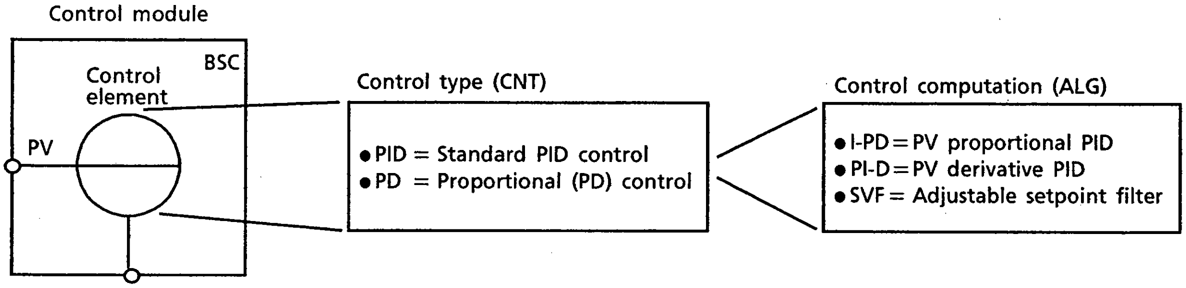


Figure 3.2.7 Control Module and Control Element (Multifunction System)

[Example of Setting]

Control mode	CTL = CAS (Control module = CSC)	
Control element	CNT1 = PID (Standard PID)	
	CNT2 = PID (Standard PID)	
	ALG1 = SVF (SVF type)	
	ALG2 = SVF (SVF type)	
Feedfoward gain computation	:	FSW=ON
Feedfoward addition to output	:	FON=ON

In this example, a cascade control loop, whose primary loop is set to the standard PID control plus feedfoword control and whose secondary loop is set to the standard PID control, is created.

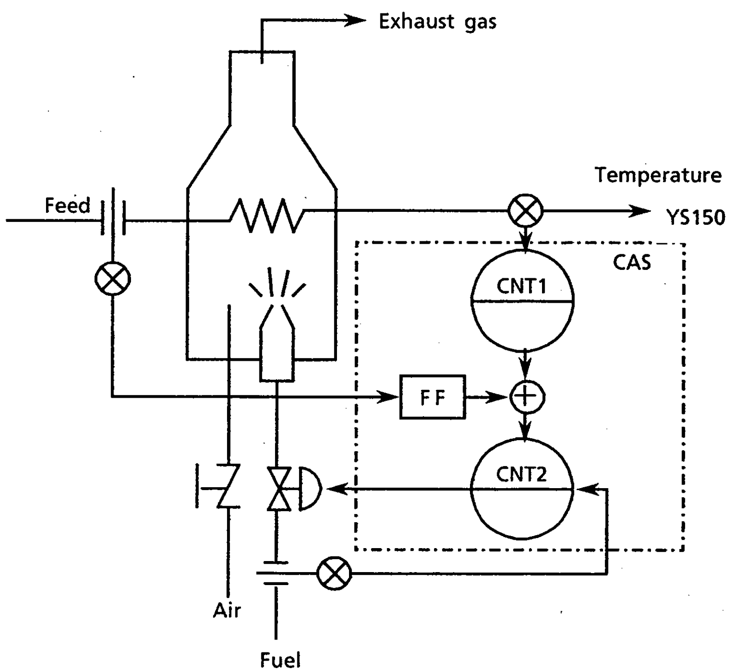


Figure 3.2.8 Example of Cascade Control (Furnace Feedfoward Control)

3.3 Control Function of YS170 Controller

This section describes the control functions in the programmable mode of the YS170 controller. The single-loop mode, the cascade mode, and the selector mode in the multifunction system are the same as those of the YS150 controller. See Section 3.2 for the modes which are available in the multifunction system.

3.3.1 Programmable Mode

The computation and control functions which are required for control are built-in and stored in the controller as the computational function library to be used in the programmable mode. It is by combining these functions on the program that computation and control functions are generated.

Because the operations in the program use reverse Polish notation, which eliminates the need to write expressions in brackets, program generation has been simplified.

The following shows an example of the program for PID control.

Program	Description
LD X1	Read input 1 (process variable)
BSC1	Standard PID computation
ST Y1	Output the manipulated variable to Y1
END	Program end

Figure 3.3.1 Example of Program

Refer to the separately supplied Technical Information TI 1B7C2-03E for "Programming Functions" for the program description.

The control functions in the programmable mode consist of:

① Control modules which determine the structure of control computation
② Control elements which determine algorithm of control computation
③ Expansion functions which select control options (refer to section 3.3.2.(3)).

3.3.2 Control Module

The instruction used to describe control functions are called control modules (commands). Configuration of the control functions in the programmable mode of the YS170 controller is programmed using the control modules (see Table 3.3.1).

Table 3.3.1 Functions of YS170 Controller and Control Modules

Functions of the YS170 Controller	Control Modules
Single-loop control	BSC1
Independent two-loop control	BSC1 and BSC2
Cascade control	CSC
Selector control	SSC

There are three control module types (see Figure 3.3.2) as follows:

① Basic control module (Command codes are BSC1 and BSC2)
This module has the control function for one loop. Two command codes, BSC1 and BSC2, are available with the basic control module. When both codes are used in programming, one YS170 controller can control two loops independently. BSC1 is used for single-loop control or for primary loop control of two independent loops. BSC2 is used for secondary loop control of two independent loops.

② Cascade control module (Command code CSC)
One controller carries out cascade control by connecting the two loops in series with each other (cascade connection).

③ Selector control module (Command code SSC)
One controller carries out autoselector control with the combination of three control signals; the outputs of two loops and an external manipulated signal.

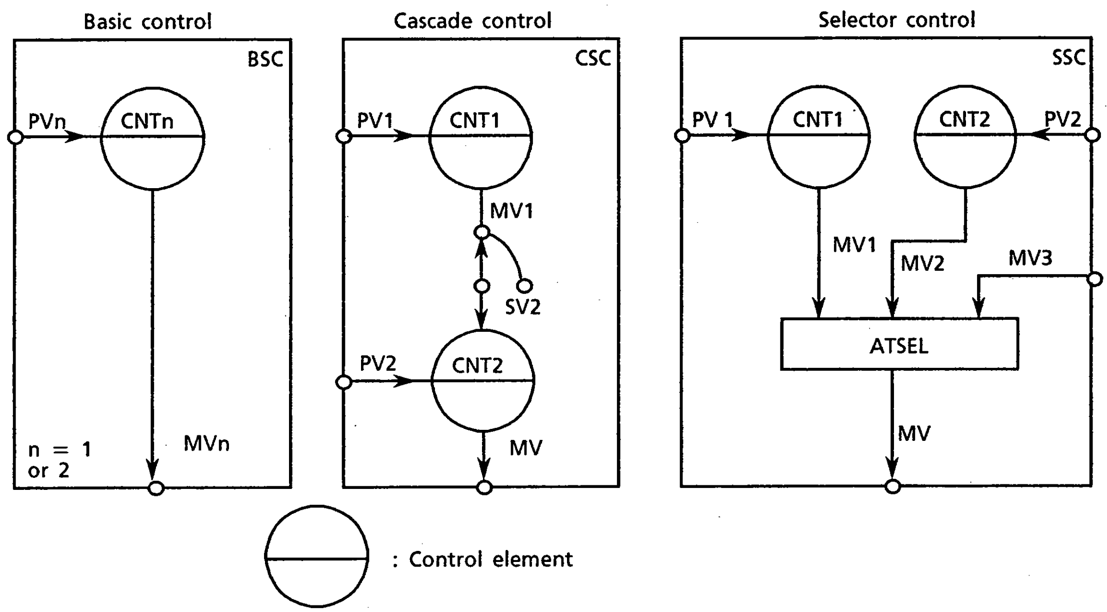


Figure 3.3.2 Control Modules

(1) Control Elements and Control Types

As shown in Figure 3.3.2, a control module consists of one or two control elements. After designating the desired control module in the program, designate the desired control type and the desired control computation from a personal computer or the configuration panel of the YS170 controller (see Figure 3.3.3).

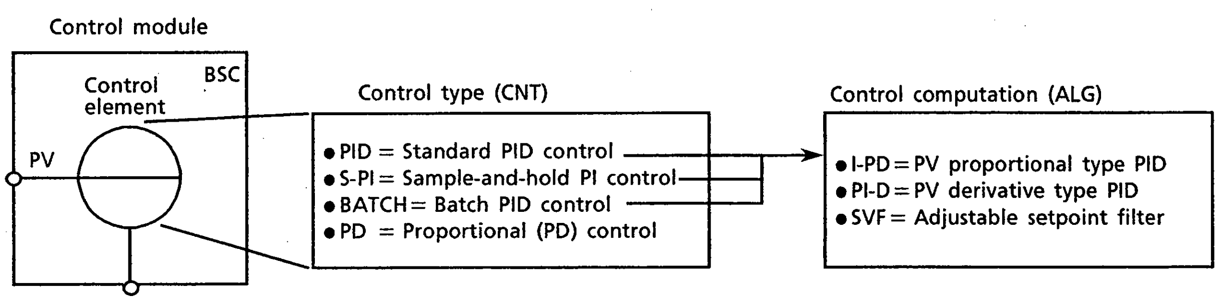


Figure 3.3.3 Control Module and Control Element (Programmable Mode)

There are four control types of control elements in the programmable mode as follows:

① Standard PID control (Built-in non-linear control and PID control with reset bias)
② Proportional (PD) control (Built-in non-linear control)
③ Sample-and-hold PI control (Built-in non-linear control)
④ Batch PID control

See Sections 3.4 and 3.5 for control action of each control type.

Table 3.3.2 shows possible combinations of control elements and control types.

Table 3.3.2 Combinations of Control Type and Control Element (Programmable Mode)

Control Element / Control Type	BSC1	BSC2	CSC		SSC	
	Loop 1	Loop 2	Loop 1	Loop 2	Loop 1	Loop 2
Standard PID control	×	×	×	×	×	×
Proportional (PD) control	×	×	—	—	—	—
Sample-and-hold PI	×	×	×	×	×	×
Batch PID	×	×	—	—	—	—

×: Can be designated.

(2) Control Computation

Designate the desired control computation when the control type is "Standard PID control", "Sample-and-hold PI control" or "Batch PID control".

Three types of control algorithm are available: "PV proportional type PID"; "PV derivative type PID"; and "Adjustable setpoint filter function" (see Sections 3.4 and 3.8 for details of control algorithm).

When using proportional (PD) control, always select the algorithm "PV derivative type PID".

(3) Expanded Function Register

The following supplementary functions are available for the control modules by using the expansion function register prepared for the control function (see Figures 3.3.4, 3.3.6, and 3.3.9 for details of the expansion function register of each control module).

The functions of the expanded register is used for computation and alarm output by writing the data to or reading the data from the register. Refer to the separately supplied Technical Information TI 1B7C2-03E for "Programming Functions" for details of the expansion register.

① Alarm (Input monitor)
② External cascade setpoint
③ Input compensation
④ Variable gain
⑤ Output compensation
⑥ Output tracking
⑦ Others

(4) Control Period

The control period in the programmable mode is selected from 0.2, 0.1, or 0.05 seconds. The desired control period is designated from the personal computer.

3.3.3 Basic Control Module (BSCn)

The following lists the specifications of the basic control module (see Section 3.4 and after for details of each specification item).

[Specifications]

- Control type : To be selected from standard PID control, proportional (PD) control, sample-and-hold PI control, or batch PID control.
- Control algorithm : To be selected from PV proportional type PID (I-PD), PV derivative type PID (PI-D), or adjustable setpoint filter (SVF) (in the case of proportional (PD) control always select PI-D type).
- Self-tuning function : Available for either BSC1 or BSC2 (selectable).
- Output limiter : Upper limit and lower limit.
- Alarm function : Upper limit, lower limit, velocity, and deviation absolute value.
- Expansion function : Cascade setpoint
  Input compensation computation
  Output compensation (feedforward) computation
  Adaptive gain
  Output tracking
  Alarm output

Figure 3.3.4 shows the block diagram of the basic control module, including the functions of the control elements and the expansion register. The S1 register and expansion register shown in the figure can be regarded as the BSC signal terminals of the controller. The desired function can be obtained by "connecting" the data to the "terminals". Use Y1 for BSC1 output and Y3 for BSC2 output.

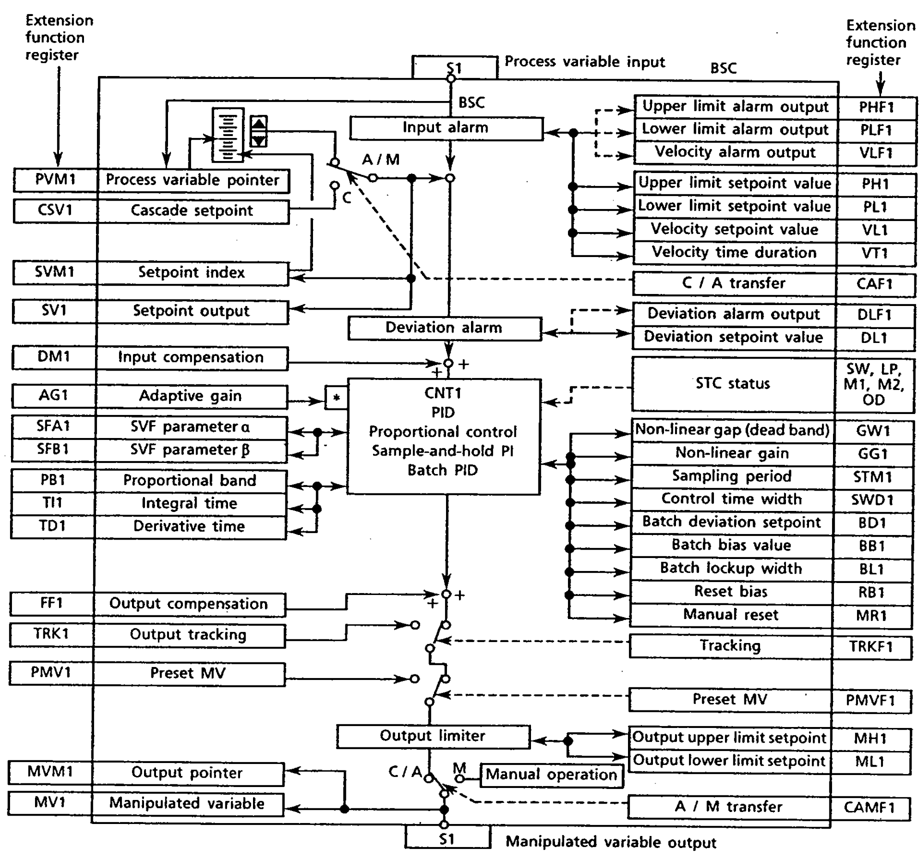


Figure 3.3.4 Block Diagram of BSC Function (For BSC1)

3.3.4 Cascade Control Module (CSC)

The following lists the specifications of the cascade control module (see Section 3.4 and after for details of each specification item).

[Specifications]

- Control type : To be selected from standard PID control or sample-and-hold PI control.
- Control algorithm : To be selected from PV proportional type PID (I-PD), PV derivative PID type (PI-D), or adjustable setpoint filter (SVF).
- Self-tuning function : Exists. Available on secondary loop when the internal cascade is open, and on primary loop when the internal cascade is closed.

Figure 3.3.5 shows the block diagram of the cascade control module, including the functions of the control elements and the expansion register.

(1) Display and Operation

As shown in Figure 3.3.5, display and operation are performed from the front panel for the cascade control module. PV and SV of the CSC and all parameters can be displayed and set from the panel of the YS170 controller.

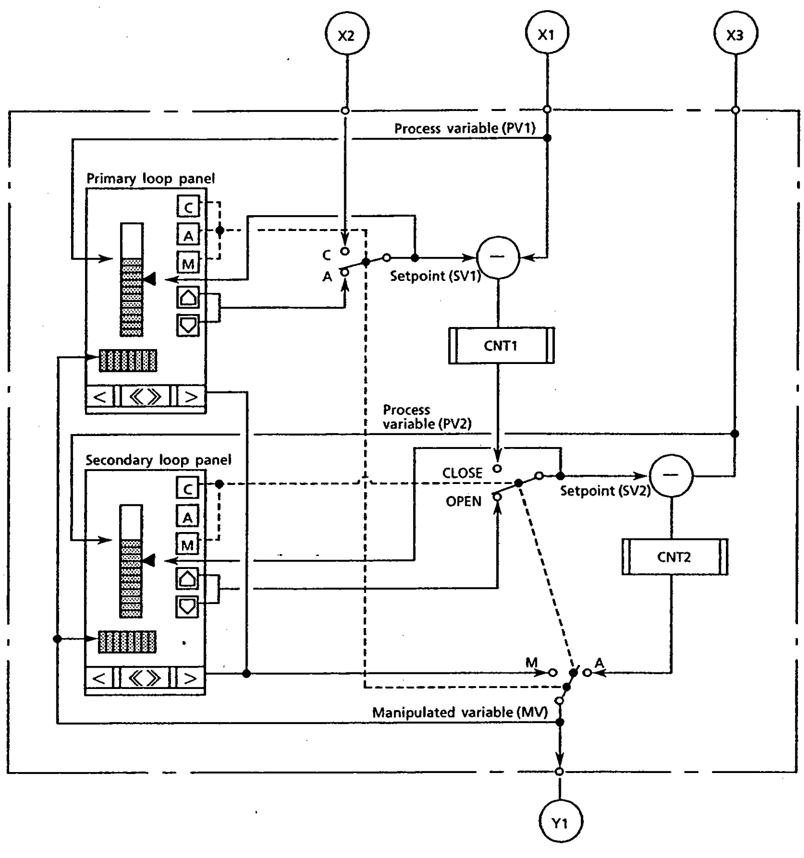


Figure 3.3.5 Display and Operation of CSC Module

(2) Computation Between Two Cascade Loops

For the cascade control module of the YS170 controller, a computation equation can be applied between the primary control loop (CNT1) and secondary control loop (CNT2). Loop-to-loop computation consists of two subprograms (CSCPR1 and CSPR2) (see Figure 3.3.6). Refer to the separately supplied Technical Information TI 1B7C2-03E for "Programming Functions" for details.

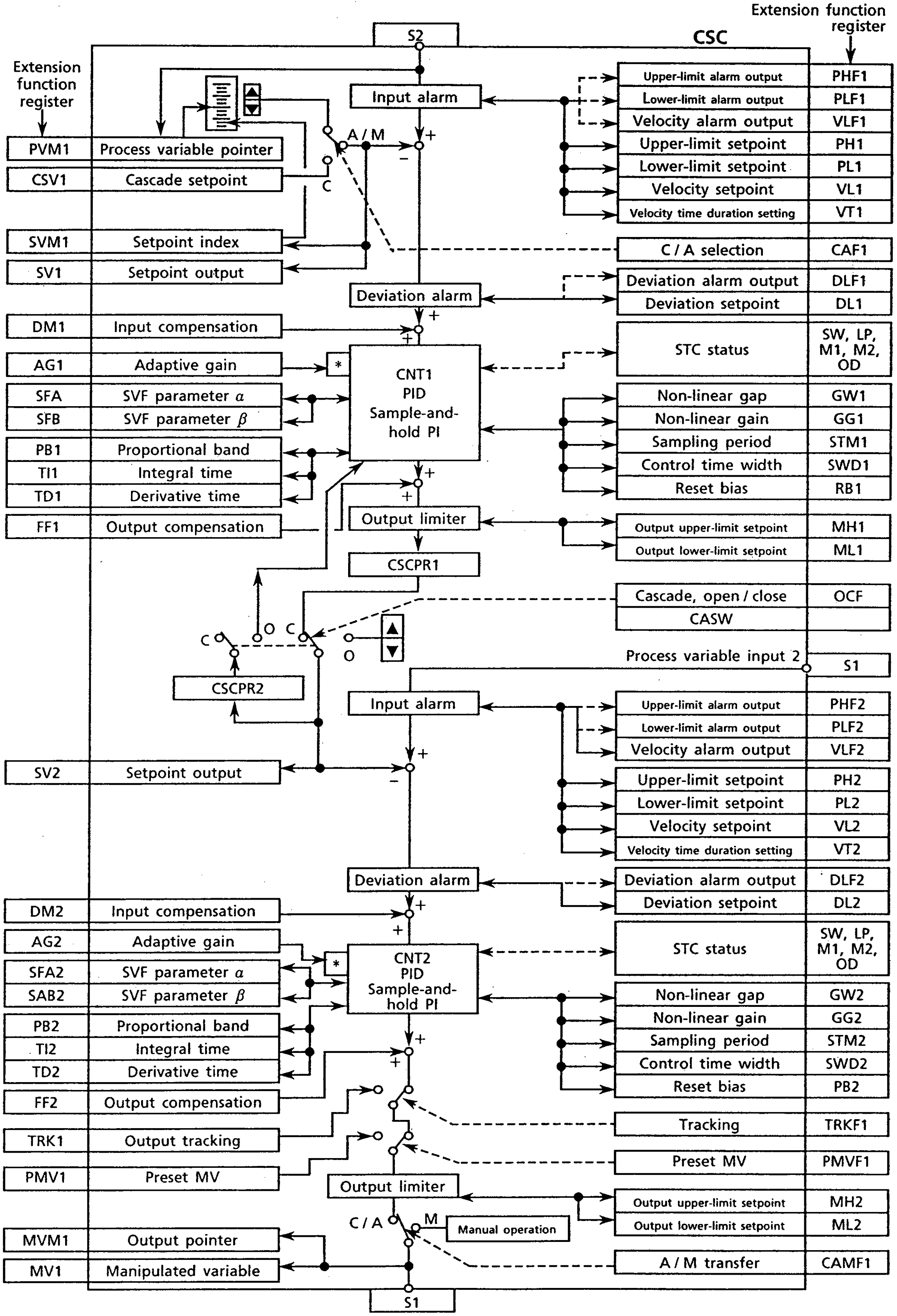


Figure 3.3.6 Block Diagram of CSC Function

3.3.5 Selector Control Module (SSC)

The following lists the specifications of the selector control module (see Section 3.4 and after for details of each specification item).

