SC100/200 Series

MULTI-FUNCTION PID CONTROLLER

FUNCTION BLOCK APPLICATION MANUAL

Contents

1. INTRODUCTION

This manual explains basic programming and processing principles of the SC100/SC200 Series Multi-function PID Controller, and detailed functions of the software function blocks including their coding examples.

These principles are also applicable to MsysNet remote I/O modules connected via peer-to-peer communication network, with differences in I/O specifications, i.e. field terminals.

It will be a helpful reference tool for the user during programming, debugging and commissioning of the Controller.

Be aware that data and parameters given in the document are only examples, and it is the user's sole responsibility to examine and determine the validity of a control strategy design he chooses and its function blocks and operations.

The SC100/200 Series products are referred to as 'the Controller' in this manual if not explained otherwise. Descriptions applicable to specific models are either mentioned with the particular model numbers, or identified with symbols such as: SC200/210

The following document will also provide helpful information when using this product:

- SC100/200 Series Function Block List (EM-6460-B)

1.1 SC100/200 MULTI-FUNCTION PID CONTROLLER

■ INPUT & OUTPUT SIGNALS

Physical field terminals: Universal input (DC, T/C, RTD and potentiometer), 2 points
Analog (voltage) input, 4 points (1-5 V DC)
Discrete/pulse input, 5 points
High-speed discrete/pulse input with excitation supply, 1 point
Analog (MV) output, 2 points (4-20 mA DC)
Analog (voltage) output, 2 points (1-5 V DC)
Discrete output, 5 points

Software communication terminals (16 blocks) SC200/210
I/O signals that can be assigned to each block:
Analog input, 2 points
Analog output, 2 points
Discrete input, 32 points
Discrete output, 32 points

For example, at the maximum of 32 analog I/O signals are usable for remote I/O if all available communication terminal blocks are assigned with analog signals, and likewise at the maximum of 512 discrete I/O signals are usable if all these blocks are assigned with discrete signals. Analog and discrete signals can be mixed according to the user's application needs.

Remote I/O modules are connected via peer-to-peer communication.

■ AVAILABLE SOFTWARE FUNCTION BLOCKS

Control blocks: 2
Computation, timer and counter blocks: 48
Sequential control blocks: 12 (1068 commands in total)

■ SETTING FUNCTION BLOCK PARAMETERS (PROGRAMMING & SET VALUES)

Parameters are set either via the front panel of the Controller or by using the Loop Configuration Builder Software (model: SFEW3E) on the PC.

■ SAVING PROGRAMMING

Parameters can be uploaded from the Controller to save as a file usable for the SFEW3E or downloaded from the software program. Maintaining a library of programs will help the user to replace a failed controller with the shortest disruption time.

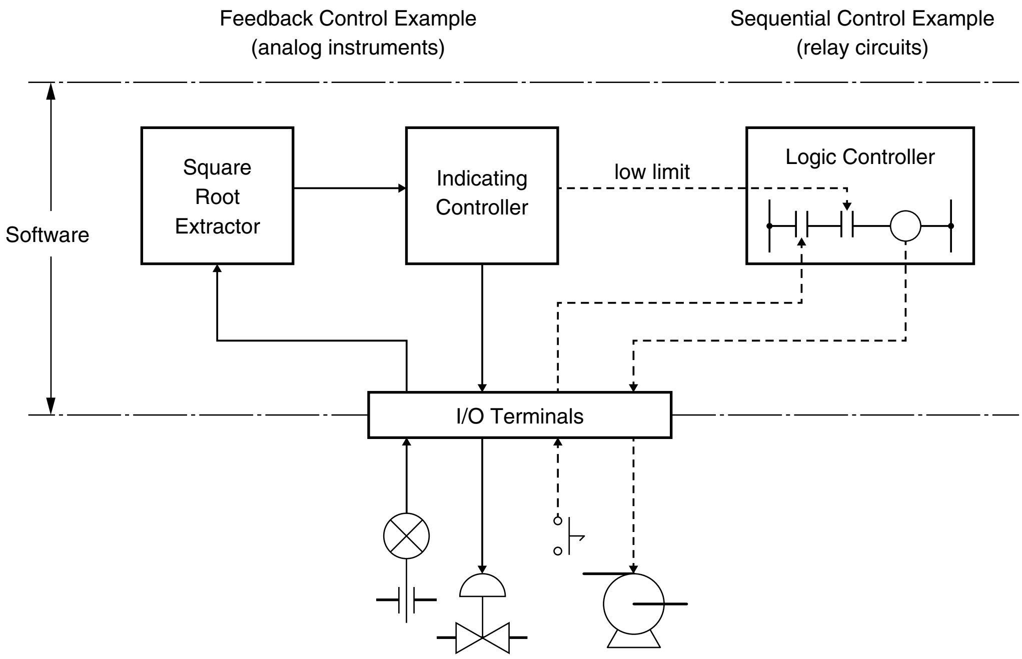
■ POWER FAILURE

Parameters are stored in the EEPROM, safely in case of a power failure. Running operation data stored in the RAM is not lost by a brief power failure (less than 10 minutes). A hot start is possible once the power is recovered.

1.2 PROGRAMMING LANGUAGE

Analog instruments for feedback control (PID controllers and function modules) and relay control circuits for sequential (logic) control functions are replaced with software function blocks connected between each other in the programming just like physical wiring. No specialized programming skill is required.

The figure below shows an example describing combined analog and sequential control functions realized on the software programming. Each rectangular box with bold lines represents a single function called 'function block.'



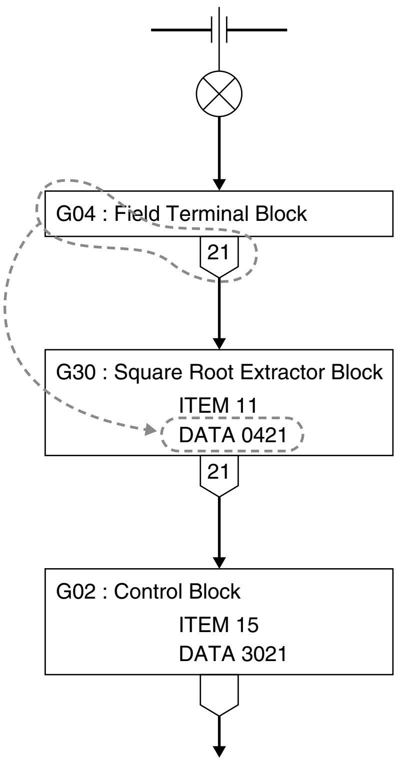
1.3 CONNECTING BETWEEN FUNCTION BLOCKS

A function block is referred to with Group No. in which it is registered. Group + terminal numbers are referred when connecting a block to another. Discrete signals are handled in a different manner from analog signals.

1.3.1 CONNECTING ANALOG SIGNALS

Group and terminal numbers of an analog signal source are registered at the destination function block where the signal is taken in and used.

A terminal is described as GGNN, where GG means Group No. and NN means Terminal No.



G01, G04 and G05 are groups for Field Terminal functions.

Group ‘04’ and Terminal ‘21’ are referred to provide the output signal of the field terminal block to ITEM 11 of G30 Square Root Extractor block.

Group ‘30’ and Terminal ‘21’ are referred to provide the output signal of the square root extractor block to ITEM 15 of G02 Control block.

1.3.2 CONNECTING DISCRETE SIGNALS

Discrete signals are registered in sequential control blocks: An input is approximated to a relay, while an output is to a coil. Inputs and outputs are represented in logic sequence commands. One block can contain at the maximum of 89 commands. Multiple blocks can be connected in serial to handle more commands. At the maximum of 1068 commands (12 blocks x 89 commands) can be registered.

■ GENERAL COMMAND FORMAT

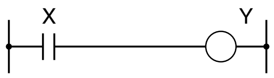
C C G G N N

- N N — Terminal No.
- G G — Group No.
- C C — Command Code

Major commands:
- 01 : INPUT............. The first N.O. contact in a relay circuit
- 03 : AND................ N.O. contact in series to INPUT
- 05 : OR.................. N.O. contact in parallel to INPUT
- 07 : OUTPUT......... Coil in a relay circuit

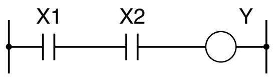
■ COMMAND EXAMPLES IN RELATION TO RELAY CIRCUITS

• Single input, single output



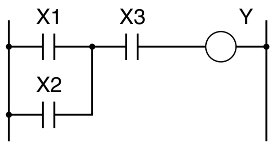
Symbol examples		Command examples
INPUT	X	0 1 0 5 1 1
OUTPUT	Y	0 7 0 5 0 1

• AND circuit



Symbol examples		Command examples
INPUT	X1	0 1 0 5 1 1
AND	X2	0 3 0 2 0 1
OUTPUT	Y	0 7 0 5 0 1

• OR and AND combination

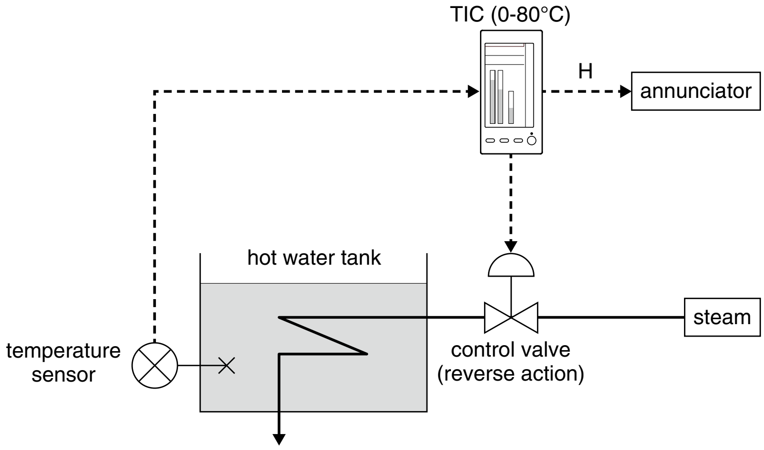


Symbol examples		Command examples
INPUT	X1	0 1 0 5 1 1
OR	X2	0 5 0 2 0 1
AND	X3	0 3 0 2 0 2
OUTPUT	Y	0 7 0 5 0 1