[Specifications]

- Control type : To be selected from standard PID control or sample-and-hold PI control.
- Control algorithm : To be selected from PV proportional PID type (I-PD), PV derivative type PID (PI-D), or adjustable setpoint filter (SVF).
- Self-tuning function : Exists. Available on the selected loop.

Figure 3.3.9 shows the block diagram of the function of the selector control module, including the functions of the control elements and the expansion register.

(1) Display and Operation

As shown in Figure 3.3.7, display and operation are perfomed from the front panel for the selector control module. PV and SV of the SSC, and all parameters can be displayed and set from the panel of the YS170 controller.

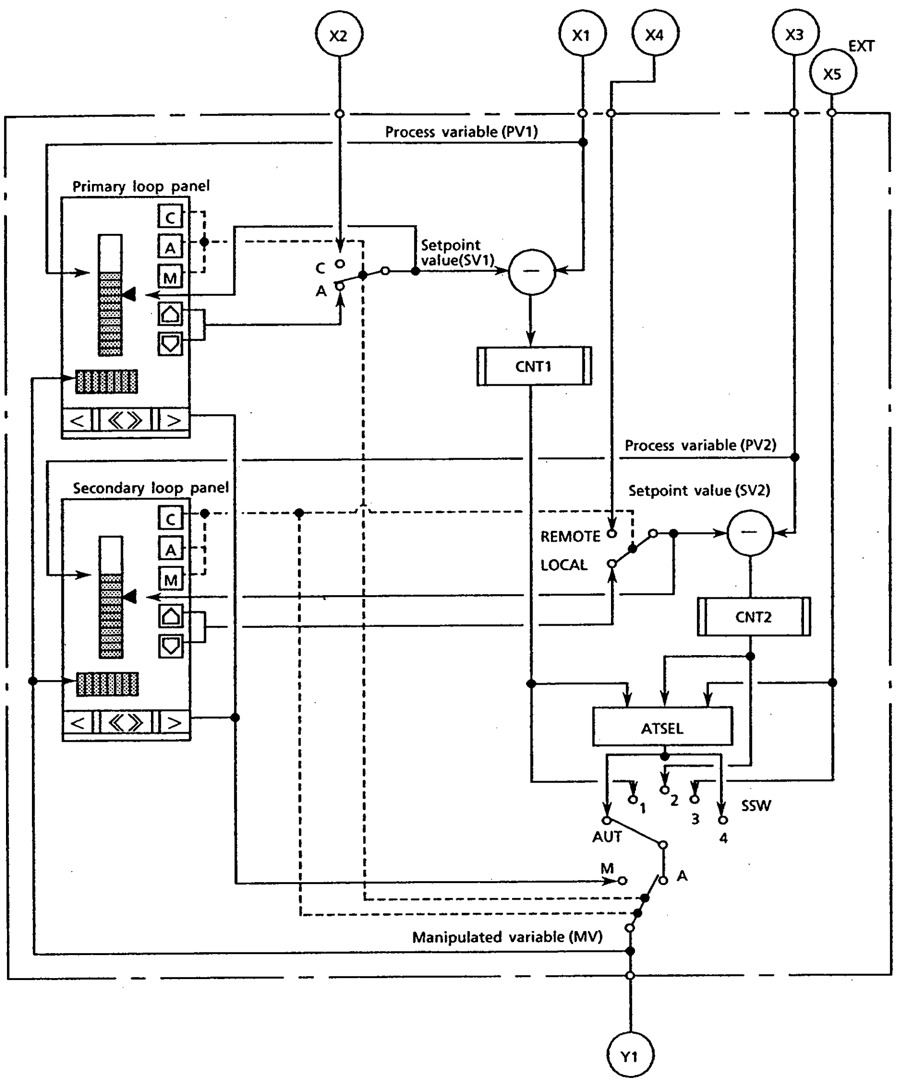


Figure 3.3.7 Display and Operation of SSC Module

(2) Operation of the Selector Control

There are two types of operations for the selector control; autoselector control and manual control. The desired control type can be selected with the selector control selecting switch (SSW).

① Autoselector

Set the selector control selecting switch (SSW) to "AUT" for autoselector control (designation of high selector / low selector is carried out from the configuration panel).
With autoselector control, the unselected control element waits in proportional action (gain × deviation), and switching can be carried out smoothly according to the process status.

② Manual selector control

In order to select the output, set the number of the desired operation outputs to the SSW.

1 = Output of CNT1
2 = Output of CNT2
3 = Output of external signal

With manual selector control, the output of the unselected control element follows manual output, and switching can be carried out bumplessly after receiving the switching signal.

(3) Selector Control Using two YS170 Controllers

A 3 to 4-loop autoselector control system can be configured using two YS170 controllers. In this case, set the SSW on the slave controller to "4" and set the SSW on the master controller to "AUT". Figure 3.3.8 shows the multi-loop autoselector configuration. Refer to the separately supplied Technical Information TI 1B7C2-03E for details on "Programming Functions".

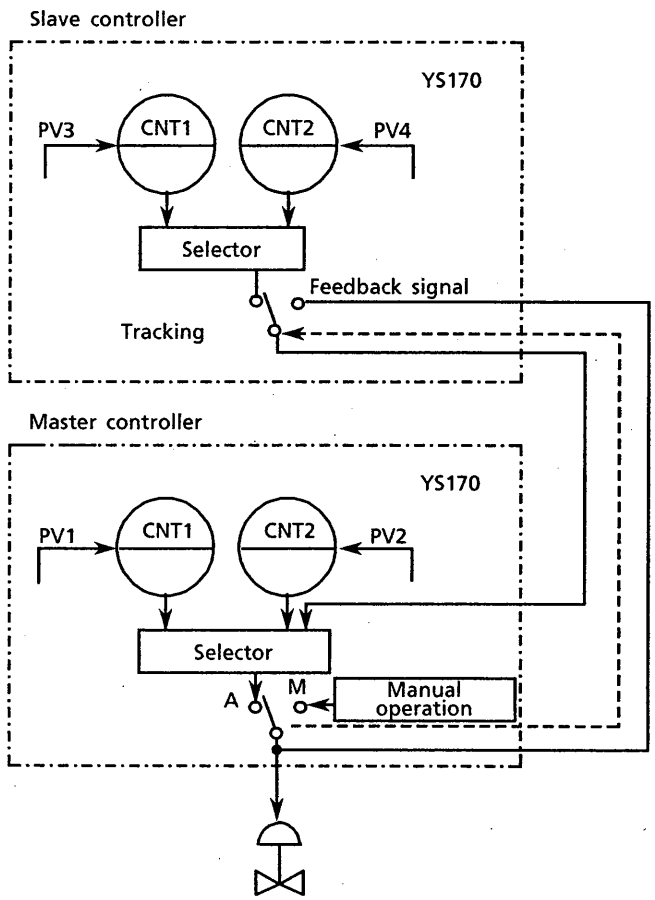


Figure 3.3.8 Multi-loop Autoselector Configuration

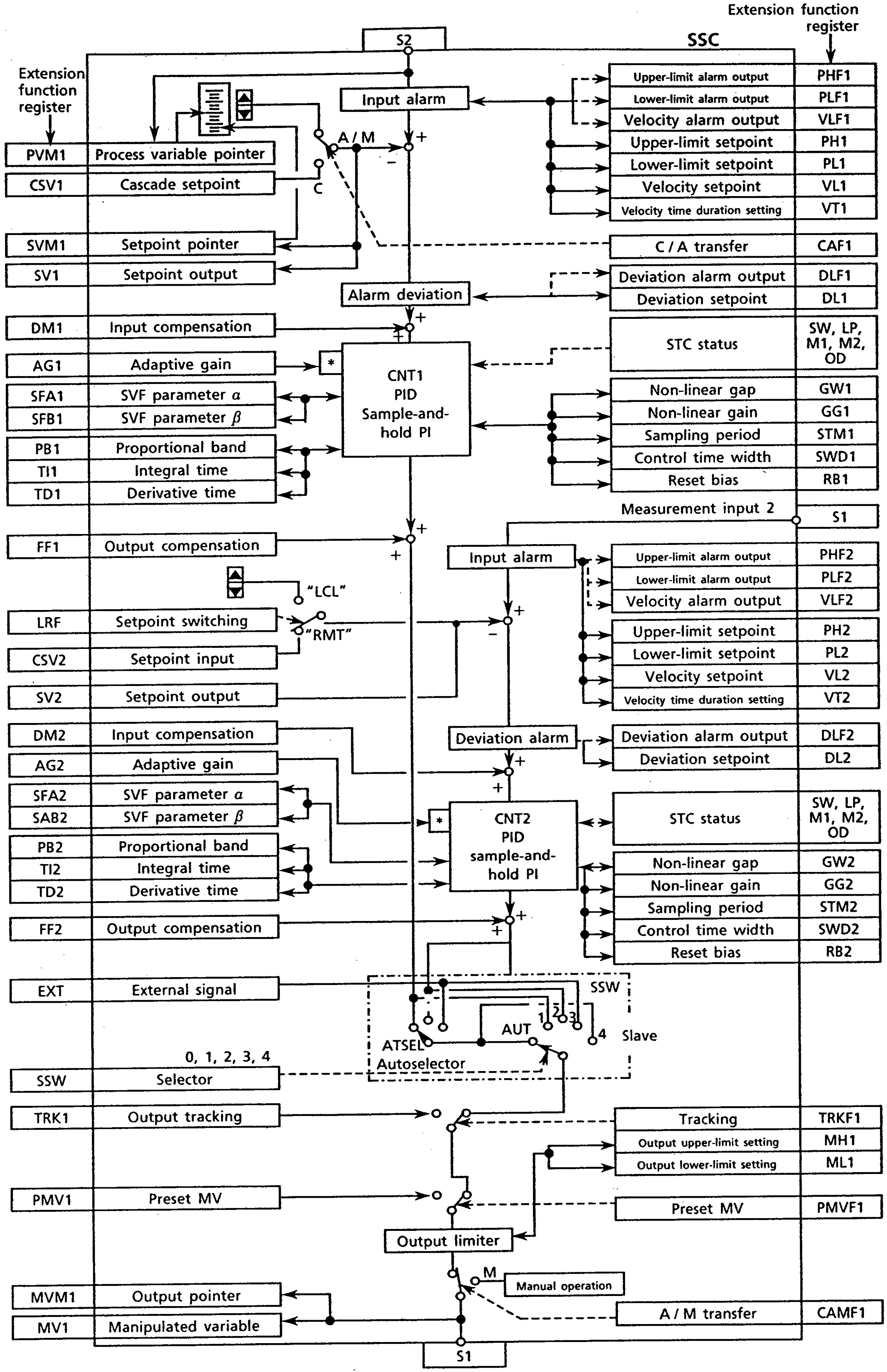


Figure 3.3.9 Block Diagram of SSC Function

3.4 Standard PID Control

This control type includes non-linear control, PID control with reset bias, and the output limiter functions.

3.4.1 PV Proportional Type PID Control (I-PD)

The control computation in the AUTO mode of the YS100 controller is described by equation 3.4.2.

General PID control equation :

$$MV=\frac{100}{P}\left(1+\frac{1}{T_I S}+\frac{T_D S}{1+(T_D/m)S}\right)\cdot E \quad \text{.......................... Eq. 3.4.1}$$

PV Proportional type PID control (I-PD) equation of the YS100 controller :

$$MV=\frac{100}{P}\left(PV+\frac{1}{T_I S}\cdot E+\frac{T_D S}{1+(T_D/m)S}\cdot PV\right) \quad \text{......... Eq. 3.4.2}$$

where : MV: Manipulated output E : Deviation (E=PV - SV) PV : Process variable
P : Proportional band TI : Integral time TD : Derivative time
m : Derivative gain S : Operator

With the YS100 controller, proportional and derivative action are effective not on the deviation but on the process variable. They are not effective on the deviation. In this case, this method is called PV proportional type PID control (I-PD).

In this system, proportional and derivative actions are not effective on changes of setpoint (SV); therefore, a big change of setpoint does not cause an abrupt change of manipulated output, and a stable control characteristic can be obtained. In other words, there is no abrupt change in manipulated output with proportional action. This characteristic is useful for the system with which parameters are numerically set from a supervisory computer or an operator station.

On the other hand, all actions (proportional, integral, and derivative) are effective on process variable (PV) varied by a change in load and in characteristics of the controlled process, and also by disturbance. Therefore, a better controllability can be obtained.

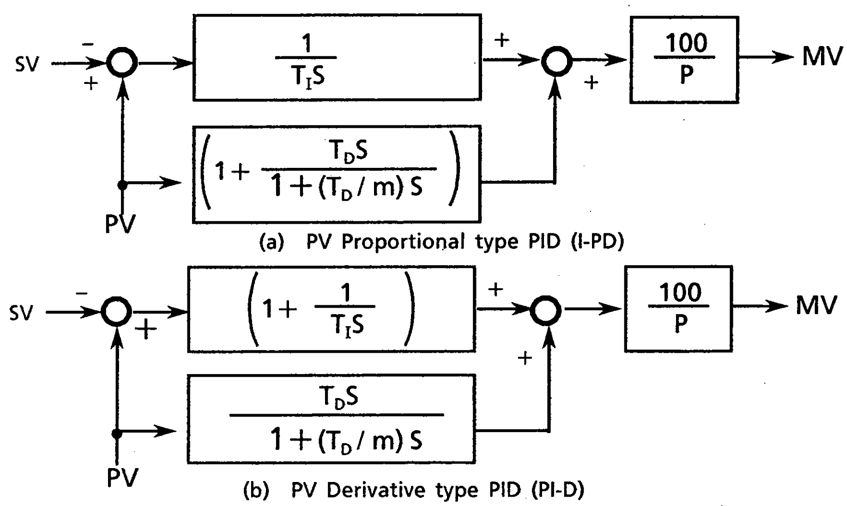


Figure 3.4.1 Block Diagram of PID Control

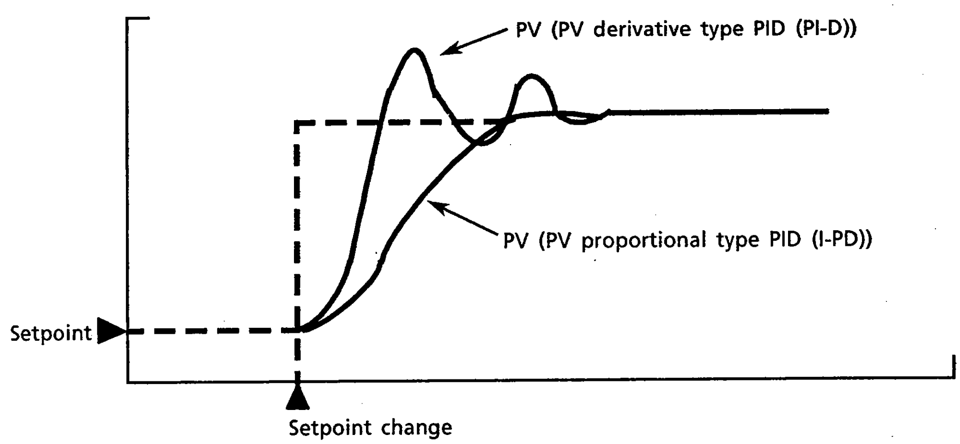


Figure 3.4.2 Response of PV for Setpoint Change

3.4.2 PV Derivative Type PID Control (PI-D)

The computational expression below (Eq. 3.4.3) is ideal for the secondary loop in a cascade control system which requires a better follow-up control characteristic. In this computation expression, the proportional action operates on setpoint change.

PV derivative type PID control (PI-D) of the YS100 controller is expressed as follows.

$$MV=\frac{100}{P}\left(E+\frac{1}{T_I S}\cdot E+\frac{T_D S}{1+(T_D/m)S}\cdot PV\right) \quad \cdots\cdots\cdots \text{Eq.3.4.3}$$

In this control system, derivative action is applied only on the process variable, and it is called PV derivative type PID control (PI-D).

3.4.3 PID Control Algorithm and Operation Mode

To use the YS100 controller in a wide range of applications, PV proportional type PID control or PV derivative type PID control may be selected in accordance with the operation mode (CAS or AUTO). The desired control algorithm can be set by setting item to "ALG" from the configuration panel 2. The control algorithm is automatically set as the table below shows, according to the operation modes "CAS" or "AUTO".

Control Algorithm \ Operation Mode	CAS	AUTO
I-PD	PV derivative type PID	PV proportional type PID
PI-D	PV derivative type PID	PV derivative type PID
SVF	PID with adjustable setpoint filter	

When I-PD is set to control algorithm, either PV proportional type PID or PV proportional type PID is automatically selected according to the operation mode selected.

When PI-D is set to control algorithm, PV derivative type PID is always selected. This control algorithm is ideal for obtaining a better follow-up characteristic to a change of setpoint in the AUTO mode.

When SVF is set to control algorithm, PID with adjustable setpoint filter operates. See Section 3.8 for details of the SVF.

3.4.4 Non-linear PID Control

When the deviation is smaller than the non-linear gap (dead-band), the deviation is multiplied by the preset small gap gain. When the deviation is larger than the non-linear gap (dead-band), the deviation is multiplied by 1.

Figure 3.4.4 shows the non-linear element characteristics.

< Specifications>

Non-linear gain (GG) : 0 to 1.000

Non-linear gap (dead-band) (GW) : 0 to 100.0%

Non-linear gain and non-linear gap (dead-band) can be set in setting items GW and GG from the PID setting panel.

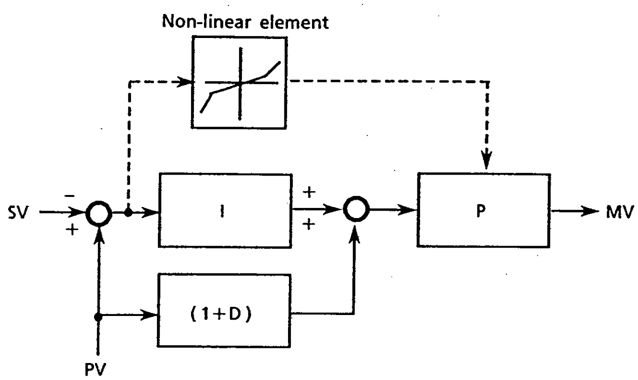


Figure 3.4.3 Non-Linear PID Control Block Diagram

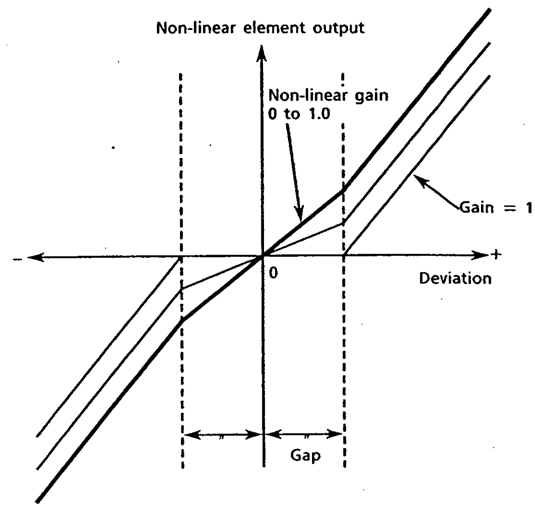


Figure 3.4.4 Non-Linear Element Characteristic

<Non-Linear PID Control Features and Applications>

(1) Excellent Follow-up to Setpoint Changes

When the setpoint is changed beyond the non-linear gap (dead-band), a rapid response is obtained by setting the narrow PB value (small PB value). When the deviation is small, overshoots are minimized by the small non-linear gain (see Figure 3.4.5).