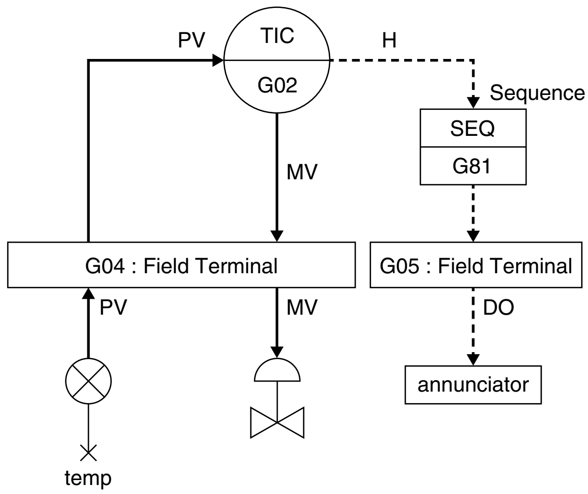
1.4 CODING PRINCIPLE

A temperature control loop with one PID control block is given as an example to explain how to proceed in coding.

■ **LOOP CONFIGURATION**



■ **BLOCK DIAGRAM**



(1) Determining necessary function blocks

- Basic PID is used for control function.
- High temperature limit is supplied to activate an alarm at DO terminal.

(2) Control Block

- Register Basic PID to Group 02 (or Group 03).
- Specify PV input from the SCxxx Extension Field Terminal 1 (Group 04).
- Set temperature range to 0.0-80.0°C, with ITEM 82 (upper range) set to ‘800,’ ITEM 83 (lower range) set to ‘0’ and ITEM 84 (decimal point position) set to ‘1.’
- Set reverse control action, with ITEM 40 set to ‘1’ so that the valve closes at MV output 4 mA.

(3) Sequential Control Block

- Register Sequential Control Block to Group 81.
- Write a command to turn on DO terminal at high alarm setpoint.
- Connect Basic PID terminal ‘01’ to trigger the alarm.

GROUP [04] SCxxx Extension Field Terminal 1 ★: Setting data

ITEM	MDFY	DATA INPUT	DISPLAY (e.g.)	CONTENTS
10	**IND**	**12**	**MD: 12**	**EXTENSION FIELD TERMINAL 1 (model)**
ANALOG OUTPUT CONNECTION TERMINAL				
★ 25	▲	GGNN	M1#: 0225	Mv 1 connection terminal (error if not connected) GG: Group No. NN : terminal No.
PV / MV SETTING				
★ 30	▲	-15.00 – 115.00 %	PH1: 115.00	Pv 1 high alarm setpoint (for error judgment)
★ 31	▲	-15.00 – 115.00 %	PL1: -15.00	Pv 1 low alarm setpoint (for error judgment)
★ 34	▲	0.00 – 115.00 %	ML1: 115.00	Mv 1 deviation alarm setpoint (for error judgment)

GROUP [02, 03] Basic PID ◆: Automatically changeable parameters ★: Setting data

ITEM	MDFY	DATA INPUT	DISPLAY (e.g.)	CONTENTS
★ **10**	▲	**21**	**MD: 21**	**BASIC PID (model)** '-' to clear.
PROCESS VALUE (PV)				
★ 15	▲	GGNN	P#: 0421	PV connection terminal GG: Group No. NN: terminal No.
◆ ★ 19	●	-15.00 – 115.00 %	PH: 95.00	PV high alarm setpoint
◆ ★ 20	●	-15.00 – 115.00 %	PL: 5.00	PV low alarm setpoint
◆ ★ 21	●	0.00 – 115.00 %	HS: 1.00	Hysteresis (deadband)
SETPOINT VALUE (SP)				
★ 24	▲	GGNN	(No connection)	CAS connection terminal
◆ ★ 27	●	-15.00 – 115.00 %	SP: 50.00	Local SP %
★ 29	▲	0, 1	SM: 0	Setting mode (0: local, 1: cascade/local)
DEVIATION				
◆ ★ 34	●	0.00 – 115.00 %	DL: 115.00	Deviation alarm setpoint (hysteresis (deadband) in ITEM 21)
CONTROL				
★ 40	▲	0, 1	DR: 1	Control direction (0: direct, 1: reverse [MV decreases with PV increase])
★ 41	▲	0, 1	DM: 0	Derivative method (0: PV derivative, 1: deviation derivative)
◆ ★ 42	●	1 – 1000 %	PB: 30	Proportional band
◆ ★ 43	●	0.00 – 100.00 min.	TI: 2.00	Integral time (0: no integral action)
◆ ★ 44	●	0.00 – 10.00 min.	TD: 1.50	Derivative time (0: no derivative action)
★ 45	▲	1, 2, 4, 8, 16, 32, 64	CP: 1	Control cycle (multiple of basic control cycle)
CONTROL OUTPUT MV				
◆ ★ 50	●	±115.00 %	MH: 100.00	Output high limit
◆ ★ 51	●	±115.00 %	ML: 0.00	Output low limit
52	▲	0, 1	08: 0	Preset value SW (1: preset)
SUPERVISORY INDICATION USE				
★ 80	▲	alphanumeric	TG: TIC-101	Tag name (10 characters max.)
★ 81	▲	alphanumeric	TC: TANK TEMP	Tag comment (16 characters max.)
★ 82	▲	±32000	MH: 800	Upper range (in engineering unit)
★ 83	▲	±32000	ML: 0	Lower range (in engineering unit)
★ 84	▲	0, 1, 2, 3, 4, 5	DP: 1	Decimal point position (from rightmost digit)
★ 85	▲	alphanumeric	TU: C	Engineering unit (8 characters max.)