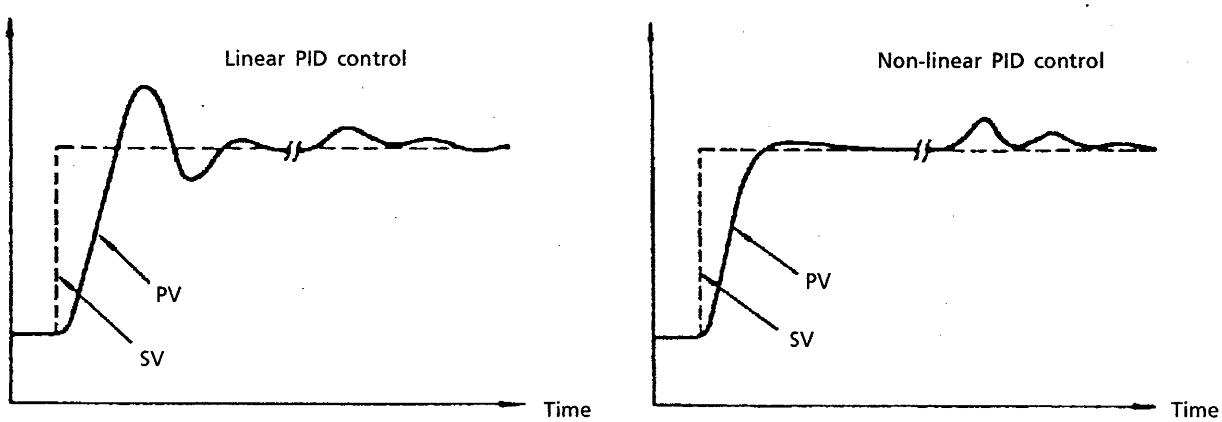
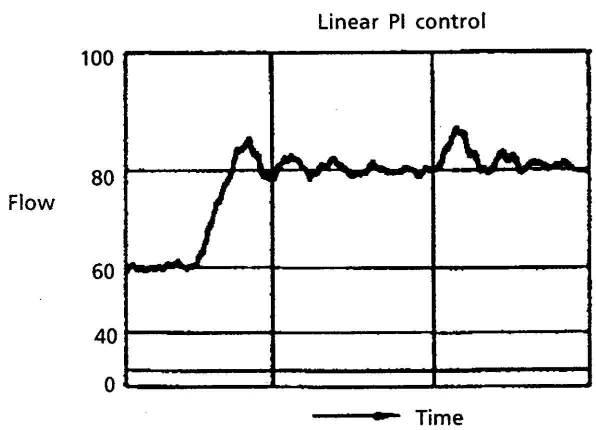


Figure 3.4.5 Response to Setpoint Change for Non-linear PID Control

(2) Suitable for Suppressing Noises and Cyclic Pulsations

When non-linear PID control is applied to process control, the gain is small for small deviation, therefore, the change of the valve opening which is caused by noise is smoothed making the control system more stable. When the deviation becomes large with a narrow proportional band setting, pull-back response is rapid.



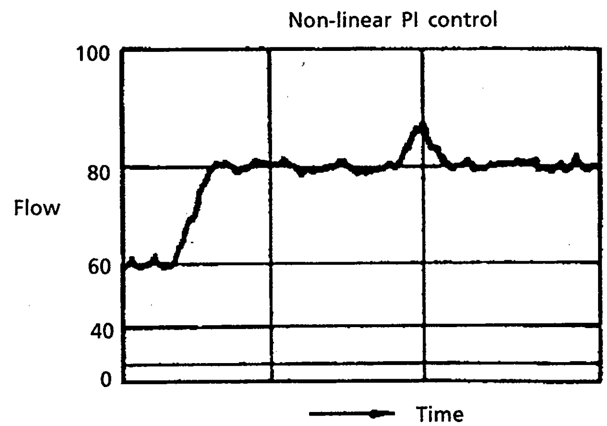


Figure 3.4.6 Effect of Non-linear PI Control in Noisy Flow Contorl System

(3) Suitable for Controlling the Liquid Level in a Tank (Averaging Level Control)

Liquid level control is mainly applied to surge tanks. In this application, it is more desirable to stabilize the outflow from a production process (i.e. the manipulated value in liquid level control) than to achieve precise liquid level control.

Non-linear PID control makes it possible to obtain an even outflow that is not affected by small fluctuations in the liquid level caused by splashing, turbulence, boiling, etc..

Figure 3.4.7 shows a simplified block diagram of such a process, and Figure 3.4.8 shows an example of the control characteristics.

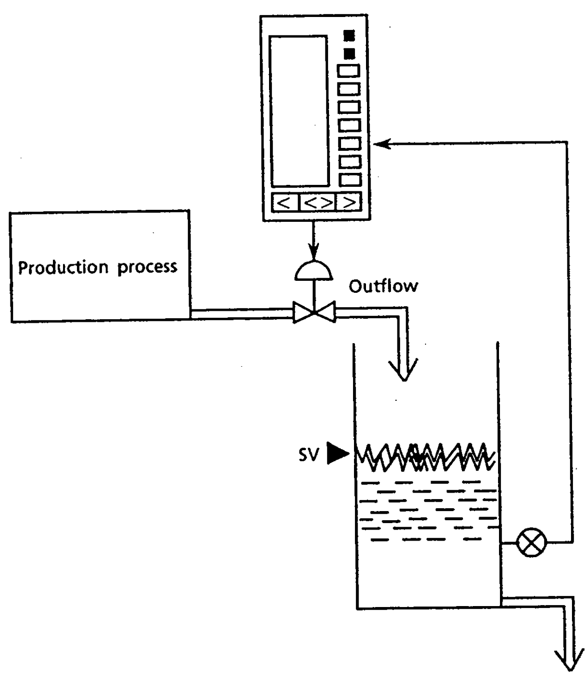


Figure 3.4.7 Averaging Level Control

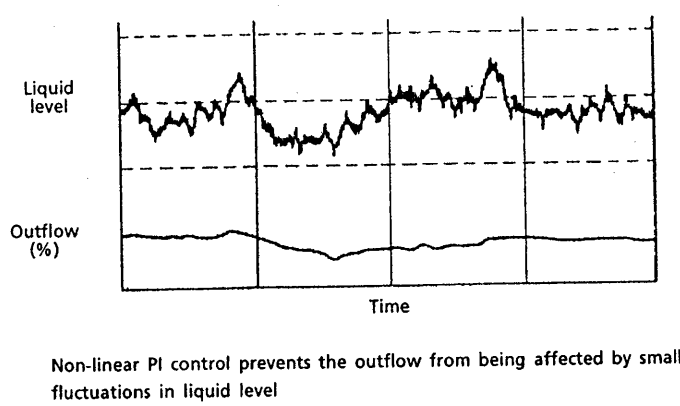


Figure 3.4.8 Example of Control Characteristic

(4) Neutralization Control Where Process Gain Changes Greatly in the Vicinity of the Control Point

Linear PID control is not applicable to neutralization processes (for maintaining a liquid at pH 7), because the neutralization process characteristic shows high gain near pH 7 and low gains at both high and low pH values.

Since a non-linear pH control system has a gain characteristic that is opposite to the neutralization process characteristic, a constant closed loop gain can be obtained over a wide range of pH. Thus, stable control can be achieved (see Figures 3.4.9 and 3.4.10).

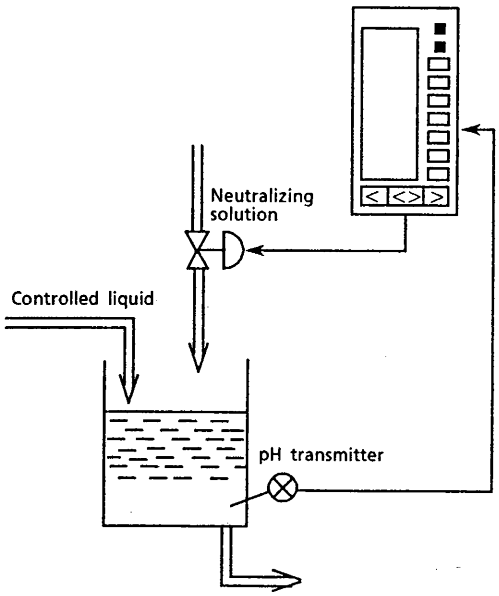


Figure 3.4.9 Neutralization Process Control

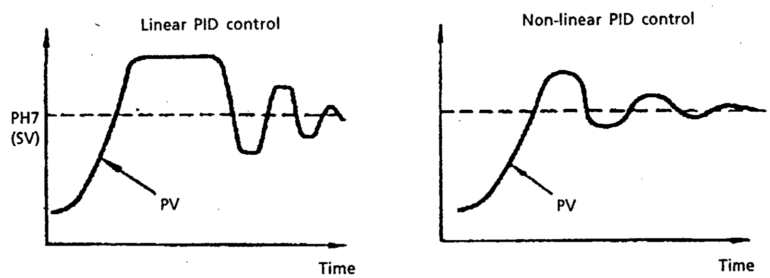


Figure 3.4.10 Comparison of Control Characteristics

3.4.5 Output Limiter

The output limiter of the YS150 / YS170 controller restricts the integral control action and decreases reset wind-up when the manipulated output begins to exceed the limit value. Thus, the process variable begins to return to the normal value with less transient overshoot.

<Output Limiter Setting Range>

The desired output limiting level can be set within the following range from the PID setting panel.

Upper limit setting (MH) : –6.3 to 106.3%
Lower limit setting (ML) : –6.3 to 106.3%
If you set "ML > MH", then only MH is effective.

3.4.6 PID Control with Reset Bias Function

The output limiter of the YS100 controller stops integral action when the manipulated output value reaches a limit, to prevent reset windup–an output saturation effect that is due to integral action.

However, some batch processes use controllers with reset bias (a type of reset windup) to improve the PV startup time.

The reset bias determines the time it takes for the output to fall below the limit after the process variable starts to revert towards the setpoint.

For the simple batch heating process shown in Figure 3.4.11, at batch end the steam stop valve is closed but the controller settings and control mode (e.g. Auto) are left "as they are". In this case, for a PID controller with reset bias, the relationship between inputs and outputs is as shown in Figure 3.4.12. The manipulated variable output remains clamped at MH after PV starts reverting towards SV, due to reset bias, a type of reset windup (MV' = MV+RB).

When the next batch starts, and the steam valve is opened, PV gradually starts to rise but –because of the effects of reset bias –MV remains for a while at the MH limit point. This results in a fast atartup time.

On the other hand, when a simple output limiter (with reset bias = 0%) is used, there is no reset windup, and as soon as the process variable begins to start up, the manipulated variable leaves the limit value (MH). Thus, as shown by the dotted line in Figure 3.4.12, the startup time for PV (for RB = 0) is relatively long.

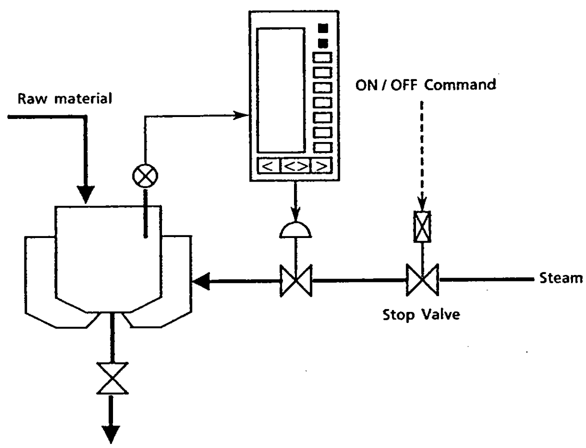


Figure 3.4.11 Simple Batch Process

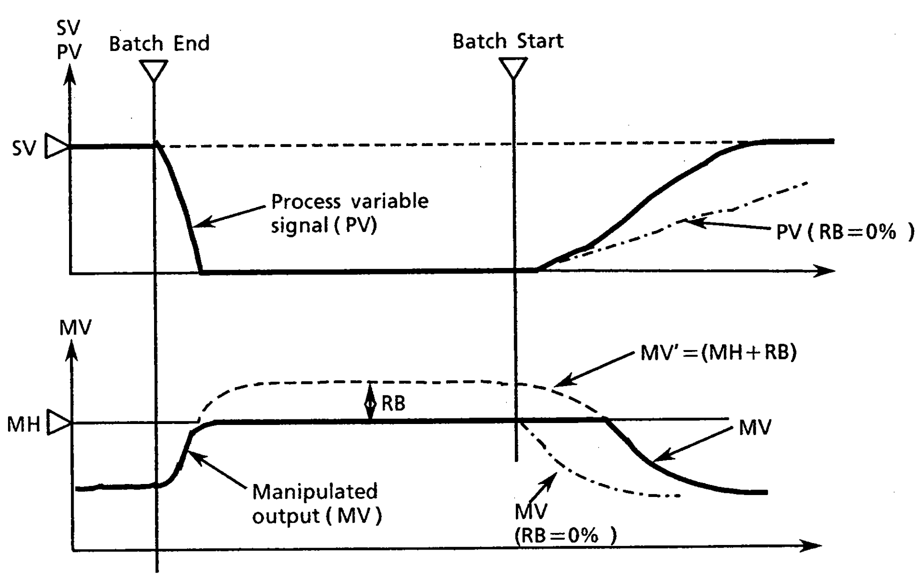


Figure 3.4.12 PID Control with Reset Bias Function

<Reset Bias Adjustment Method>

The reset bias value RB is set by the RB key from the PID setting panel of the instrument.

When this key is set to 0%, PID control is performed without the RB function. As the RB value is gradually increased, the response characteristic is improved, and the time required to reach the set value decreases. Set the optimum RB value empirically, while monitoring the response characteristic.

If the RB value is increased above the optimum RB value, the response characteristic will exhibit overshooting and oscillation.

When the RB value is increased to greater than 100%, the corrective action begins after the set value exceeds the process variable value.

This is applicable to the special control of pressure relief valves, etc..

<Application of PID Control with Reset Bias Function>

(1) Batch Process Temperature Control

This is effective for improving the startup-time characteristic of batch processes, as previously described.

(2) Relief / Safety Valve Control

A relief valve or safety valve can be operated by increasing the reset bias to 100%.

The safety valve is shut off under stable conditions, and opened to release the internal pressure and keeps the process safe if the internal pressure rises to a high value due to a process abnormality. Figure 3.4.13 shows this process. Figure 3.4.14 also shows the relationship between the internal pressure and the opening of the safety valve.

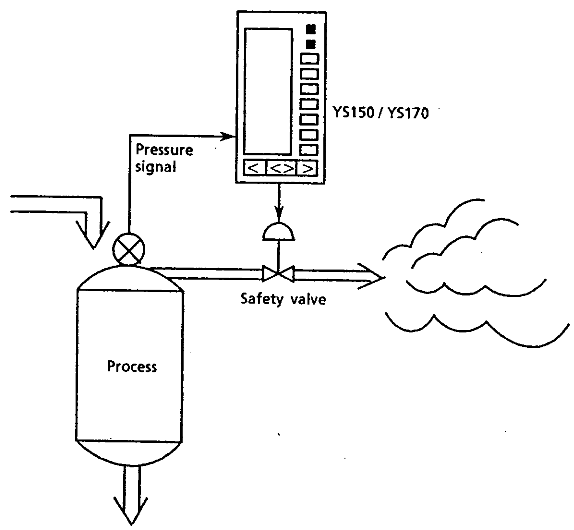


Figure 3.4.13 Safety Valve Control

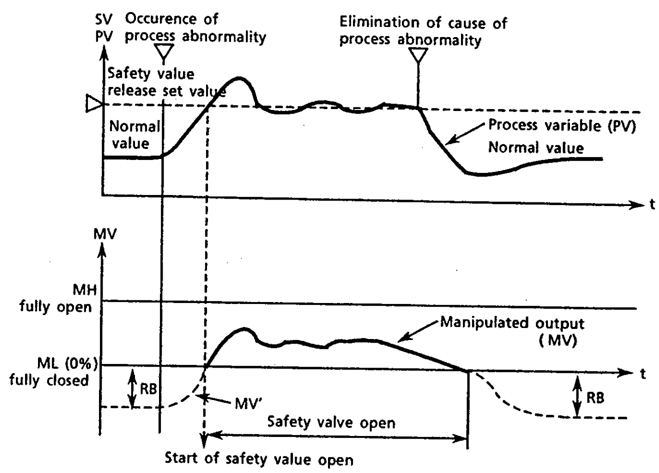


Figure 3.4.14 Internal Process and Safety Valve Release

3.5 Proportional Control (PD Control)

Proportional control is used for special control effects by eliminating the integral control action from the PID control action.

<Operating Description>

The manipulated output for proportional control is expressed by the following equation for both the AUTO and CAS mode.

$$MV = \frac{100}{P}\left(E + \frac{T_D S}{1+\left(\frac{T_D}{m}\right)S}\cdot PV\right) + MR \quad \cdots\cdots\cdots\cdots\cdots \text{Eq. 3.5.1}$$

In the equation, MR is manual reset (bias to compensate for any offset caused by proportional control).

MR can be set from the PID setting panel.

In order to avoid an output bump caused by operation mode switching, first-order lag follow-up switching is provided. A non-linear computating function is also possible.

When using PD control be sure to always set the item ALG in the configuration panel 2 to PI-D.

<Specifications>

Manual Reset : –6.3 to 106.3%.

First Order Lag Time Constant : 1 to 9999s (set by T_I).

Table 3.5.1

Operation Mode Switching \ Variable	Set Value	Manipulated Output
A → C	Quick response	First-order lag follow-up
M → A	No change	First-order lag follow-up

Other operational mode switching is the same as for PID control

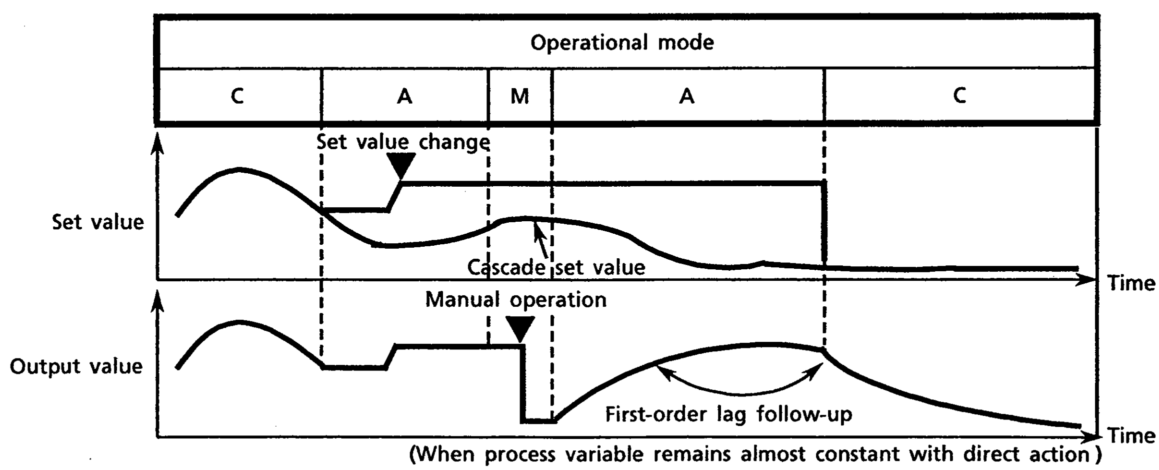


Figure 3.5.1 Operation Mode Switching and Movement of Set Value and Manipulated Output

<Proportional Control Applications>

(1) Tank Level Control (Integral Process Control)

One application of proportional control is in controlling the level of liquid in a tank, from which liquid is being pumped by a constant-volume pump, by controlling the flow rate of liquid into the tank.

Pure proportional control results in stable control with no overshoot (see Figure 3.5.2). (For PI control, the integral action results in oscillation.)

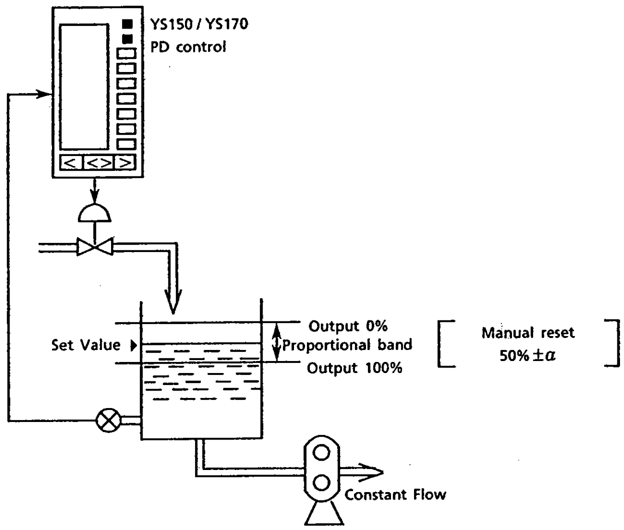


Figure 3.5.2 Example of Level Control

(2) Control of End-point in a Chemical Reaction

In a process where the product is produced by a thermal reaction which is started by heating raw materials (Figures 3.5.3, 3.5.4), an analyzer is used to determine the status of the product, and an end point is set to switch off the steam valve (stop the applied heat) and ensure that the reaction does not "run away".

In this situation, PD control is ideal. (PID control is not suitable because of overshoot).

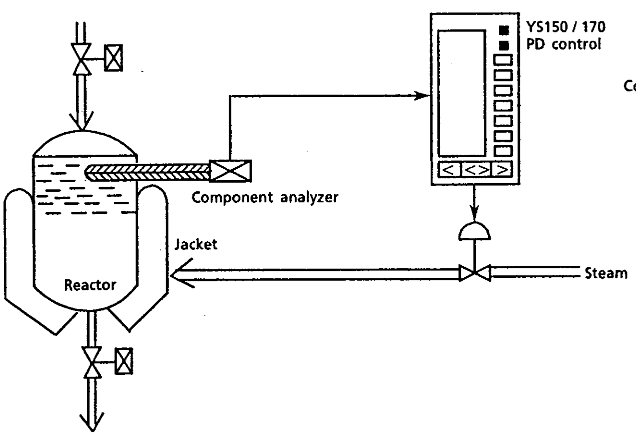


Figure 3.5.3 Chemical Reaction End Point Control

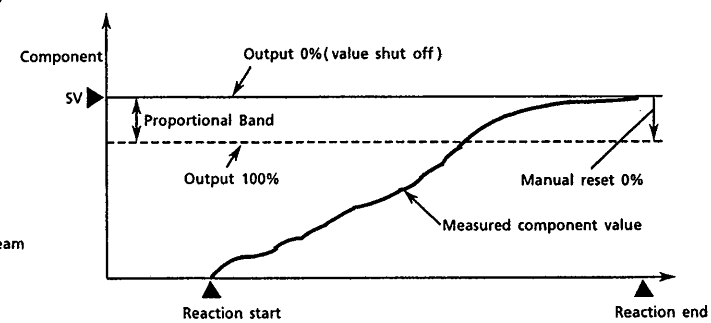


Figure 3.5.4 Component Control Results

3.6 Sample-and-Hold PI Control (applies only to YS170 Controller)

Sample-and-hold PI control is ideal for processes with long dead time–processes where changes in the manipulated variable are not reflected immediately in the process variable. Sample-and-hold PI control provides control action for short periods every sampling cycle.

This controller also includes non-linear control.

<Operation>

Sample-and-hold PI control is illustrated in Figure 3.6.1.

PI control is carried out only during the start of the control time (SWD) in the sampling period (STM). The manipulated variable is maintained after it goes past the control time.

<Parameters>

The following parameters are added to the standard PID parameters.

- Control parameters

  Sample-and-hold PI control parameters are as follows:

  Sampling period (STM): 0 to 9999 seconds

  Control time (SWD) : 0 to 9999 seconds

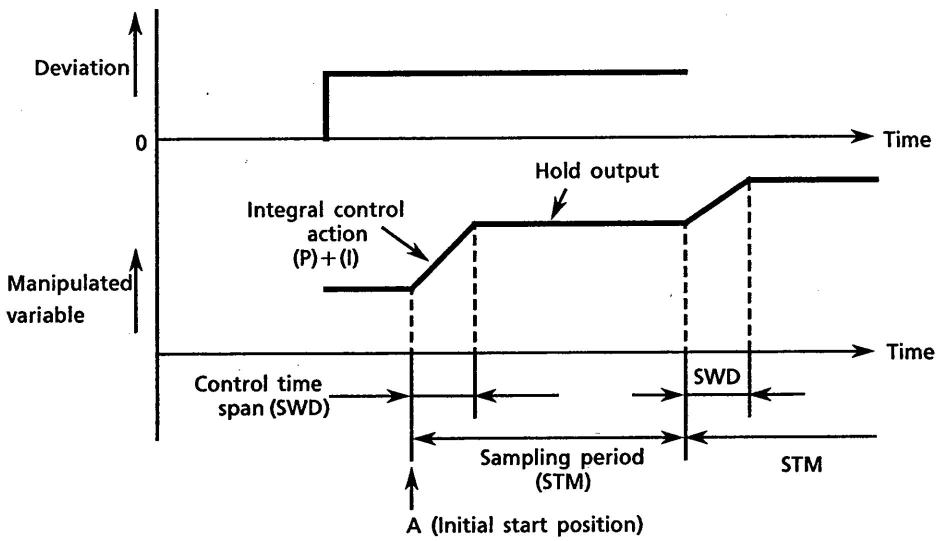


Figure 3.6.1 Sample-and-Hold PI Control Operation

Sample and hold PI control guidelines are shown below:

STM $= L + T \times (2 \text{ to } 3)$ L : Dead Time

SWD $=$ STM / 10   T : Lag time constant

STM should be as long as possible in relation to risetime characteristics in order to reduce overshoot. However, if the minimum period T_N of the main disturbance affecting the process is smaller than STM, the disturbance cannot be controlled. Thus, the setting should be: $STM \leqq T_N / 5$.

<Detail>

- When SWD $= 0$ no PI control is performed

  When SWD $\geqq$ STM (SWD $\neq 0$) PI contrl is performed every control period.
- The control operation when changing the mode C, A, or M is as follows.

  M→A : Resets and starts from the point A in Figure 3.6.1.

  A→C : (Same as above)

  Other cases : Continues the operation
- When changing STM or SWD from user program or the engineering panel (SMPL & BATCH) the control operation continues using changed values soon after the changing.

3.7 PID Control with Batch Switch (applies only to YS170 Controller)

PID control element with batch switch is used to obtain a desired value (set point) quickly and to provide control without overshoot.

<Operation>

In PID batch operation with reverse control action (see Figure 3.7.1), the manipulated output high limit value (MH) is output if the deviation is outside the deviation band (BD). When the deviation is brought within the deviation band, a bias BB is subtracted from the output (MV = MH−BB) to prevent overshoot, and the controller switching to PID control.

After switching to PID control, the output does not return to the output high limit value unless the deviation exceeds deviation set point BD plus lockup band BL.

In the case of direct control action, the manipulated output low limit ML is used instead of manipulated output high limit MH, and bias BB is added to the output instead of being subtracted from the output.

<Parameters>

The following parameters are added to the standard PID parameters.

- Setting Parameters from the Panel.

  The following parameters are associated with batch control:

  Deviation band (BD): 0 to ± 100% (absolute value setting)
  Bias band (BB) : 0 to ± 100%
  Lockup band (BL) : 0 to ± 100%

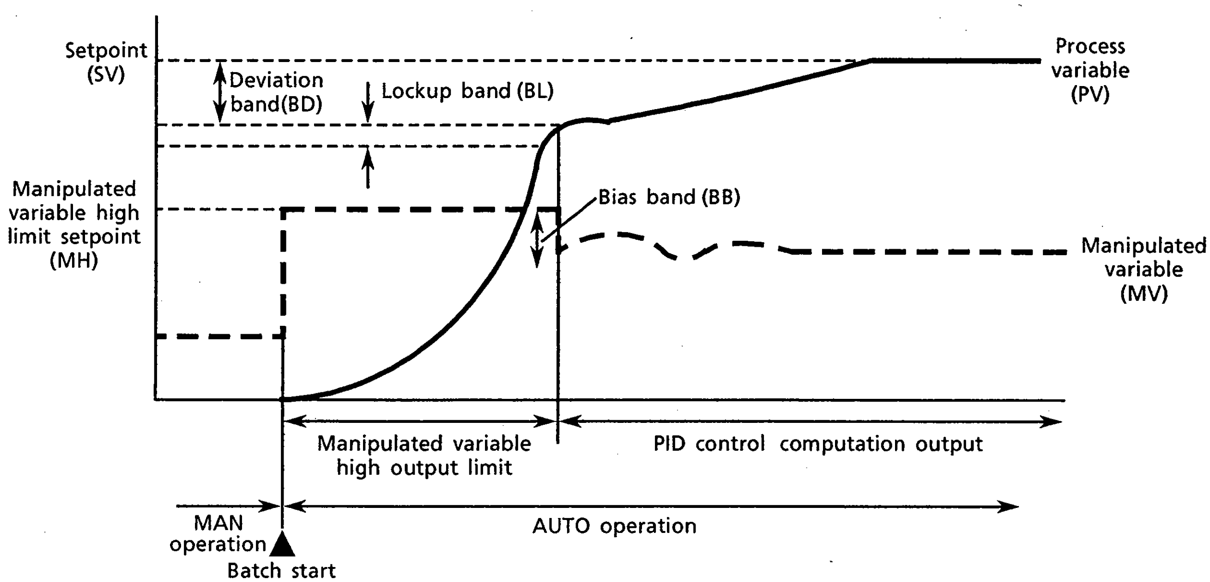


Figure 3.7.1 Batch PID Control Operation

3.8 Adjustable Setpoint Filter (SVF)

In PID control, the values of parameters P, I, and D which are optimum from the point of view of suppressing noise that is superimposed on the process variable, and the values that provide optimum response to setpoint changes, are not necessarily the same. PI-D (PV derivative type PID control) and I-PD (PV proportional type PID control) implementations of the PID control algorithms are frequently used; After optimum tuning is performed for disturbance, their characteristic response to setpoint changes is as shown in Figure 3.8.1. Adjustable SetPoint Filter provides a convenient way of allowing the response curve to be continuously adjusted between these two characteristics.

3.8.1 Principles of Operation

In the YS150/YS170 controller, a PI-D (PV derivative type PID control) algorithm is used, and the Adjustable SetPoint Filter (SVF) is installed in series with the setpoint input. By varying the two filter parameters, α and β, the controller response characteristic can be changed continuously between a PI-D characteristic and an IP-D characteristic (see Figures 3.8.2 and 3.8.3).

The SVF filter is described as follows:

$$SVF = \frac{1+(\alpha T_I-\beta T_D)S}{1+(T_I+T_D)S} \quad \cdots\cdots\cdots\cdots \text{Eq. 3.8.1}$$

however, $\alpha = 0$ to 1, $\beta = 0$ to 1, $(\alpha T_I-\beta T_D) \geqq 0$

T_I = integral time, T_D = derivative time

$T_D = 0$ in the SVF equation when no derivative action or $\beta = 0$.

Filter characteristic = 1 when $\alpha = 1$, $\beta = 0$ and the controller response is PI-D.

If $\alpha = 0$, $\beta = 0$, the characteristic reduces to first-order lag (time constant = T_I), and the controller response is I-PD.

By varying α in the range $0<\alpha<1$, the controller response can be varied continuously between PI-D and I-PD.

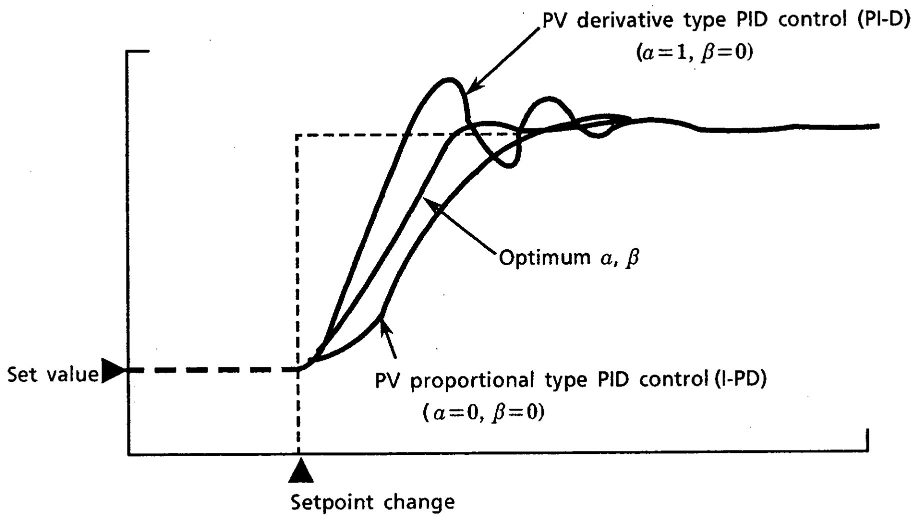


Figure 3.8.1 Response When Set Point is Changed

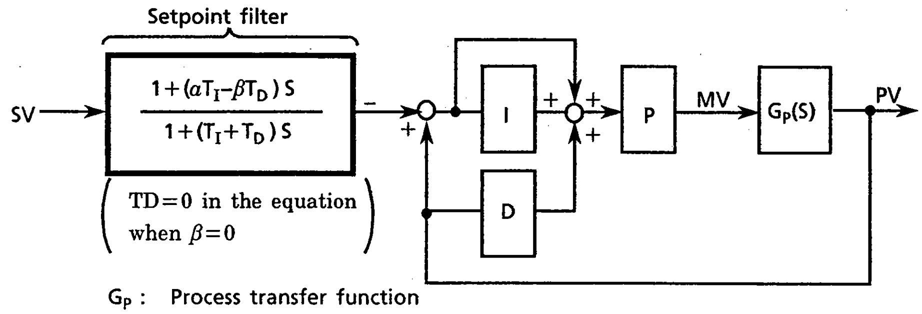


Figure 3.8.2 Setpoint Filter Function Block Diagram

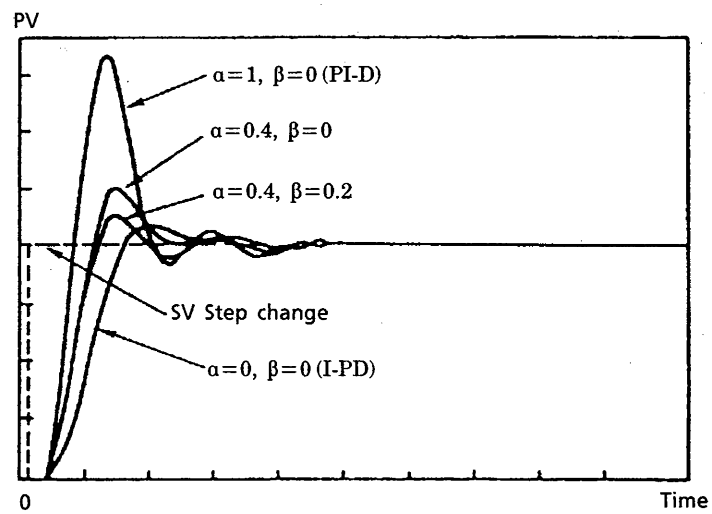


Figure 3.8.3 Examples of Setpoint Response Characteristics

3.8.2 Effects of Parameteters α and β.

Some examples of setpoint response characteristics with different values of α and β in the range of 0 to 1 are shown in Figure 3.8.4.

Varying the α has a large effect on the response. Increasing the value of α shortens the rise time and increases the overshoot. β has much less effect on the response, and is useful for "fine-tuning" the response. The larger the value of β, the smaller the overshoot.

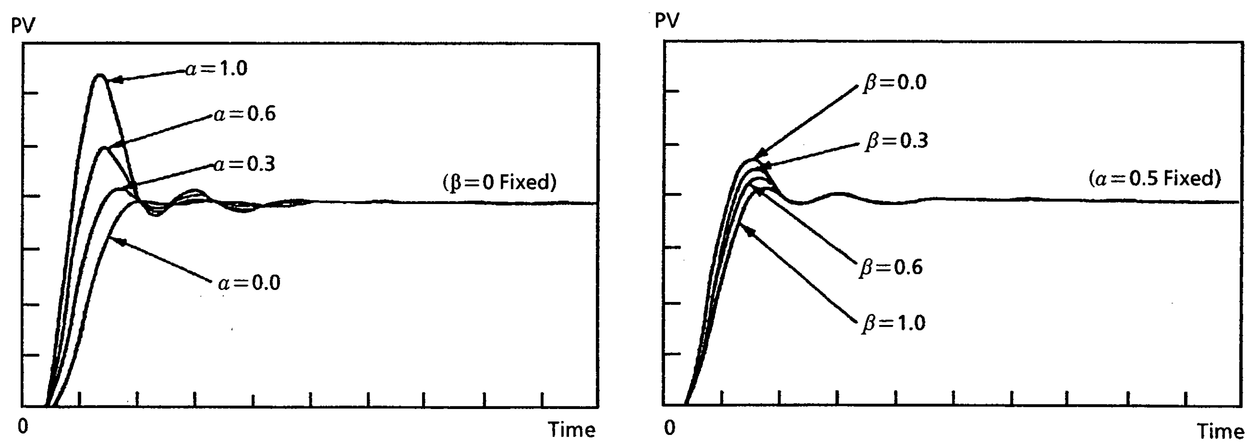


Figure 3.8.4 Effects of Parameters α and β

3.8.3 Setting SVF Function

Set "SVF" in setting item "ALG" from configuration panel 2, and set values of α and β from the PID setting panel.

The data type of α corresponds to the data type of SFA, and the data type of β corresponds to that of SFB.

3.8.4 Tuning Methods

(1) Without Using Self-Tuning Function:

(i) Apply a step change to the manipulated output, measure the response, calculate optimum values of P, I, and D by the usual methods and set these values.

(ii) Apply a step change to the setpoint, and adjust α (SFA) until the desired response characteristic is obtained. If derivative control action is being used, further fine adjustment with β (SFB) if possible.

(iii) The recommended values of α and β are $\alpha = 0.5$ and $\beta = 0.0$.

(2) Using Self-Tuning Function

(i) Set values of α and β to 0.5 and 0.0 respectively and start up the instrument with the self- tuning function.

Table 3.8.1 SVF Setting Mode and Parameter

MODE	Operation Mode		Srtpoint Filter	Parameter	
	CAS, SPC	AUTO		SFA($=\alpha$)	SFB($=\beta$)
I-PD	PI-D	I-PD	$\frac{1}{1+T_I S}$	–	–
PI-D		PI-D	1	–	–
SVF	SVF		$\frac{1+(\alpha T_I-\beta T_D)S}{1+(T_I+T_D)S}$	0.0 to 1.0	0.0 to 1.0

3.8.5 Application Examples of the SVF Function

The SVF function is effective in the following applications:

- Secondary controller in cascade control (when the response with PI-D control is too oscillatory).
- Program control of temperature.
- Control loops with frequent setpoint changes.

3.9 Feedforward Control

3.9.1 Description of Operation

When only feedback control is used, the corrective action (PID control) acts after the effects of a disturbance appear in the process variable signal, and so restoration of the controlled system to normal is delayed.

When the disturbance can be measured, the disturbance can be cancelled before the effects of the disturbance appear in the controlled system by applying a signal – to correct the disturbance–directly to the controller.

This action is called feedforward control or feedforward compensation. Usually it is used together with feedback control. The YS-150 / 170 also implements feedforward plus feedback control.

In Figure 3.9.1

$$PV = (MV_c - G_f \cdot D)\, G_p + G_d \cdot D$$
$$= MV_c \cdot G_p + (G_d - G_f \cdot G_p)\, D$$

Where MV_c: Manipulated output before feedforward compensation

G_r : Feedforward factor for disturbance D

G_p : Process transfer function

G_d : Process transfer function for disturbance D in PV

Therefore, if $G_f = G_d / G_p$, the effect of a disturbance can be compensated.