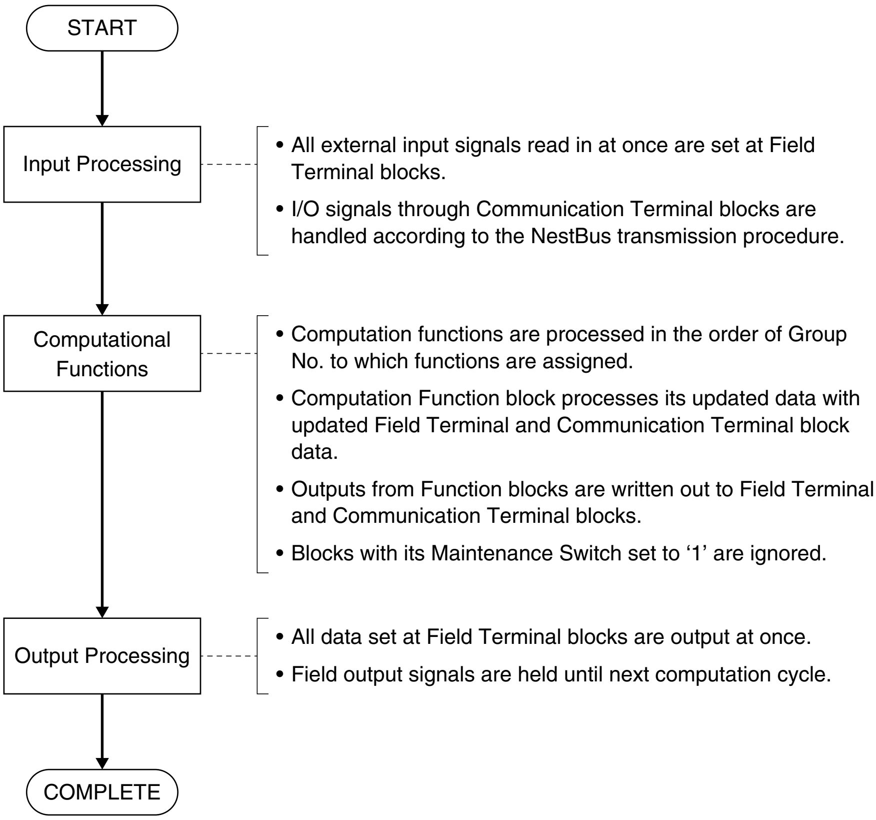
GROUP [81 – 92] Sequential Control Program ★: Setting data

ITEM	MDFY	DATA INPUT	DISPLAY (e.g.)	CONTENTS
★ **10**	▲	**95**	**MD: 95**	**SEQUENTIAL CONTROL PROGRAM** (model) '-' to clear.
★ 11	▲	CCGGNN	010201	PV high alarm (Group 02, Terminal 01)
★ 12	▲	CCGGNN	070501	Output at Do 1