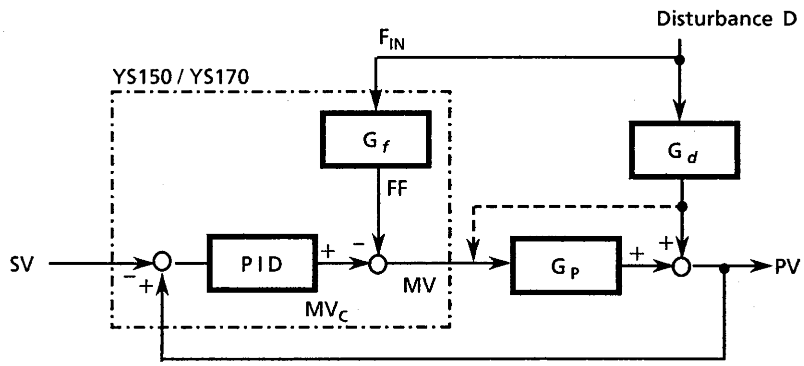


Figure 3.9.1 Feedback Plus Feedforward Control in YS100

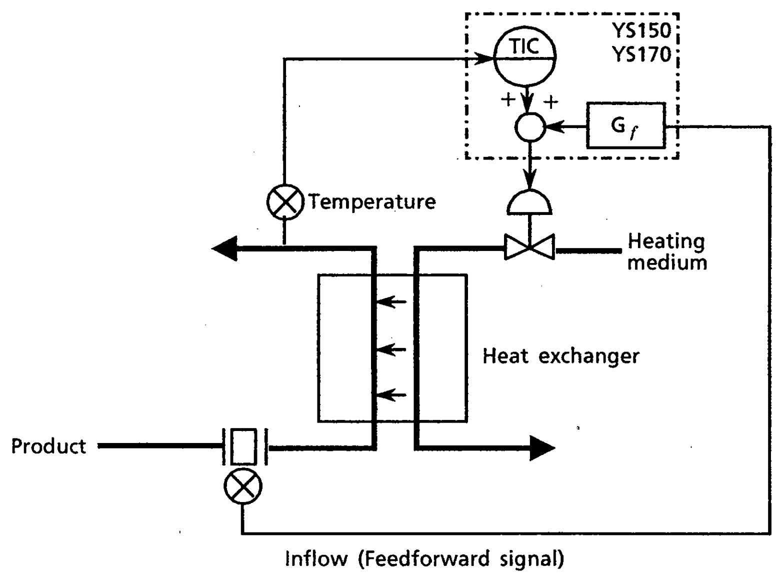


Figure 3.9.2 Control of Heat Exchanger

Using the YS-150 / 170, the gain and bias calculations for the process variable input signal (feedforward input) are as follows:

The manipulated output (MV) is

$$MV = MV_C + FF$$

$$FF = F_{GN} \left\{ \frac{1}{1+F_{LG} \cdot S} F_{IN} + F_{BI} \right\} + F_{BO}$$

Where MV_C: Manipulated output for feedback control

F_{GN} : Gain (−8.000 to 8.000)

F_{LG} : First-order lag time constant

F_{IN} : Feedforward input (1 to 5V / 0 to 100%

F_{BI} : Input bias (−106.3 to +106.3%)

F_{BO} : Output bias (−800.0 to+ 800.0%)

The value FF is limited to within the following range, regardless of the above equation: $-100\% \leqq FF \leqq 200\%$.

The above parameters can be set in the items FGN, FLG, FBI, and FBO on the parameter setting panel.

In the programmable mode of YS170, the computation expression can be programmed by using computation functions and expansion registers.

3.9.2 Application Examples of Feedforward Control

(1) Improving Control Characteristic of Heat Exchanger

For the control of a simple heat exchanger such as the one shown in Figure 3.9.2, you can provide automatic compensation for the variation in the inflow by adding feedforward control.

(2) Neutralizing Control

Neutralizing reactions are difficult to control due to their long reaction time. In the same manner as above, by adding feedforward control, variations in treated water flow and composition (pH value) can be compensated.

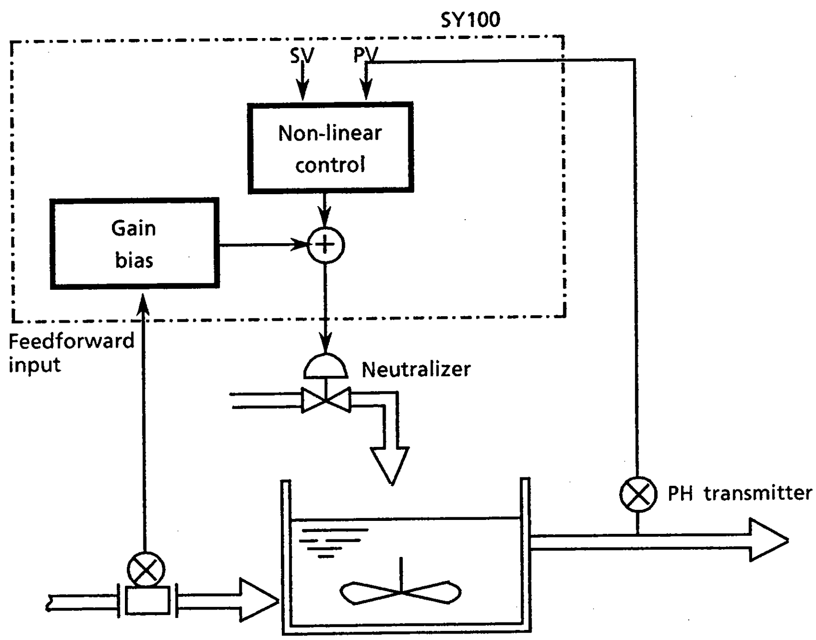


Figure 3.9.3 Neutralizing Control

3.10 Preset PID (applies only to YS170 controller)

In preset PID control, the eight PID parameters are set in the preset PID table. The desired PID parameters, depending on the process status, are selected from the eight preset PID parameters using the user program, and they are set to two control elements. Refer to the separately supplied Technical Information TI 1B7C2-03E "Programming Functions" for details.

3.11 Operation Mode Switchings

Three operation modes, cascade setting automatic control (C), automatic control (A), and manual control (M) are available on the YS150 / YS170 controller. The desired operation mode can be selected from the C-A-M key on the front panel, the contact input, or the supervisory system.

Two modes, analog cascade setting mode and computer cascade setting mode (or DDC mode) can be selected as the C mode by setting one of them to the item CMOD from the configuration panel.

3.11.1 Operation Mode Switchings of Single-loop Mode and Basic Control Module

Table 3.11.1 shows the operation modes and the switching status.

Table 3.11.1 Operation Modes and Switching Status

Operation Mode	Setpoint	Control	Operation Mode Switchings		
			Switchings	Setpoint	Control
C (Cas) (CMP) (Note 1)	• Cascade input signal	Automatic control	→ A	Hold the value just before the transition.	Continue automatic control balancelessly and bumplessly.
			→ M	Hold the value just before the transition.	Hold the manipulated output just before transition. Manual operation.
A (Auto)	• To be set by the △▽ key on the front panel	Automatic control	→ C (Note 2)	Cascade Setpoint value is set.	Continue automatic control balancelessly and bumplessly.
			→ M	Hold the value.	Manual operation
M (Man)	• To be set by the △▽ key on the front panel	Manual operation	→ C	Impossible to switch from M to C directly (possible via A). It is possible to switch from M to C in DDC mode.	
			→ A	Hold the value.	Control using the value just before transition setting as the initial value.

Note 1 : See Chapters 6 and 7 for setting by the computer.
Note 2 : An external setting signal is set to setpoint. Even if the set values do not coincide with each other at switching operation, the manipulated output is switched smoothly without any abrupt change (see Chapter 4, Section 1 Setpoint Tracking Function).
In a control loop where the C mode is not used, the operation mode does not change to C mode even when the C key is pressed in order to prevent the controller from illegal operation.

Figure 3.11.1 shows the setpoint and manipulated output transition during operation mode switching.

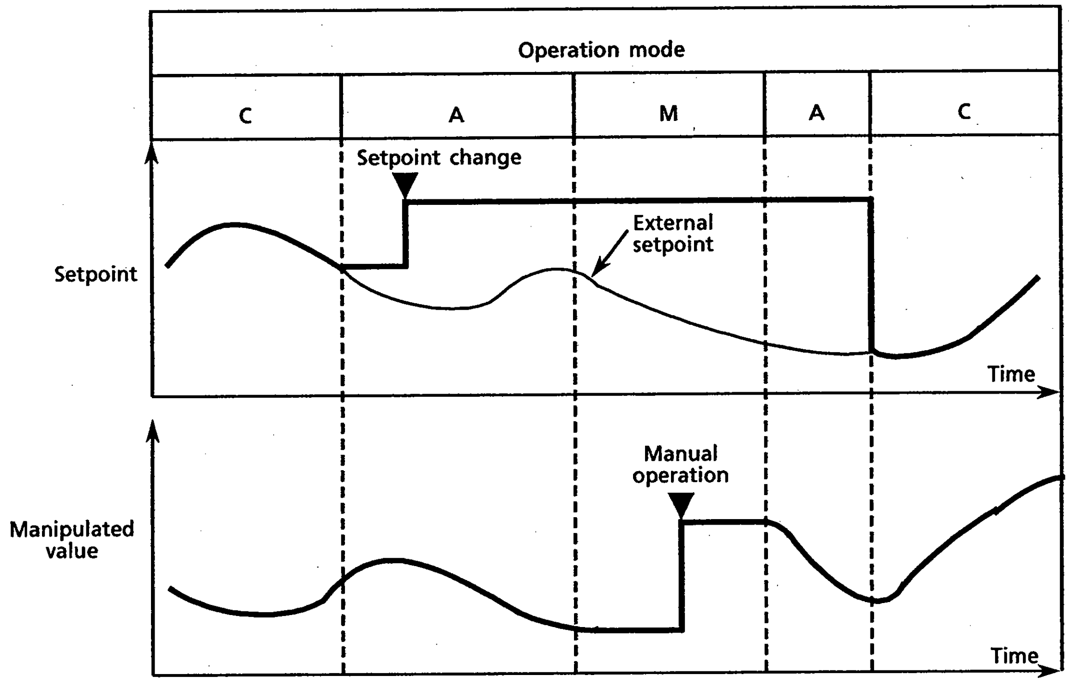


Figure 3.11.1 Setpoint and Manipulated Output Change for Operation Mode Switching

When two independent loops are configured in the programmable mode, the C-A-M key on the front panel corresponds to the displayed loop in the loop panel or in the trend record panel. Also, in the dual loop panels which display both loop 1 and loop 2, the C-A-M key corresponds to either loop 1 or loop 2.

3.11.2 Operation Mode Switchings of Cascade Mode and Cascade Control Module

The C-A-M mode is available for each of the two control elements of the cascade control module. The internal cascade connection can be opened or closed by the external status input or the program (see Figure 3.11.2).

Table 3.11.2 shows the combination of the operation modes, the status of the control, and the transition between the operation modes.

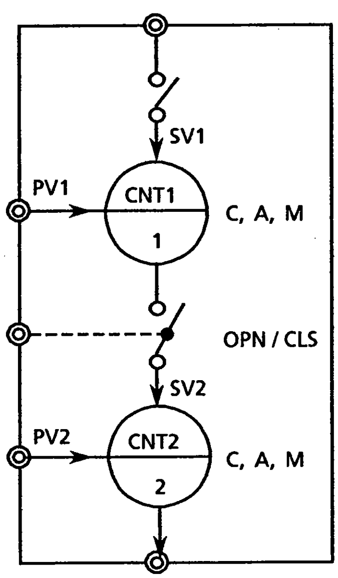
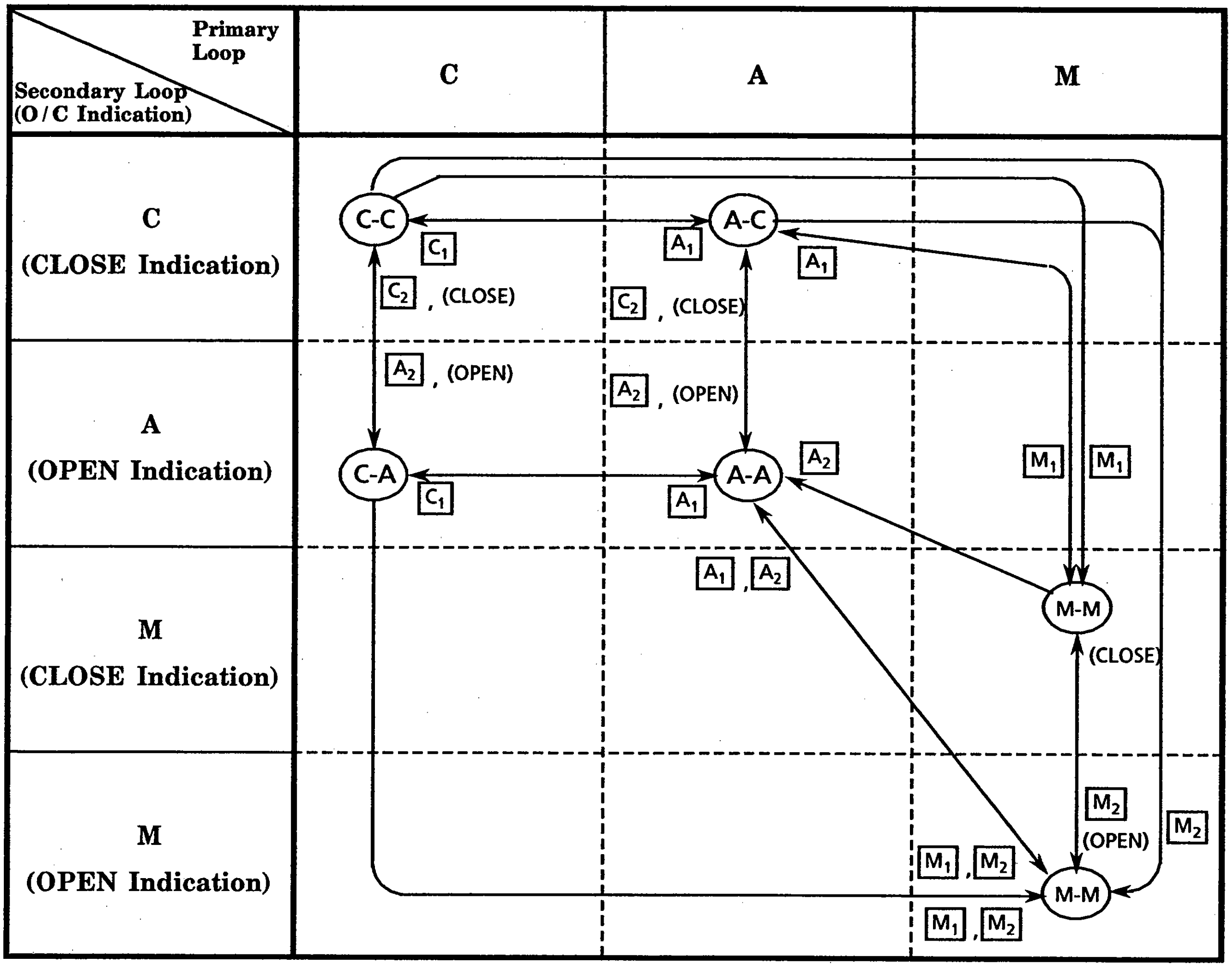


Figure 3.11.2 Cascade Control Module

Table 3.11.2 Operation Modes Transition for the Cascade Control Module



Symbols such as $\boxed{A_1}$ and $\boxed{C_2}$ in the table means to operate the operation mode switching key from MAN to AUTO, AUTO to CAS respectively for each loop.

That is: $\boxed{C_1}$, $\boxed{A_1}$ or $\boxed{M_1}$ means the C, A, or M key operation (or command) for primary loop.

$\boxed{C_2}$, $\boxed{A_2}$ or $\boxed{M_2}$ means the C, A, or M key operation (or command) for secondary loop.

(OPEN) or (CLOSE) means the open / close command for the internal cascade connection.

Two keys such as $\boxed{M_1}$ and $\boxed{M_2}$, which are indicated with one arrow in the table, means that either of the two keys can be operated.

The following lists the control status indication such as (C-C) and (A-A).

C-C : Cascade control status, setpoint value for primary loop shall be set externally.
A-C : Cascade control status for the secondary loop.
C-A : Control stops for primary loop, automatic control for secondary loop.
A-A : Control stops for primary loop, automatic control for secondary loop.
M-M: Control for both primary and secondary loops stops, manual operation.

Any combinations other than the above cannot exist.

As shown in the table, operation with the C, A, or M key from the secondary loop panel (the panel title "Loop 2", "TREND 2", or "DUAL 2") changes the open / close status of the internal cascade connection. The operation from the external status input or the user program, if existing, has priority over the control with the key for open / close control of the internal cascade connection.

3.11.3 Operation Mode Switchings of Selector Mode and Selector Control Module

The C-A-M mode is available for each of the two control elements of the selector control module. The local / remote setting for secondary loop setpoint (SV2) can be carried out from the external status input or the user program in the programmable mode (see Figure 3.11.3).

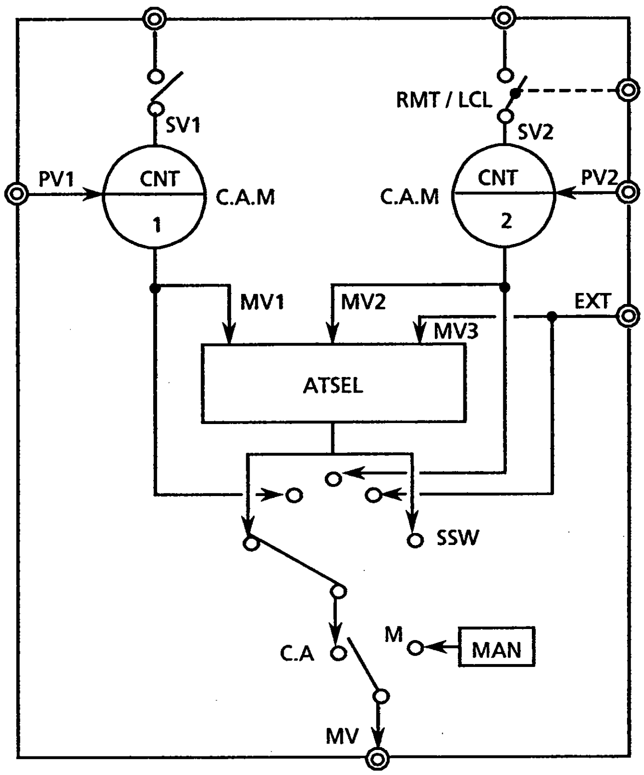
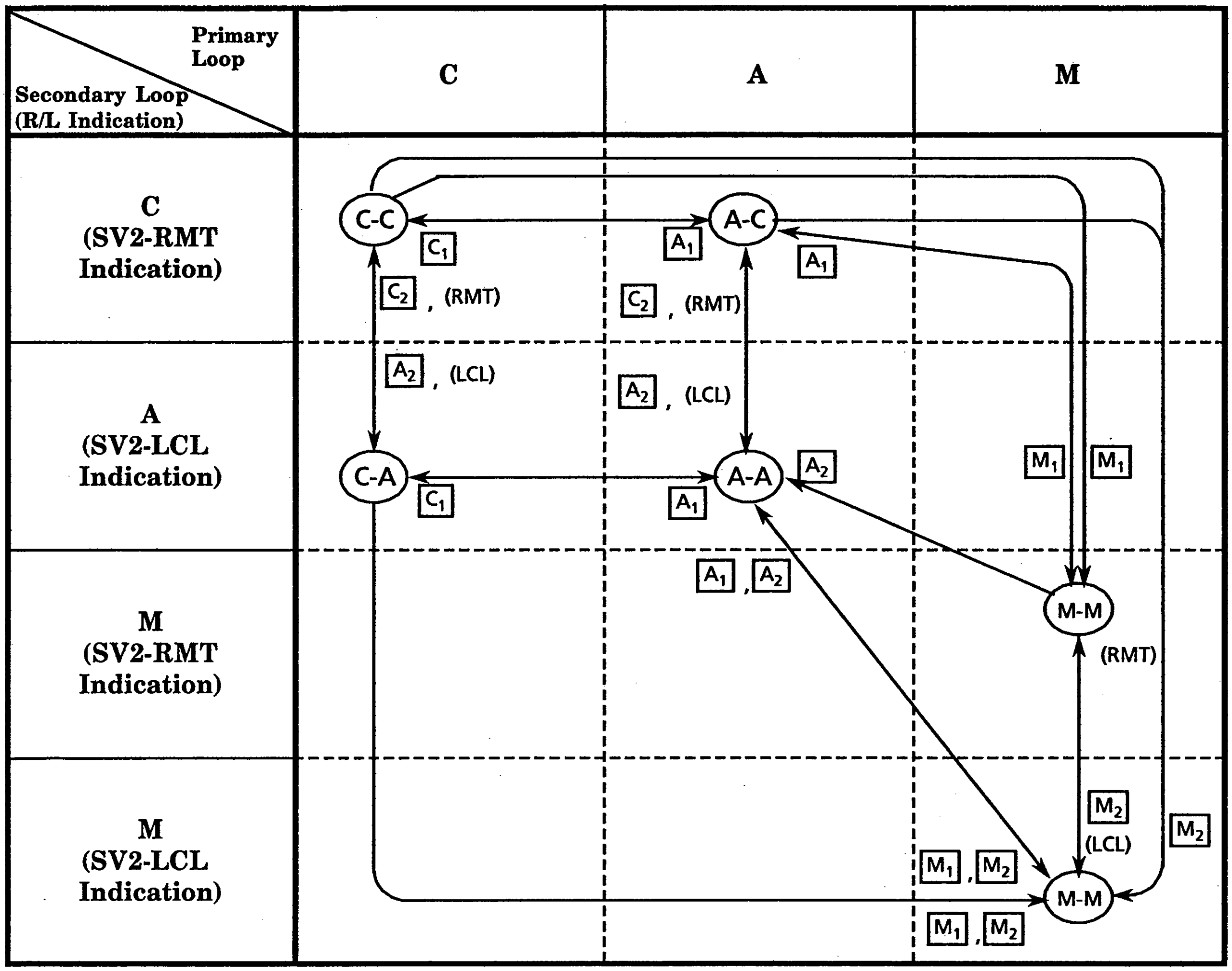


Figure 3.11.3 Selector Control Module

Table 3.11.3 shows the combination of the operation modes, the status of the control, and the transition between the operation modes.

Table 3.11.3 Transition Between Operation Modes of the Selector Control Module



Symbols such as (RMT) and (LCL) in the table mean the operation command used to set the remote / local setpoint to secondary loop setpoint.

The following lists the control status indication such as C-C and A-A.

C-C : Both primary and secondary loops are cascade control status, Setpoint values are set externally.

A-C : Primary loop is automatic control status, secondary loop is cascade control status.

C-A : Primary loop is cascade control status, secondary loop is automatic control status.

A-A : Both primary and secondary loops are automatic control.

M-M: Control of both primary and secondary loops stop, manual operation.

Combinations other than the above cannot exist.

As shown in the table, operation with the C, A, or M key from the secondary loop panel (the panel title "Loop 2", "TREND 2", or "DUAL 2") changes the remote / local control status for the secondary loop setpoint value. Control from the external status input or the user program, if exists, has priority over the control with the key for remote / local setting.

Table 3.11.4 shows the functions of each operation mode per each setting of the selector control selector switch (SSW).

Table 3.11.4 Selector Function

Setpoint Value		Selector Function	Control Element 1 (CNT1)				Control Element 2 (CNT2)			
SSW (Note 1)	ATSEL		C·A·M Button	Setpoint Value	Process Variable	Control (output)	Setpoint Value	Process Variable	Control (output) (Note 2)	C·A·M Button
AUT	LO	Auto low selector; selects the smallest output signal from CNT1, CNT2 outputs and EXT signal	C	CSV1 signal	PV 1	Auto control (refer to CNT2 when not selected)	CSV2 signal	PV2	In non-selected status: $MV2 = MV + K_{P2} \cdot e_2$	C
			A	SET button	PV 1		SET button	PV2		A
			M	SET button	PV 1	Varies with MV	SET button	PV2	Varies with MV	M
	HI	Auto high selector	-	The status of all items is the same as the above column. However the highest signal value is selected.						-
1		Control element 1; selects CNT1 output signal irrespective of signal value	C	CSV1 signal	PV 1	Auto control	CSV2 signal	PV2	Varies with MV1	C
			A	SET button	PV 1	Auto control	SET button	PV2	Varies with MV1	A
			M	SET button	PV 1	Manual operation	SET button	PV2	Varies with MV	M
2		Control element 2; selects CNT2 output signal irrespective of signal value	-	CNT1 output follows CNT2 output (output tracking). CNT2 is set to auto control mode.						-
3 (Note 3)		External signal; selects signal irrespective of signal values	C	CSV1 signal	PV 1	Varies with EXT signal	CSV2 signal	PV2	Varies with EXT signal	C
			A	SET button	PV 1	Varies with EXT signal	SET button	PV2	Varies with MV	A
4 (Note 3)	LO	Auto low select (Slave); used when 2 YS170s are used in the auto select control	M	SET button	PV 1	Varies with MV	SET button	PV2	Varies with MV	M
			C	CSV1 signal	PV 1	Auto control (refer to CNT2 when not selected)	CSV2 signal	PV2	If not selected: $MV2 =$ (Master side MV) $+ K_{P2} \cdot e_2$ (Note 4)	-
			A	SET button	PV 1		SET button	PV2		C
			M	SET button	PV 1	Varies with MV	SET button	PV2	Varies with MV	A
	HI	Auto high selector (Slave)	-	The status of all items is identical to the above column. However, the highest signal value is selected.						M

Note 1 : Set SSW in the "PID 2" panel when using Selector mode in YS150 or YS170.
Set SSW by user program when using Selector module in YS170.
Also, when setting SSW to 1, 2, or 3, the setting of ATSEL (in the 'CONFIG 1' panel) is not effective.

Note 2 : Kp = Proportional gain, e = Deviation.

Note 3 : SSW can be set to 3 or 4 only in the "Programmable mode" of YS170.
Refer to TI 1B7C2-03E "YS170 Programmable Functions" for the examples of its usage.

Note 4 : Master side MV means the input signal to the output tracking register TRK in the slave side YS170. The equation is effective when the output tracking flag TRKF=0 at the slave side YS170. When the TRKF=1, the normal output tracking function works.

4. AUXILIARY CONTROL FUNCTIONS (MULTIFUNCTION MODE)

The auxiliary control functions are built-in in the multifunction mode. In the programmable mode, by using the expansion register from the user program, the auxiliary control functions can be used.

4.1 Tracking Function

4.1.1 Output Tracking

This function changes the manipulated output from the controller to follow an external signal (tracking input signal). During automatic [A] or cascade [C] mode, if the external status signal is received, the manipulated output signal becomes the same as the tracking input signal. The status of the [A] or [C] lamps do not change.

<Application Example>

Constant airflow and constant air pressure control in blast furnace blowers are typical examples of output tracking control. Transfer between constant airflow and constant air pressure control can be made balanceless and bumpless by using two YS150 controllers (see Figure 4.1.1).

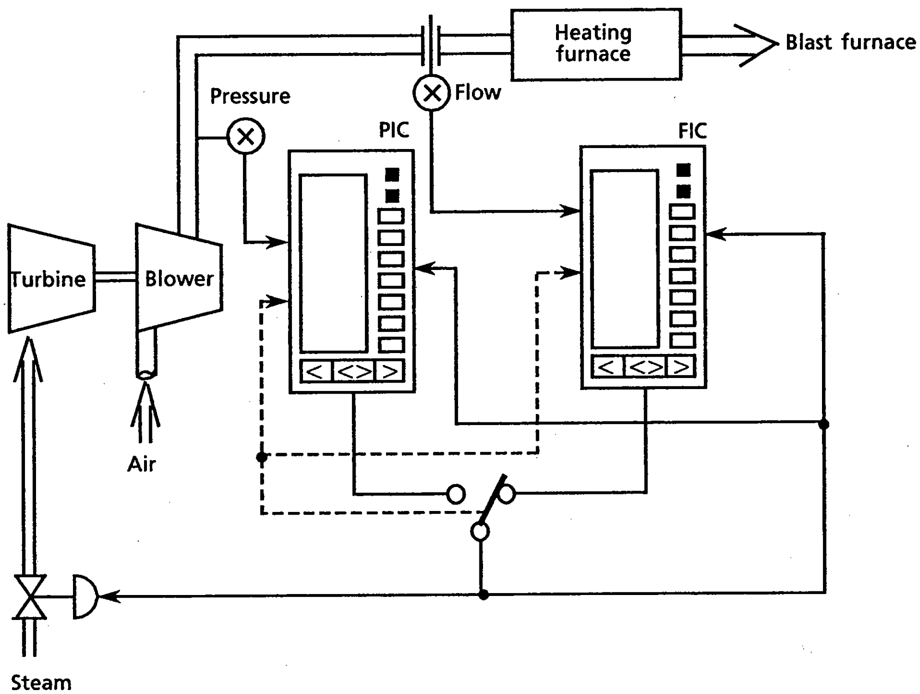


Figure 4.1.1 Blast Furnace Blower Control

4.1.2 Cascade Setpoint Tracking (applies only to Single-loop Mode)

This function may be used in the following case.

When the operation mode is transferred from automatic [A] to cascade [C] mode, it is desirable to adjust the setpoint to equal the cascade setpoint input in advance.

- **Selection of SV TRK Function**

  Set the "TRKSW" item on the configuration panel to SVTRK.

  In this status, by setting the operation mode switch to manual M, the cascade setpoint input is displayed by the setpoint index, and the controller internal setpoint tracks the cascade setpoint input. Figure 4.1.2 shows the principle drawing of SV TRK.

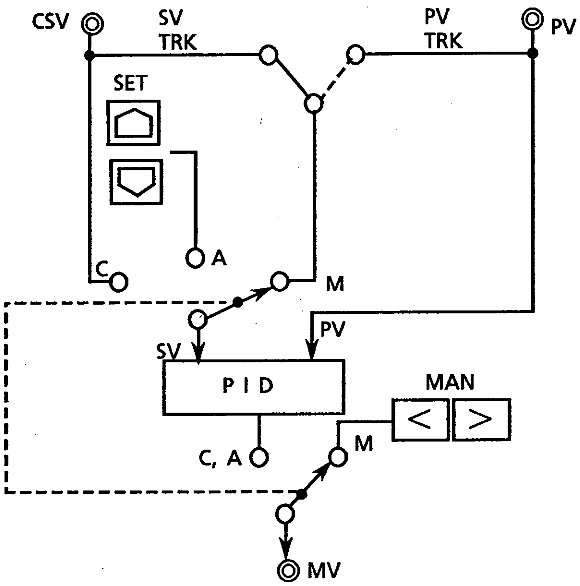


Figure 4.1.2 SV Tracking and PV Tracking

4.1.3 Process Variable ("Measure") Tracking (applies only to Single-loop Mode)

When transferring from manual (MAN) to automatic (AUTO) mode, if the deviation (between process variable and setpoint) is large there will be an abrupt change in the manipulated variable; this is undesirable (especially in PI-D control). To avoid this, YS100 can automatically adjust the setpoint (SV) to equal the process variable (PV) before transferring from manual to auto mode. So when the mode is transferred from MAN to AUTO, abrupt control action does not occur. This function is process variable ("measure") tracking.

- **Selection of PV TRK**

  Set the "TRKSW" item function on the configuration panel to PV TRK.

  Figure 4.1.2 shows the principle drawing of PV Tracking.

4.2 Process Variable Signal Alarm Function

The control modules have the following four alarm functions per each process variable input.

Upper limit alarm PH : Setting range is –6.3 to 106.3 % in engineering unit (to be set for control process variable input with hysteresis of 2%)

Lower limit alarm PL : Setting range is –6.3 to 106.3 % in engineering unit (to be set for control process variable input with hysteresis of 2%)

Deviation alarm DL : Setting range is 0.0 to 106.3 % in engineering unit (to be set for control deviation with hystersis of 2% and irrespective of sign)

Velocity alarm VL : Velocity setting range is 0.0 to 106.3 % in engineering unit , time duration setting is 1 to 9999 seconds

Setpoint can be changed by setting items PH, PL, DL, VL, and VT on the PID parameter panel.

When an alarm occurs, the process alarm lamp on the front panel of the controller is lit, and the alarm status is displayed on the alarm-related panel.

The following alarm status output are available:

Single-loop mode : One point each for PH and PL, and one logic OR point for DL and VL.

Cascade mode : One point each for primary and secondary loop alarms.

Selector mode : One point each for primary and secondary loop alarms.

Note: A loop alarm is created from the logic OR of PH, PL, DL, and VL.
The status of the alarm status output (close or open for normal status) can be set by the item AOUT in the configuration panel 3.

4.3 Operation Mode Switchings by Status Input

There are seven types of operation mode switchings by the status input, and the desired one can be selected by the item DI1F in the configuration panel 3. Table 4.3.1 lists the possible operation mode switchings for each control mode.

Table 4.3.1 List of Operation Mode Switchings Type by Status Input

Type	Single-loop Mode	Cascade Mode	Selector Mode
(CAS, AUTO) ⇆ MAN switching	O		
CAS ⇆ AUTO switching	O		
Preset MV switching	O	O	O
Output tracking switching	O		
Self-tuning switching	O	O	O
OPEN ⇆ CLOSE switching of the internal cascade		O	
LOCAL ⇆ REMOTE switching of the secondary loop of selector control			O

O: Settable

The switching direction by the open and close of the status input is selected by the item DI1D in the configuration panel 1. With the default settting (DI1D=OPN) when status input changes from closed to open, there is a switching to the specified operation mode. The mode returns to the previous operation mode when the status input closes. It will be reversed by setting DI1D to CLS.

When performing SPC / DCC control by communication with the supervisory computer, switchings by status input is disabled. Table 4.3.2 summarizes the operation mode switchings by status input for each type.

4.3.1 Switchings Between (CAS, AUTO) and MAN

This function enables transfers of the selected mode from automatic or cascade mode to manual mode when an external status signal is received. When this function is enabled, "EXT-MAN" is indicated on the loop panel. The status of the [A] or [C] lamps is not changed. When the external status signal reverts to normal, the mode reverts from the [M] mode to the previous ([A] or [C]) mode.

4.3.2 Switchings Between CAS and AUTO

This function enables transfers of the selected mode from cascade mode to automatic mode when an external status signal is received. When this function is enabled, "EXT-AUT" is indicated on the loop panel. The status of the [C] lamps is not changed. When the external status signal reverts to normal, the mode reverts from [A] mode to the previous [C] mode.

4.3.3 Switchings of Preset MV

During automatic or cascade operation mode, if an external status signal is received, a preset MV setting is output as manipulated output. Manual operation is disabled (manual operation is possible only if the controller is set in the manual operation mode). When the external status input returns to normal, the mode reverts to the previous mode. "EXT-PMV" is indicated in the loop panel for the preset MV output status. The status of the [A] or [C] lamps is not changed.

By setting the preset MV value below 0%, this function can be used for emergency shutdown if a system failure occurs.

The preset MV value is set by setting item PMV on the PID setting panel.

4.3.4 Switchings of Output Tracking

The function is just like the switchings of preset MV.

The MV output when switched comes from the external analog signal. (Ref. 4.1.1)

4.3.5 Switchings of Self-tuning

When receiving an external status signal, the self-tuning function is stopped. When the external status input is released, the self-tuning starts to operate as specified by the STC mode.

4.3.6 Switchings of Internal Cascade Open / Close (Cascade Control Mode)

When receiving an external status signal, the internal cascade connection of the cascade control module opens. When the external status input is released, the internal cascade connection closes.

"OPEN" or "CLOSE" is indicated in the loop panel for the internal cascade connection status.

4.3.7 Switchings of Local / Remote (Selector Control Mode)

When receiving an external status signal, the setpoint of the secondary loop of the selector control module is set by local operation. When the external status signal is released, the setpoint is set to the cascade input signal as "remote" mode.

"SV2-LCL" or "SV2-RMT" is indicated on the loop panel for the status of the setpoint of the secondary loop.

Table 4.3.2 (1) Operation Mode Switchings by Status Input

Type	Operation Mode \ Input		Status (Voltage Level) Input (Note 1) CLOSE (Low)	OPEN (High)
(CAS. AUTO) ⇆ MAN switching (E – MAN)	C (Cascade)	Setting	Cascade	Local
		Operation mode	Auto	Manual
		Status indication	Not indicated	"EXT-MAN"
	A (Auto)	Setting	Local	
		Operation mode	Auto	Manual
		Status indication	Not indicated	"EXT-MAN"
	M (Manual)	Operation mode	Always manual operation	
CAS ⇆ AUTO switching (E – AUT)	C (Cascade)	Setting	Cascade	Local
		Operation mode	Auto	
		Status indication	Not indicated	"EXT-AUT"
	A (Auto)	Operation mode	Always auto operation	
	M (Manual)	Operation mode	Always manual operation	
Preset MV switching (E – PMV)	C (Cascade)	Setting	Cascade	
		Operation mode	Auto	Preset MV value
		Status indication	Not indicated	"EXT-PMV"
	A (Auto)	Setting	Local	
		Operation mode	Auto	Preset MV value
		Status indication	Not indicated	"EXT-PMV"
	M (Manual)	Operation mode	Always manual operation	
Output tracking switching (E – TRK)	C (Cascade)	Setting	Cascade	
		Operation mode	Auto	Tracking
		Status indication	Not indicated	"EXT-TRK"
	A (Auto)	Setting	Local	
		Operation mode	Auto	Tracking
		Status indication	Not indicated	"EXT-TRK"
	M (Manual)	Operation mode	Always manual operation	

Table 4.3.2 (2) Operation Mode Switchings by Status Input

Type	Status (Voltage Level) Input (Note 1) CLOSE (Low)	OPEN (High)
Self-tuning switching (E-STC)	STC function disabled	STC function enabled (Note 2)
Internal cascade Open / Close switching (E-O / C)	CLOSE	OPEN
SV2 Local / Remote switching (E-L / R)	REMOTE	LOCAL

(Note 1) When DI1D=OPN (default).

(Note 2) Operation is performed according to the STC mode set in the STC panel 1.

4.4 Signal Computation

4.4.1 Input Filter (First-Order Lag Computation)

First-order lag computation can be carried out for each analog input.

First-order lag time constant: 0 to 799.9 seconds

4.4.2 Square Root Extraction (Variable Low Cutoff Point Type)

Square root extraction may be performed for process variables or cascade setting variables. As shown in Figure 4.4.2, input / output characteristic is "output = input" for inputs below the low cutoff point.

The low cutoff point can be set to any point within the range of 0 to 100%.

Square root extraction can be selected and the low cutoff point can be set from the parameter setting panel.

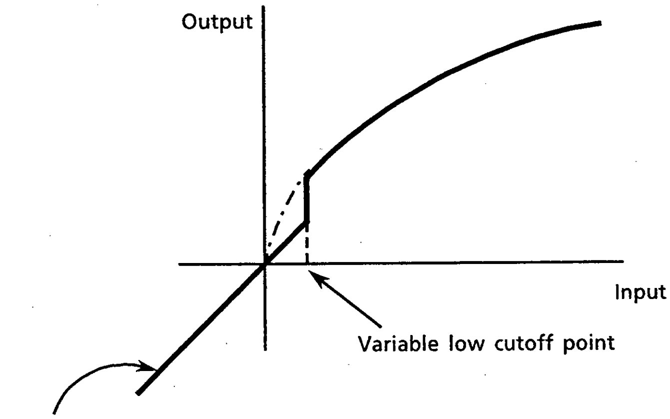


Figure 4.4.2 Square Root Extraction Characteristic

4.4.3 10-Segment Line-Segment Function

Non-linear process variable inputs can be linearized using the 10-segment line-segment function.

The 10-segment line-segment function allows the outputs corresponding to each of ten equally-spaced input points to be set to arbitrary values, with linear interpolator between the values (see Figure 4.4.3).

When input is 0%, conversion is possible down to –6.3% with the segments from 0 to 10% extended.

When input is 100%, conversion is possible up to 106.3% with the segments from 90 to 100% extended.

10-segment function conversion can be selected from configuration panel 3, and the output values for each break point can be set from the FX table setting panel.

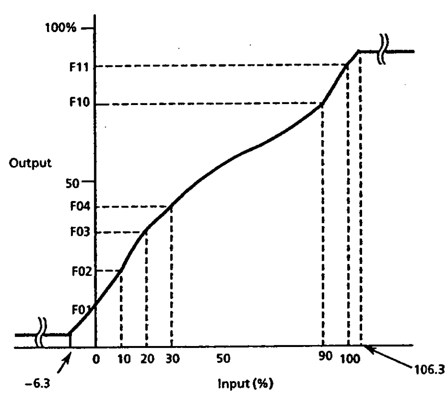


Figure 4.4.3 10-Segment Line-Segment Function

4.4.4 Scaling

Scaling according to the following equation can be performed for cascade setting inputs.

CSV = CGN (CIN + CBI) + CBO

where CSV : Cascade setpoint value
CIN : Cascade setting input
CGN : Gain (−8.000 to 8.000)
CBI : Input bias (−106.3 to 106.3%)
CBO : Output bias (−800.0 to 800.0%)

When scaling is carried out for cascade setting input, control computation is executed using the value (CSV) as the setpoint value (SV). Scaling computation can be selected from configuration panel 3, and gain and bias can be set from the parameter setting panel.