2. COMMON FEATURES

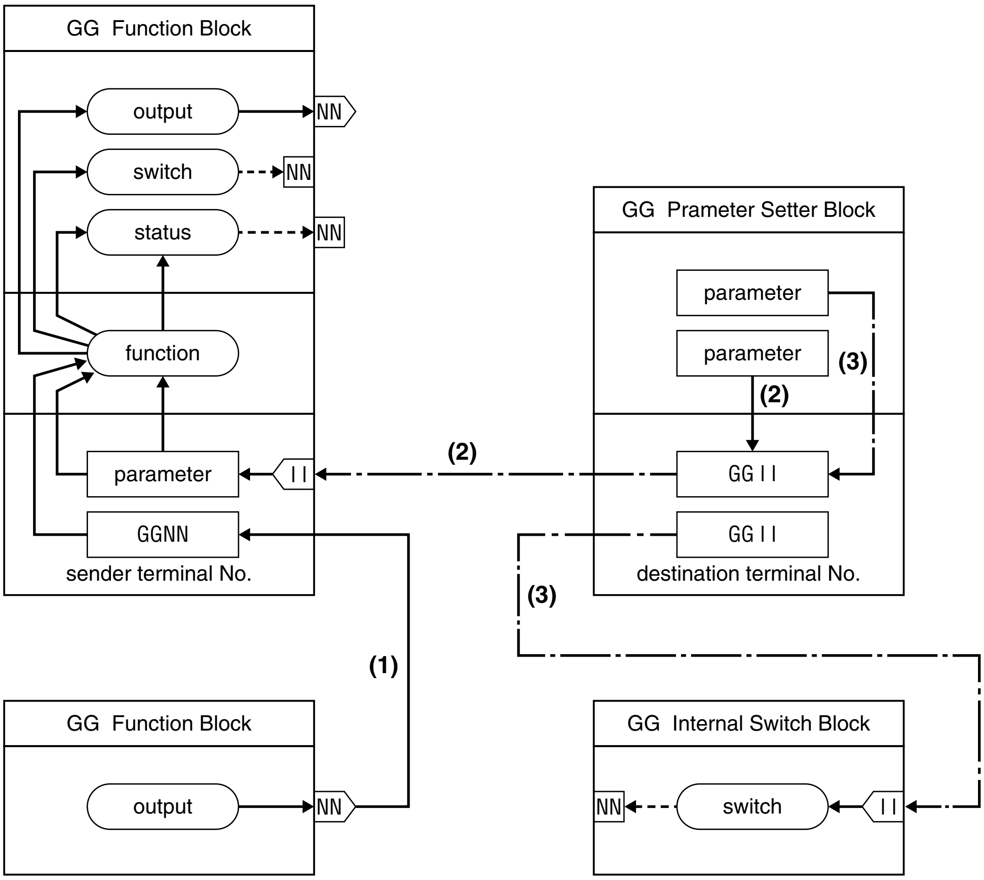
2.1 FUNCTION BLOCK PROCESSING ORDER

Field inputs are read in every computation cycle (basic control cycle) and each function block operates in turn. After the last function block has been processed, the values set at the field terminal block are output.



2.2 READING & SENDING DATA/PARAMETERS

Paths to read or send data and parameters are categorized in the following three types: Path (1) is a basic connecting method, while Paths (2) and (3) are used to apply a set of parameters at a specific point in the control sequence.



GG : Group No.

(1) Supplying an output from another function block

Specify Group and Terminal No. (GGNN) of the source block to the destination block input terminal.

(2) Changing parameters at a specific point of control sequence

Register parameters at Parameter Setter function block and send them to a specified block by a sequential control command. Available parameters depend upon each function block. Refer to the SC100/SC200 Series Function Block List (EM-6460-B).

(3) Changing internal switch values by using Parameter Setter function block

Parameter Setter block can be used to change internal switch values.

3. COMMUNICATION TERMINALS SC200/210

When built-in input and output signals available at Field Terminal blocks (Group 01, 04 and 05) are not enough, external input and output signals can be used by using Communication Terminal blocks. Those of remote I/Os and controllers connected via peer-to-peer communication network (NestBus) are available.

At the maximum of 16 Communication Terminal blocks of the following types are available:

- Di Receive Terminal (Di 32 points per block)
- Do Send Terminal (Do 32 points per block)
- Ai Receive Terminal (Ai 2 points per block)
- Ao Send Terminal (Ao 2 points per block)

When sending/receiving signals between devices, the one at the receiving side specifies the sender terminal.

3.1 DI RECEIVE TERMINAL

Di Receive Terminal is used to receive 32-point discrete signals from an external remote I/O or controller module.

Identifying the sender:

ITEM 11 Sender Station No. (Set always to ‘FF’)

ITEM 12 Sender Card No.

ITEM 13 Sender Group No.

3.2 DO SEND TERMINAL

Do Send Terminal is used to send 32-point discrete signals to an external remote I/O or controller module.

ITEM 11 Transmission range (Set always to ‘0’)

ITEM 12 Receiver address (Set always to ‘0’)

3.3 AI RECEIVE TERMINAL

Ai Receive Terminal is used to receive 2-point analog signals from an external remote I/O or controller module.

Identifying the sender:

ITEM 11 Sender Station No. (Set always to ‘FF’)

ITEM 12 Sender Card No.

ITEM 13 Sender Group No.

3.4 AO SEND TERMINAL

Ao Send Terminal is used to send 2-point analog signals to an external remote I/O or controller module. Transmission range ‘0: within the same NestBus’ must be set in ITEM 11.

ITEM 11 Transmission range (Set always to ‘0’)

ITEM 12 Receiver address (Set always to ‘0’)

ITEM 18 Ao 1 connection terminal (GGNN)

ITEM 19 Ao 2 connection terminal (GGNN)

4. CONTROL BLOCKS

4.1 CONTROL BLOCK TYPES

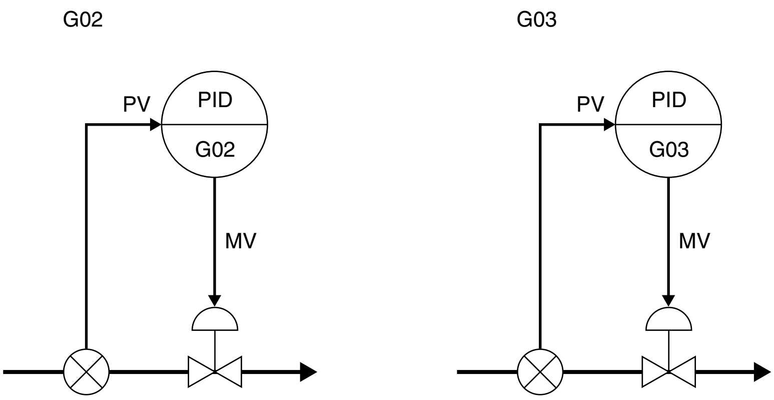
Two control blocks of the following types are available, registered in Group 02 and 03.