4.5 Operation Mode Status Output

4.5.1 Operation Mode Status Output of Single-loop Mode

Table 4.5.1 lists the two status outputs for the operation modes of the controller.

Table 4.5.1 List of Status Outputs

Operation Mode Lamp	Mode Designation by External Status Input		Status Output	
	Operation Setting	Internal Status of the Controller	CA/M Status Output	C/AM Status Output
C	OFF (Designation released)	C	CLOSE	CLOSE
	Output tracking	C	CLOSE	CLOSE
	Preset MV output	C	CLOSE	CLOSE
	EXT. Automatic	A	CLOSE	OPEN
	EXT. Manual	M	OPEN	OPEN
A	OFF (Designation released)	A	CLOSE	OPEN
	Output tracking	A	CLOSE	OPEN
	Preset MV output	A	CLOSE	OPEN
	EXT. Manual	M	OPEN	OPEN
M	(Always manual mode)	M	OPEN	OPEN

4.5.2 Operation Mode Status Output of Cascade Mode and Selector Mode

(1) CA / M and C / AM Status Outputs

Table 4.5.2 shows the status outputs of the operation mode in the cascade or selector mode. Control element (CNT1) of the primary loop represents the operation mode in the cascade and selector modes.

Table 4.5.2 List of Status Outputs (Cascade and Selector Modes)

Primary Loop (CNT1) Operation Mode Lamp	Status Output	
	CA / M	C / AM
C	CLOSE	CLOSE
A	CLOSE	OPEN
M	OPEN	OPEN

(2) Open / Close and Remote / Local Status Output

In the cascade mode, open / close status of the internal cascade connection is output to DO3. In the selector mode, remote / local selection status is output to DO3.

- Open / close status output
  - When open : Status output = OPEN
  - When closed : Status output = CLOSE
- Remote / local status output
  - When remote : Status output = CLOSE
  - When local : Status output = OPEN

5. SELF-TUNING FUNCTION

The PID parameters are automatically adjusted by the self-tuning function for optimum value of the PID control. The YS150 / YS170 controller is equipped with the self-tuning function. Refer to the separately supplied Technical Information TI 1B7C0-01E "Intelligent Self-Tuning Functions" for details of the self-tuning function.

5.1 Designation of Self-Tuning Mode

The self-tuning function is to be used with the control modules: the basic control module; the cascade control module; and the selector control module. In both the multifunction mode and the programmable mode, the self-tuning function can be used in the self-tuning mode by setting item "STC" from the STC setting panel.

In the multifunction mode, the self-tuning function can be activated or deactivated from the external status signal or the PF key, by setting item "DI1F (DI1 function designation)" to E - STC or by setting item "PFKEY (PF key function designation)" to STC from configuration panel 3. (Note)

In the programmable mode, the self-tuning function can be activated or deactivated from the user program.

(Note) When both items were set only DI1F will be effective.

5.2 Loops Subject to Self-Tuning

The following lists the control loops subject to the self-tuning function.

- For the multifunction mode :
  - Single-loop mode ; Primary loop.
  - Cascade mode ; Secondary loop when the internal cascade is open
    Primary loop when the internal cascade is closed
  - Selector mode ; Selected loop
- For the programmable mode :
  - Single-loop mode ; Loop designated by the user program for independent two-loop control
  - Cascade mode ; Secondary loop when the internal cascade is open
    Primary loop when the internal cascade is closed
  - Selector mode ; Selected loop

5.3 Applications

Table 5.3.1 shows the possible combinations of the control functions and STC.

Table 5.3.1 Combination of Control Functions and STC

Control Function			Combination
Controller mode	Programmable mode	Basic control (BSC)	○
		Cascade control (CSC)	○
		Selector control (SSC)	○ *1
	Multi-Function mode	Single loop mode	○
		Cascade mode	○
		Selector mode	○ *1
Control element	Standard PID control		○
	Sample PI control		—
	Batch PID control		—
	PD control		—
Optional functions	Nonlinear elements		○
	Reset bias function		○
	Output limiter		○
	Input compensation (dead-time compensation)		×
	Variable gain		×
	Feed forward		×
Mode switching	CAS ↔ AUTO switching		○
	CAS, AUTO ↔ MAN switching		○ *2
	Output tracking		○ *2
	Preset MV		○ *2
Operation mode	CAS, AUTO, SPC		○
	MAN, DDC		—

○=Combination available ×=Not recommended —=Not allowed

*1: Auto start-up and on-demand can not be used.

*2: STC does not operate in MAN, output tracking or preset MV.

6. SELF-DIAGNOSTIC FUNCTION AND PROCESSING AT POWER FAILURE

The YS100 controller has a diagnostic function to check whether the control is in a normal range by monitoring the input and output. It also has a self-diagnostic function to check failures of the controller itself.

To counter power failures, the YS100 controller contains functions for quick and safe recovery depending on the length of the power failure such as momentary shutdown or power failure of a relatively long time.

6.1 Self-Diagnostic Function

When the YS100 controller detects a fault, the lamps (FAIL and ALARM) on the front panel are lit. The lit lamps tell the operator that some troubles have occurred with the controller.

While the FAIL lamp (red) and the ALARM lamp (yellow) are lit, the cause of the alarm is indicated in the alarm display panel (see Figure 6.1.1). While the FAIL lamp is lit, the cause of the failure is indicated on the left side of the display panel (see Figure 6.1.2).

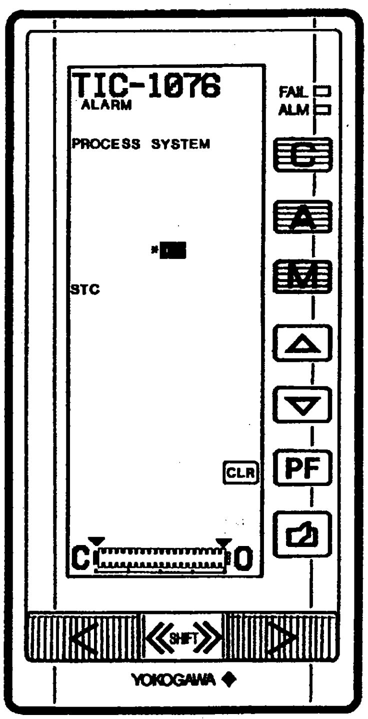


Figure 6.1.1 Alarm Panel

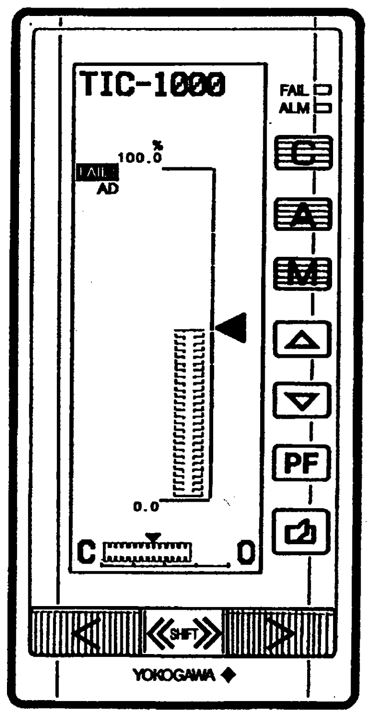


Figure 6.1.2 Display Panel When FAIL Lamp is Lit

While using the YS170 controller, the registers for the system flag are set to ON when some trouble occurs. Therefore, the cause of the trouble can be found using the user program.

(1) FAIL lamp (red)

- This lamp lights when some serious problem which leads to a failure of the controller has occurred.
- When this lamp lights, the FAIL contact is set open.

(2) ALARM lamp (yellow)

- This lamp lights when a process alarm, STC alarm, or system alarm has been generated.
- This lamp lights when the trouble is not serious and the controller may still be operated.

Table 6.1.1 shows the displays and operations of self-diagnostic functions.

Table 6.1.1 Displays and Operation of Self-Diagnostic Functions

Lamp	Type of Alarm	Display on the Alarm Display Panel	Status of the lamp	Contents of Diagnostic	Remedy process (Operation in Abnormal Conditions)	
FAIL lamp (red)	System alarm		Lights	CPU failure	Control stop	∘ Fail contact is open ∘ Current output HOLD (MAN mode) ∘ Output operation is possible with hard manual operation ∘ Communication (RS-485, DCS, YS-net) is stopped
		A/D	Lights	A/D converter failure		
		D/A	Lights	D/A converter failure		
		RAM	Lights	RAM error (including data erase)		
		ROM	Lights	System ROM error		
		EEPROM	Lights	EEPROM error (including data erase)		
ALARM lamp (yellow) (Note 1)	Process alarm	PH1	Lights	Process variable upper limit alarm 1	Operation continues	
		PH2	Lights	Process variable upper limit alarm 2		
		PL1	Lights	Process variable lower limit alarm 1		
		PL2	Lights	Process variable lower limit alarm 2		
		DL1	Lights	Deviation alarm 1		
		DL2	Lights	Deviation alarm 2		
		VL1	Lights	Velocity alarm 1		
		VL2	Lights	Velocity alarm 2		
	STC (self-tuning control) alarm	SYSALM	Lights	System alarm		STC stops.
		PVOVR	Lights	PV alarm		
		MVLMT	Lights	MV alarm		
		OPERR	Lights	Operation error		
		IDERR	Lights	Identification disabled		
		PWRDWN	Lights	Power failure		
		PBLMT	Lights	PB alarm		
		TILMT	Lights	TI alarm		
		TDLMT	Lights	TD alarm		
		RTALM	Lights	RT alarm		
	Others	X1~X5	Lights	Input range overflow of the input terminals		Computation is carried out with limiting value
		CALC	Lights	Computation overflow		
		Y1, Y3	Lights	Outputs of 1st output (Y1) and 3rd output (Y3) are open		
		RAM	Not lit	RAM volatilized (Note 2)	Power recovery processing	Initial start (Note 3)
		OVER	Lights	Control period overtime	Operation continues	

Note 1: Alarm which has occurred before power failure are memorized in memory (RAM), and they are displayed again when HOT start is performed. (If power fails while alarms have occurred and then the controller is started without using the control module, the ALARM lamp lights by performing HOT startup. In this case, to release the alarm display, set power ON by performing COLD start once.

Note 2: This is detected when starting after the power failure of 2 seconds or more.

Note 3: See Section 7.3.

6.2 Displays and Operations When Controller Fails

The YS100 controller is designed for high quality, to be used for the strict system control of a plant. It has backup functions when failures occur in the controller.

The YS100 controller has the control operation circuit independent from the input data display circuit. It also has the backup circuit as current output.

When failure has occurred in the control computation circuit, control computation stops and the output is held. The communication function is also stopped. However, under this condition, input data (X1) display and operation of the current output signal (Y1) by the output operation key can be performed. Panel switching is disabled.

When failure has occurred in the display circuit, display and operation cannot be performed. Therefore, control computation stops and the output is held. The communication function also stops and the failure is reported to the supervisory system. Under this condition, the operation current output 1 can be controlled with the manual operation wheel behind the front panel. Adjust the operation wheel so that the backup current output is the same as the held current output. When the current output becomes the same, the lamp located on the side of the operation wheel lights. Then, set the output selector switch to ON. Because the backup manual circuit is independent from other circuits, these operations can be carried out without being affected by the failure of the digital circuits.

Besides the functions described above, a Standby Manual Station (Model YS110) is available so that the internal unit can be replaced without interrupting the output of the controller.

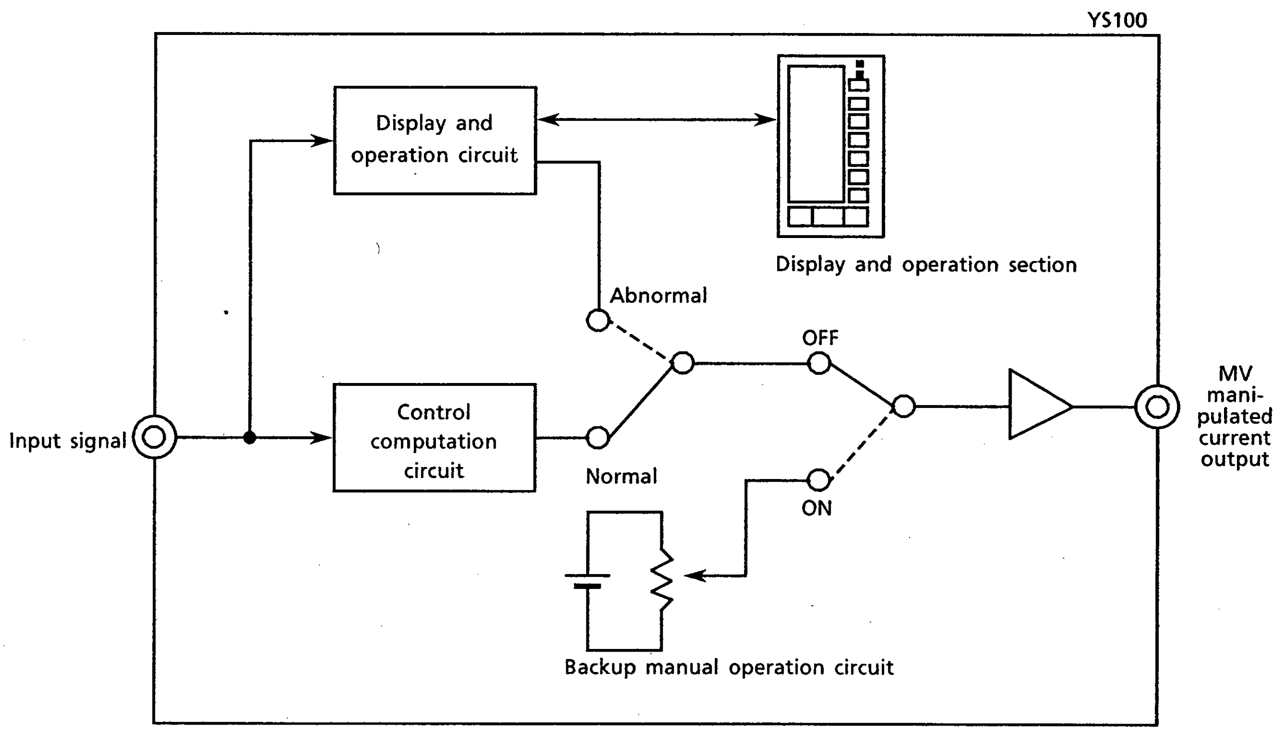


Figure 6.2.1 Output Backup System

6.3 Restart Functions After Power Failure

YS100 enters the shutdown status if the 100V AC power fails for 20 ms or more or the 24V DC power fails for 1 ms or more. Operation after recovery of power (TIM1, TIM2, or AUT) can be set by the user. Setpoint (SV), manipulated value (MV), and parameters set from the front panel of the controller, are stored in the memory for a minimum of 48 hours after power failure.

When the contents in the memory have been destroyed after a long power failure, the controller is started with the initial parameters stored in the EEPROM (initial start).

In trend recording, when power failure exceeds the time insensitive to power failure, the stored trend data will be erased.

6.3.1 Start of Operation When Power Has Recovered

Select one of the following from the engineering panel in order to start operation after recovery of power.

①AUT : HOT start regardless of the length of power failure time
Initial start after the contents of memory has volatilized by a long power failure

②TIM1: HOT start when power failure is less than about 2 seconds
COLD start when power failure is 2 seconds or more
Initial start after the contents of memory has volatilized by a long power failure

③TIM2: HOT start when power failure is less than about 2 seconds
Initial start when power failure is 2 seconds or more

Figure 6.3.1 shows the relationship between power failure and the start mode, and Table 6.3.1 shows the operation for startup.

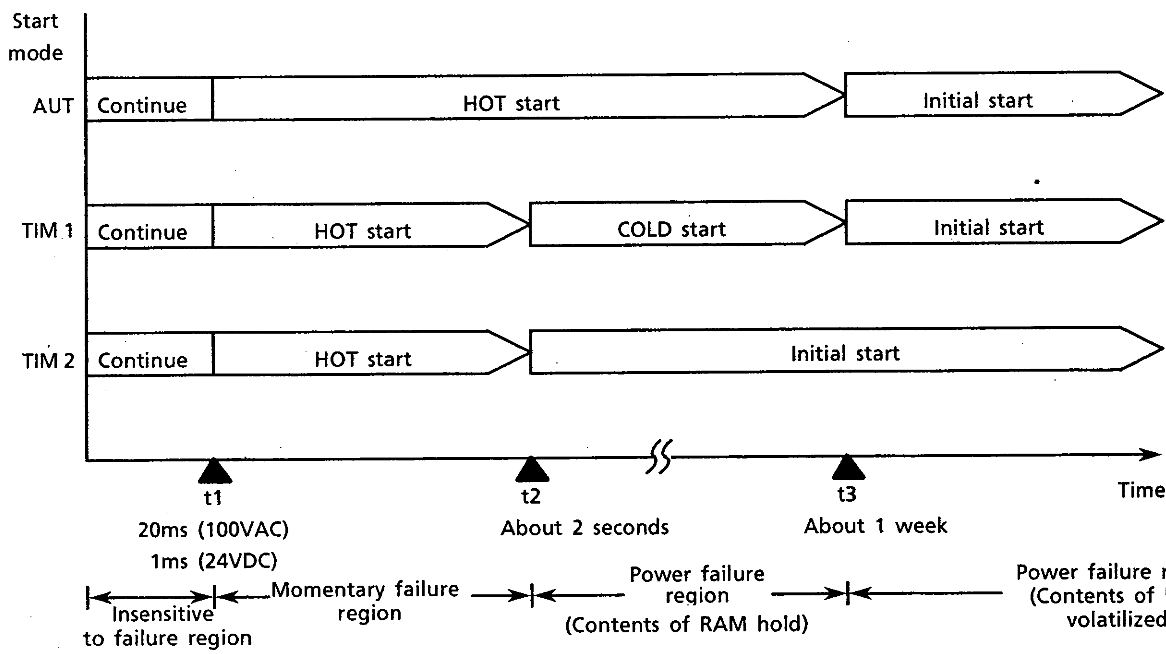


Figure 6.3.1 Power Failure and Start Mode

Table 6.3.1 Operations for Startup

Item \ Start Mode	HOT Start	Cold Satrt	Intial Start
Control mode	Same as before power failure	Manual (MAN)	MAN
Set points (SV)	Same as before power failure	−6.3%	−6.3%
Manipulated variables (MV)	Same as before power failure	Same as before power failure	Parameters same as values stored in EEPROM
Parameters (e.g. PID)	Same as before power failure	Same as before power failure	
Temporary storing register (T)	Same as before power failure	0	0
Time-dependent computations (e.g. first-order lag, dead time)	Operation suspended during power failure	Initialized	Initialized

6.3.2 Memory of Parameters and User Programs

YS150 and YS170 use RAM and EEPROM (Electrically Erasable and Programmable Read Only Memory) to store parameters and user programs (for YS170 only). The information that has been written into the EEPROM will not become lost unless an abnormal condition occurs. User programs, parameters for function settings, and the setpoint values (SV) that are used as the initial value during start-up (as shown in Fig. 6.3.1) and the tuning parameters for PID is stored in EEPROM.

User programs that have been created or set in a personal computer, and data for operation and register setting are stored in YS170's RAM and also EEPROM at the same time by downloading from the personal computer (Note).

The data that has been set in the tuning panel of YS150 and YS170 will be stored in RAM. Also, if the [SAV] key on the display is pressed, the data on display will be written into EEPROM.

The data that has been set on the engineering panel of YS150 and YS170 will be written into RAM and EEPROM. However, the data that has been set in the engineering display that contains the [SAV] key will first be stored in RAM, and if the [SAV] key is pressed, then the data on display will be written into EEPROM.

The operation mode (C, A, M) will be stored in RAM only. By pressing the [SAV] key on the tuning panel of the YS150 or YS170, the data on display can be written into EEPROM, and the data for the setpoint value (SV) during start-up can be stored in EEPROM. Also, for YS170, the initial value of the setpoint value (SV) during start-up is input into a personal computer, and it written into EEPROM by downloading from the personal computer (Note).

(Note) When the style code of the YS170 is "S1" (shipping before Feb. 1994) the writing to the EEPROM is done only when performing "RUN" command through the personal computer.