- Basic PID
- Advanced PID
- Manual Loader
- Ratio Setter
- Indicator

4.1.1 SIMPLE LOOP CONTROL

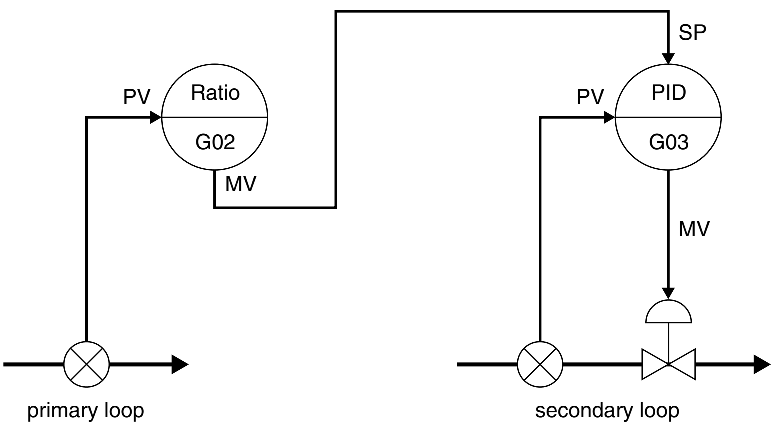
PID control function is applied to Group 02 and 03 to realize two independent PID control loops. In the following example, Group 02 and Group 03 MV outputs are provided via respective MV output terminals of the Controller.

If PID is not needed, Manual Loader function block is also available to directly manipulate the MV output.



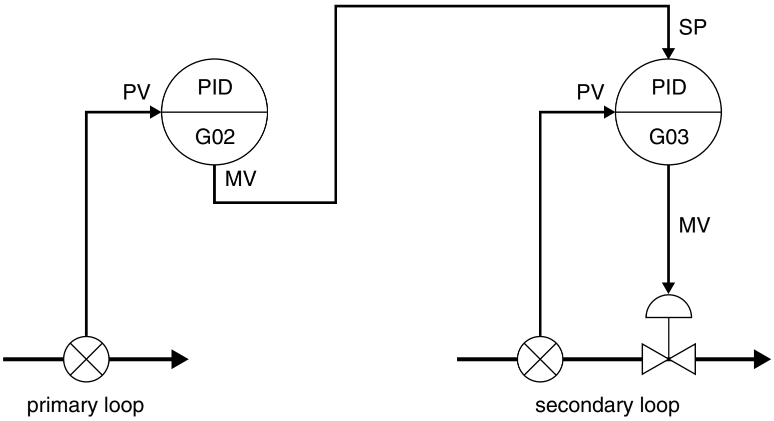
4.1.2 RATIO CONTROL

Ratio Setter function is applied to Group 02, and PID Control function is applied to Group 03 in the example shown below.



4.1.3 CASCADE CONTROL

PID control function is applied to Group 02 and 03, and the primary loop MV output is connected to the secondary loop SP input in the example shown.



4.2 PID CONTROL

Refer to Basic PID and Advanced PID blocks in the SC100/SC200 Series Function Block List (EM-6460-B) for the following ITEM numbers and explanations.

4.2.1 PROCESS VALUE PV

• Engineering unit range (ITEM 82 thr. 85)

In order to set temperature range to 0.0-1200.0°C for example, set ITEM 82 (upper range) to '12000,' ITEM 83 (lower range) to '0,' ITEM 84 (decimal point position) to '1,' and ITEM 85 (engineering unit) to 'C.'

• PV connection terminal (ITEM 15)

Used to specify Group and Terminal No. of measured input signal terminal.

4.2.2 SETPOINT VALUE SP

• CAS connection terminal (ITEM 24)

Used to specify Group and Terminal No. of the analog input used for cascade control. If 'Local' setting mode (ITEM 29) is specified, the terminal is not needed.

• Setting mode (ITEM 29)

Used to specify whether the setpoint value is controlled only locally (Loc mode) or its setting should be able to be switched between cascade and local control (Cas/Loc mode). When Cas/Loc mode is specified, a sequence control command is used to remotely select between modes.

• C/L switch (Terminal 03, ITEM 30)

Used to switch cascade or local setpoint control. The command is invalid when ITEM 29 is set to the local setting mode. A sequence control command (1: Cascade, 0: Local) can switch it.

• SP rate-of-change limit (ITEM 32) (Advanced PID)

Used to apply a limit in the rate of change in the setpoint. Set '0' if the function is not needed.

• Current SP monitoring (ITEM 33)

Current SP can be read out on the Programming View of the Controller.

• Current SP transmission (Terminal 22)

Current SP can be re-transmitted via the terminal 22.

• SP tracking SW (Terminal 04) (Advanced PID)

When the terminal 04 is set with '1,' the SP tracks the PV. The SP always equals the PV.

4.2.3 ALARM

• Setpoint setting

ITEM 19	PV high alarm setpoint (%)
ITEM 20	PV low alarm setpoint (%)
ITEM 21	Hysteresis (deadband) (%) common to high/low and deviation alarm
ITEM 34	Deviation alarm setpoint (%)

• Alarm trip status monitoring

ITEM 22	PV high alarm status
ITEM 23	PV low alarm status
ITEM 35	Deviation alarm status

• Alarm output

Terminal 01	PV high alarm
Terminal 02	PV low alarm
Terminal 03	Deviation alarm

4.2.4 INPUT COMPENSATION (Advanced PID)

Input compensation is a function applied to input deviation before it is supplied to the PID control.

• Input compensation SW (Terminal 06, ITEM 37)

The input compensation is applied in the method specified with ITEM 38 when the switch is turned on. Use the terminal 06 to control it from a sequential control block.

• Input compensation method (ITEM 38)

0 : Without compensation ... The deviation signal is supplied directly to the PID.
1 : Addition .... An external signal is added to the deviation before it is supplied to the PID.
2 : Subtraction..................... An external signal is subtracted from the deviation before it is supplied to the PID.
3 : Substitution .... An external signal is supplied to the PID instead of the deviation signal.

• Input compensation connection terminal (ITEM 39)

Used to specify Group and Terminal No. of the external signal used for input compensation.

• Deviation output (Terminal 23)

Deviation of the PV from the SP used for input compensation.

4.2.5 PID CONTROL

PID control transfer function is expressed with the following formula:

$$G(s) = \frac{100}{PB} \times \left\{ 1 + \frac{1}{T_I s} + \frac{T_D s}{(1 + T_D s / m)} \right\}$$

where PB = Proportional band
T_I = Integral time
T_D = Derivative time
m = Derivative gain (= 10)
s = Laplace operator

The first term on the right side represents the proportional control function, which provides an output proportional to deviation.

The second term represents the integral control function, which provides an output proportional to an integration of deviation.

The third term represents the derivative control function, which provides an output proportional to a rate-of-change of deviation.

Respective time constants for the integral and the derivative are completely independent from each other in the above equation, therefore each control strategy can be achieved without interference.

• Control direction (ITEM 40)

Used to determine the relation between the increasing/decreasing of deviation (= PV – SP) and the manipulated output.

Direct action: The output increases when the deviation increases.

Reverse action: The output decreases when the deviation increases.

Relations between control valve action and control direction

CONTROL LOOP	VALVE LOCATION / CONTROL OBJECT	CONTROL DIRECTION	
		DIRECT ACTION VALVE	REVERSE ACTION VALVE
Temperature control	Heating Cooling	Direct Reverse	Reverse Direct
Pressure control	Upstream control (release valve) Downstream control	Reverse Direct	Direct Reverse
Flow control	Valve connected in series with a sensing element Return valve (pump bypass valve)	Direct Reverse	Reverse Direct
Level control	Tank inlet Tank outlet	Direct Reverse	Reverse Direct
pH control	Alkali Acid	Direct Reverse	Reverse Direct

Remark: Control valve action
Direct action: Opening 100% at 4 mA (Air to Close)
Reverse action: Opening 0% at 4 mA (Air to Open)

• Derivative method (ITEM 41)

Choose either PV derivative or deviation derivative according to the user's application needs. In general, PV derivative setting, in which the derivative action is inactive at a setpoint change, does not give unnecessary disturbance to the process. However, the deviation derivative setting may produce a better control result when the secondary loop in cascade control is set with derivative action.

• Proportional band (ITEM 42)

Choose between 1 and 1000%.

• Integral time (ITEM 43)

Choose between 0.00 to 100.00 minutes. The integral action is cancelled when '0.00' is set.

• Derivative time (ITEM 44)

Choose between 0.00 to 10.00 minutes. The derivative action is cancelled when '0'.00 is set.

• Auto-tracking bumpless transition

The integral term is adjusted automatically to avoid a bump in the control output signal when the control is switched from manual to automatic, or when a PID constant is changed.

Adjustments are applied when:

- A/M SW is turned from 0 (Manual) to 1 (Auto).
- Preset value SW is turned from 1 (Preset) to 0 (Cancel).
- Output hold SW is turned from 1 (Hold) to 0 (Cancel).
- I/O compensation SW is turned from 0 (Cancel) to 1 (With) or from 1 (With) to 0 (Cancel).
- External feedback SW is turned from 1 (With) to 0 (Cancel)
- Error status is cancelled.
- Maintenance SW (lock command) is turned from 1 (PROGRAM mode) to 0 (MONITOR mode).
- A PID parameter is changed.
- The Controller is at the startup.

4.2.6 OUTPUT COMPENSATION (Advanced PID)

Output compensation is a function applied to the output of PID control.

• Output compensation SW (Terminal 07, ITEM 47)

The output compensation is applied in the method specified with ITEM 48 when the switch is turned on. Use the terminal 07 to control it from a sequential control block.

• Output compensation method (ITEM 48)

0 : Without compensation

1 : Addition .... An external signal is added to the PID output.

2 : Subtraction..................... An external signal is subtracted from the PID output.

3 : Substitution .... An external signal is supplied as the PID output. Used also to reroute the PID output for an external computation function. The control output with output compensation may bump when the control is switched from Manual to Auto.

• Output compensation connection terminal (ITEM 49)

Used to specify Group and Terminal No. of the external signal used for output compensation.

4.2.7 OUTPUT LIMITS

• Output high/low limits (ITEM 50, 51)

Used to limit the highest and lowest control outputs within certain range. When the output reaches either of the limits, the integral term is adjusted so that the output remains at the limit. This prevents the integral term acting excessively, and reduces overshooting caused by integral windup when the deviation is reversed to the direction toward inside of the limits.