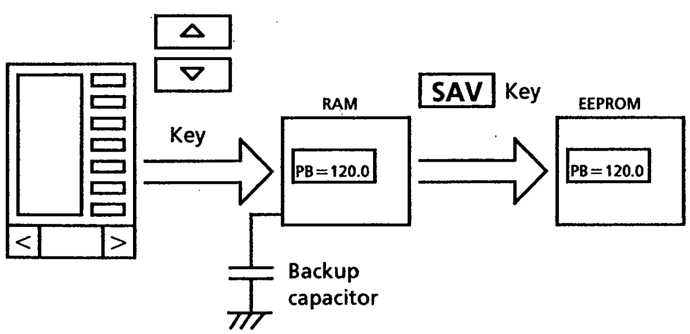


Figure 6.3.2 Flow of Parameter Writing

7. FLOW OF INPUT / OUTPUT SIGNALS AND CIRCUIT OPERATION

7.1 Analog I / O Circuits

Figure 7.1.1 shows the circuit block diagram of the YS100 controller.

The analog inputs Xn pass the input multiplexer, are converted to digital values with a successive-approximation A / D converter, and stored in the RAM. Resistor R_{IN} (1MΩ) in each input circuit makes the positive signal line fall to common potential and equalizes the input terminal to 0V input (–25%) when the input circuit is open.

Analog signals are not isolated from each other but use a common negative line and are isolated from the power supply. The data from the front panel switches are stored in RAM via the I / O ports.

After all the data have been set, the CPU executes control computations according to the user program stored in EEPROM.

Computational results are output as analog signals through the D / A converter and output amplifier.

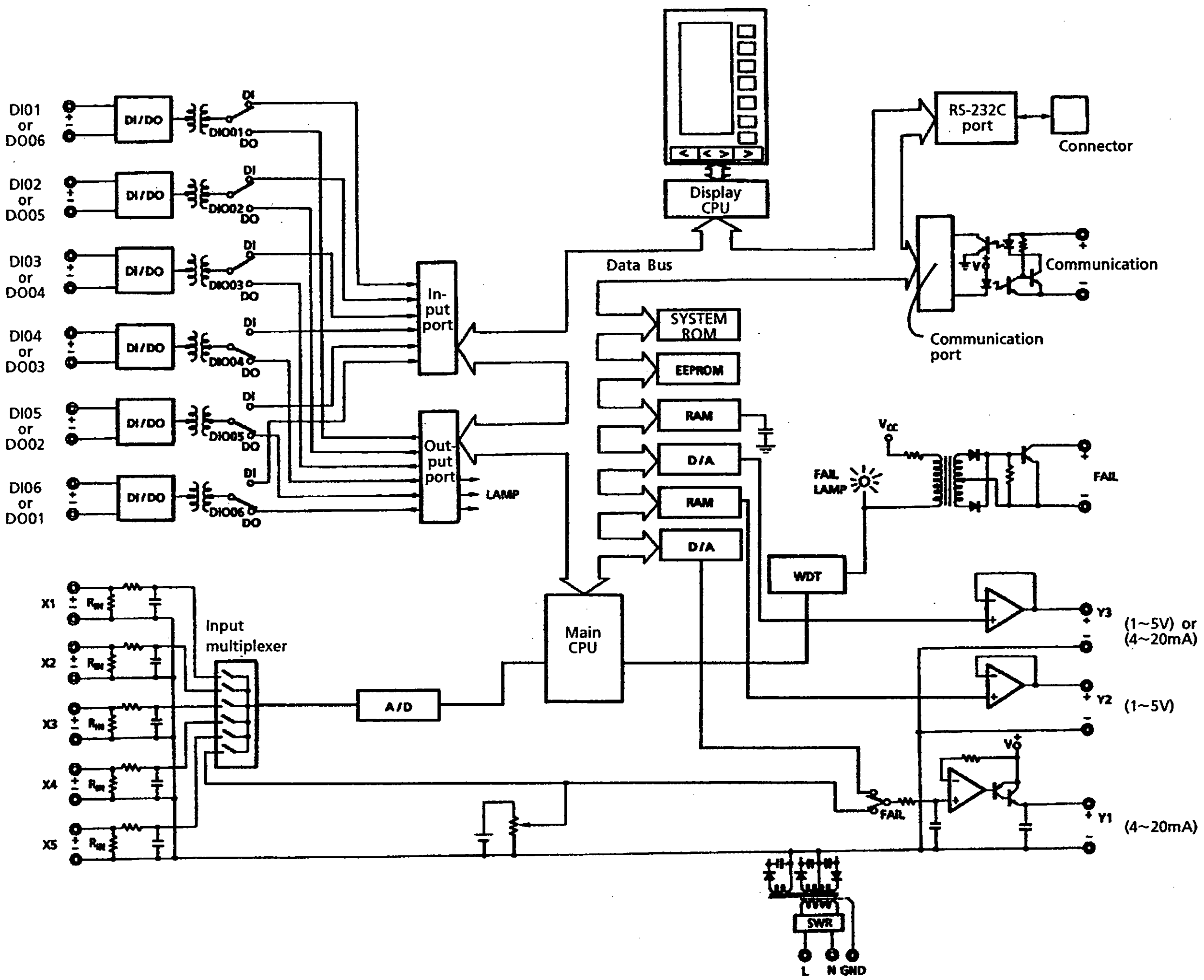


Figure 7.1.1 Circuit Block Diagram of YS100 Controller

7.1.1 Direct Sensor Input Circuit

The direct sensor input circuit accepts one input signal such as small voltage source (mV), thermocouple, resistance thermometer detecter, slidewire resistance, 2-wire transmitter, and pulses. Measurement range is set from the engineering panel.

For the YS170 controller, as shown in Figure 7.1.2, the sensor signal is applied to the sensor input terminals, and is read as 5th analog data (X5). The sensor signal is then converted to a 1 to 5 V signal, and output from 5th input terminal.

For the YS150 controller, as shown in Figure 7.1.3, the sensor signal is applied to the sensor input terminals. The signal is converted to a 1 to 5 V signal by the internal signal converter circuit, and then is output from the sensor output terminals. This output is connected to the desired input terminals using wires. Because the signal converter circuit is independent from the control computation circuit, the sensor signal can be assigned to any input terminals by means of wiring. When it is assigned to X1, the process variable can be monitored with the Standby Manual Station when the control display circuit is defective.

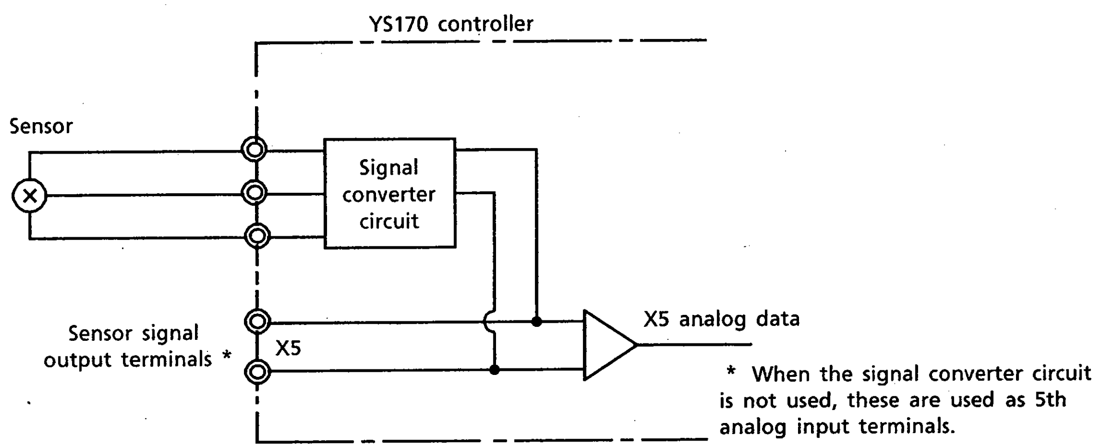


Figure 7.1.2 Sensor Input Circuit of the YS170 Controller

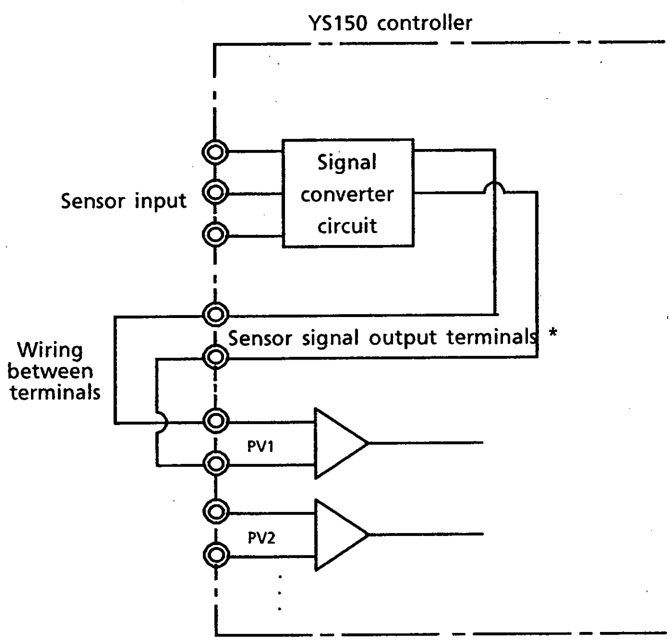
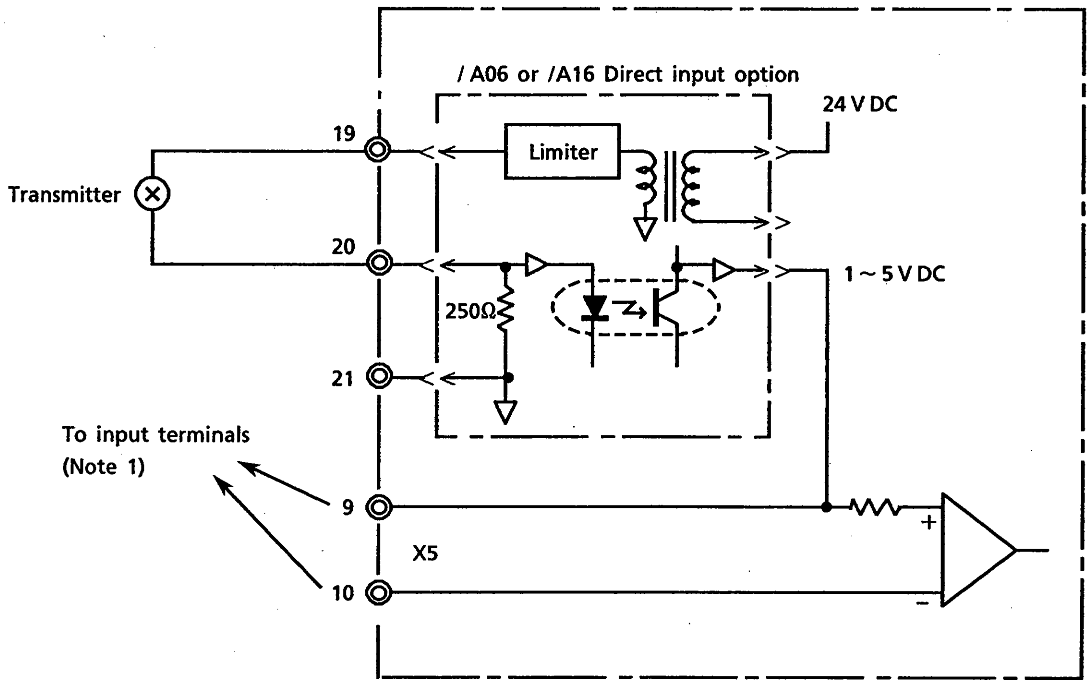


Figure 7.1.3 Sensor Input Circuit of the YS150 Controller

7.1.2 Connections to 2-wire Transmitter

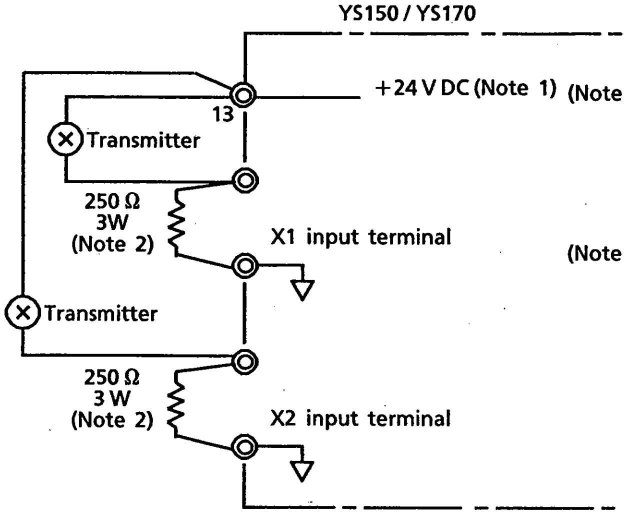
We recommend that when connecting the 2-wire transmitter directly to YS150 or YS170 without using an external signal converter, the YS150 or YS170 sensor input terminal with direct-input option (/A06 or /A16) is used to connect to the sensor signals (primary is insulated from secondary, as shown in Figure 7.1.4).

The YS150/YS170 controller has a transmitter power supply terminal (24 V DC) to connect a 2-wire transmitter simply. Wiring shown in Figure 7.1.5 allows the controller to read the signal sent by the transmitter, however, power of the controller is supplied to the transmitter without isolation. Also, there is no short circuit protection. When it is shorted the computation will stop and the controller may operate as if the power supply to the controller were off.



(Note 1) Connection and wiring unnecessary for input to X5 on the YS170

Figure 7.1.4 Connecting to Direct-Input Option (for two-wire transmitter /A06)



(Note 1) Power supply for transmitter:
With direct-input option ; 24 V DC 30 mA
Without direct-input option ; 24 V DC 60 mA
(possible to connect to 2 two-wire transmitters)

(Note 2) To prevent accidental transmitter burn-out from a short circuit, attach a 250 Ω±0.1% 3 W resistor to the input terminals.
We recommend YOKOGAWA Part No. E9760TM for this resistor.

Figure 7.1.5 Example for Connection Case for Using Internal Distributor Terminal

7.2 Status Input / Output Circuits

7.2.1 Status Input Circuits

The status input is isolated from the main internal circuit. With YS170, an ON status is handled as the numeric value "1" while an OFF status as the numeric value "0".

Input Specification:

Type \ ON, OFF	ON	OFF
Contact input	200 Ω or less	100 kΩ or more
Voltage input	−0.5 to 1 V DC	+4.5 to 30 V DC

Time span between ON and OFF : Control period plus 20 ms or more
Signal source rating : 5 V DC, 20 mA

Note: Upper limit of the voltage input specification shall be 30 V DC or less.

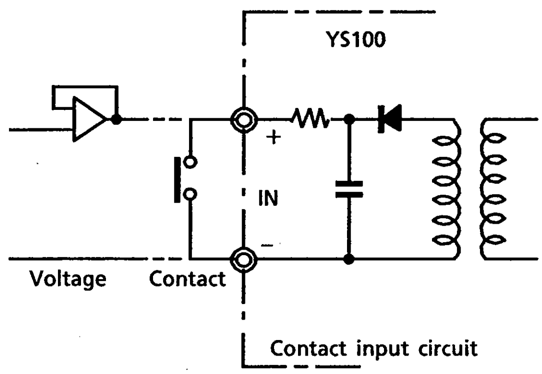


Figure 7.2.1 Principle of Status Input Circuit

7.2.2 Status Output Circuits

Status output data such as, alarm status and logical computation results, pass the output port and the numeric value "1" shows the status where transistor output continuity is ON and numeric value "0", OFF.

With YS170, status data ":" corresponds to status output "ON" (transistor continued).

Output specification: Transistor open collector
Rating: 200 mA, 30 V DC

Note: (a) If switching the equipment containing inductance such as relays, be sure to add the protecting diode.
(b) This circuit cannot be used after reversing the polarity.
(c) AC loads cannot be switched directly. In this case use a relay (Refer to Figure 7.2.3).
If the three notes are not followed, the transistor may become damaged.

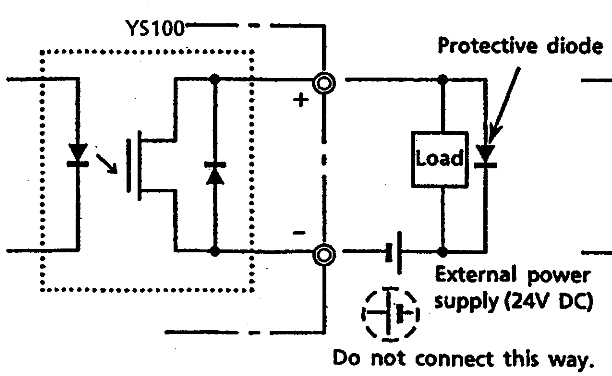


Figure 7.2.2 Principle of Status Output Circuits

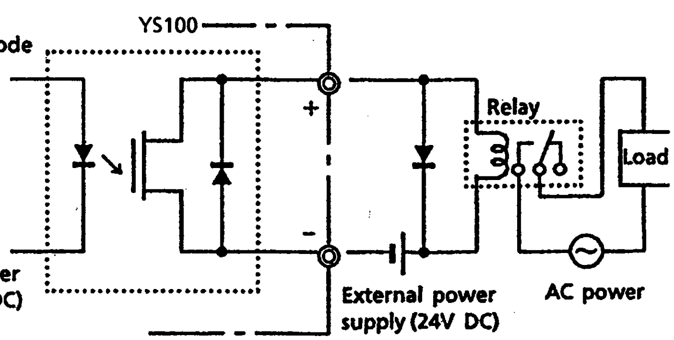


Figure 7.2.3 Connection of the Status Output when Driving a Load with AC Power

7.2.3 Status Input/Output Circuit of the YS170 Controller

Status input circuits and status output circuits of the YS170 controller use common terminals. Whether the terminals are used for input or output should be designated from the personal computer when the program is created. When not designated, three terminals (DI01 to DI03) are used for input and the other three terminals (DO01 to DO03) are used for output.

Take care of the relationship between logical input/output (DIO) numbers and corresponding DI or DO numbers.

The status input signal is stored in the DI register. The computation result output is stored in the DO register and used as the status output. The DO registers which are not assigned to the output terminals can be used as flag registers (memory for the status data).

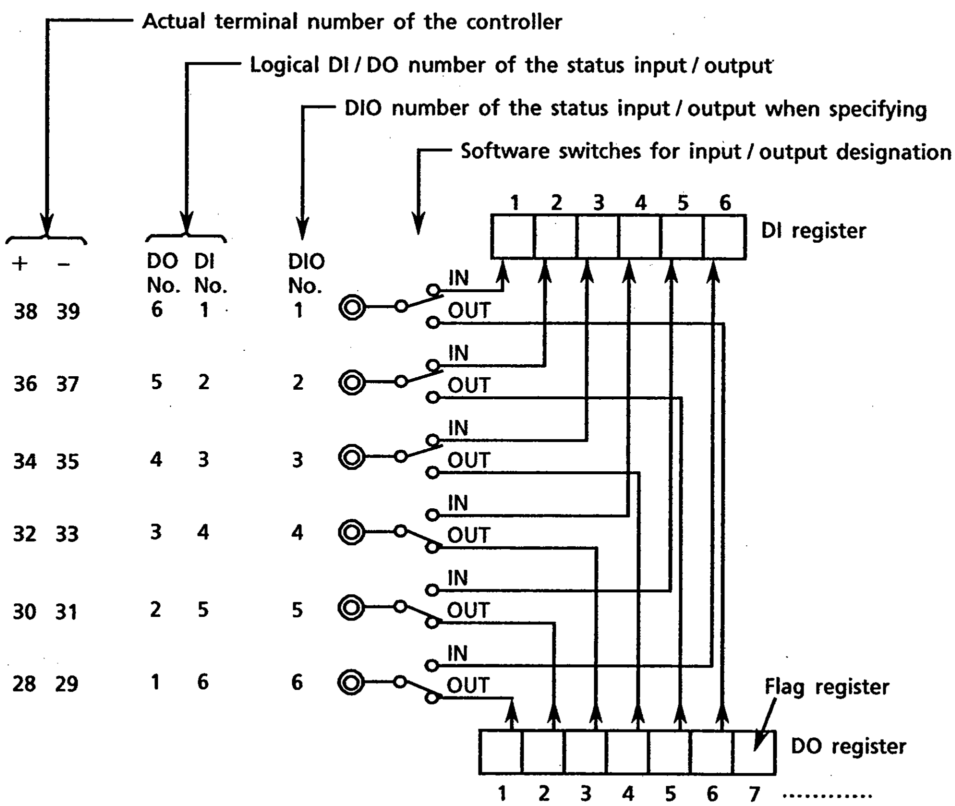


Figure 7.2.4 Principle of DIO Designation

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