• Output rate-of-change limit (ITEM 54) (Advanced PID)

Used to limit the rate-of-change in control output. Typically used to prevent a boiler from abrupt load disturbance by limiting opening/closing speed of a large steam valve.

4.2.8 PRESET VALUE SW

• Preset value SW (Terminal 08, ITEM 52)

The control output is fixed at a preset value when the switch is turned on. Use the terminal 08 to control it from a sequential control block.

• Preset value (ITEM 53)

Used to specify the preset value. The preset value lies downstream of the output high/low limits and thus not is limited by them.

4.2.9 OUTPUT HOLD SW (Advanced PID)

• Output hold SW (Terminal 09, ITEM 55)

The control output is held when the switch is turned on. Use the terminal 09 to control it from a sequential control block.

4.2.10 EXTERNAL FEEDBACK (OUTPUT TRACKING) (Advanced PID)

External feedback signal is routed to the PID control output (output tracking) when the switch is turned on. When the function is reset, the output transitions smoothly to that by PID control.

• External feedback connection terminal (ITEM 56)

Used to specify Group and Terminal No. of the external feedback signal.

• Output hold SW (Terminal 10, ITEM 58)

The control output tracks the external feedback signal when the switch is turned on. Use the terminal 10 to control it from a sequential control block.

4.2.11 AUTO/MAN SW

• A/M SW (Terminal 11, ITEM 59)

Automatic or manual control is selected by the switch. Use the terminal 11 to control it from a sequential control block.

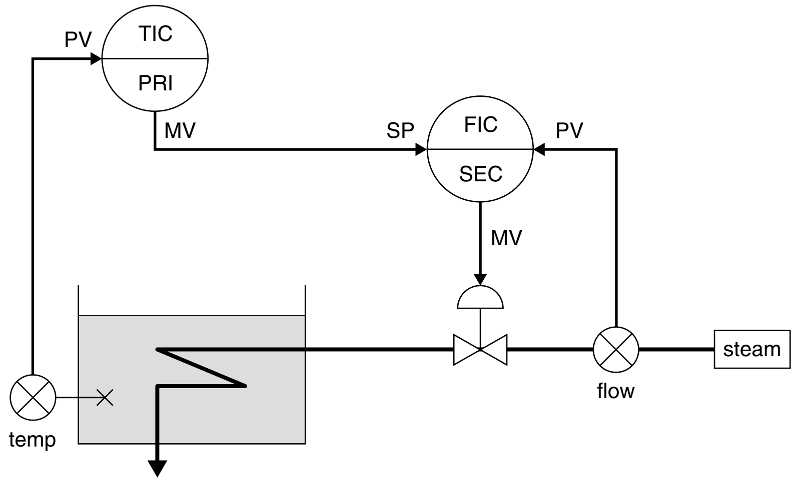
4.3 CONTROL LOOP CONFIGURATION EXAMPLES

4.3.1 CASCADE CONTROL

The main purpose for configuring a cascade control system is to eliminate, through use of a secondary controller, the influence of disturbance on the primary loop, which enters through the secondary control loop.

■ LOOP CONFIGURATION EXAMPLE

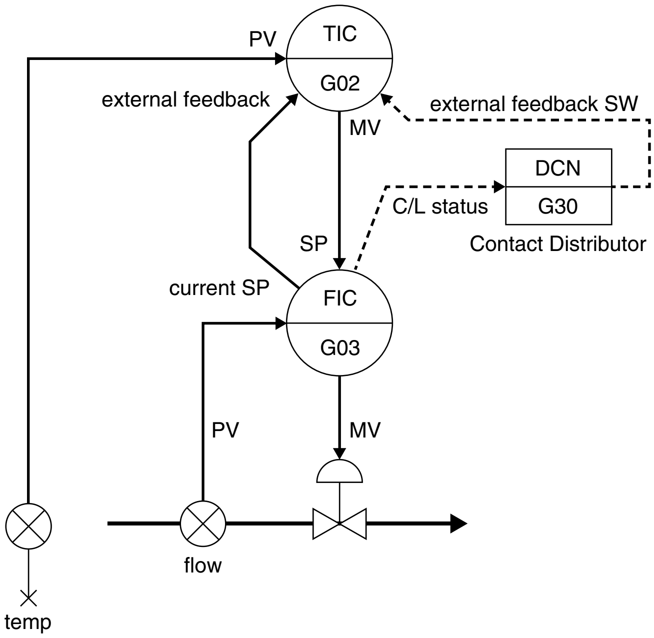
The MV output from the primary temperature loop is provided as setpoint to the secondary flow loop.



■ BLOCK DIAGRAM EXAMPLE (1): USING CONTACT DISTRIBUTOR BLOCK

Using the external feedback (output tracking) function of the primary loop, the primary loop MV tracks current SP of the secondary loop when the secondary is at Loc mode setting. This configuration realizes smooth control output transition of the primary loop with automatic tracking when the secondary loop control is switched to/from the Loc mode.

Contact Distributor block enables the C/L SW status signal to directly control the external feedback SW, without needing a sequential control block.

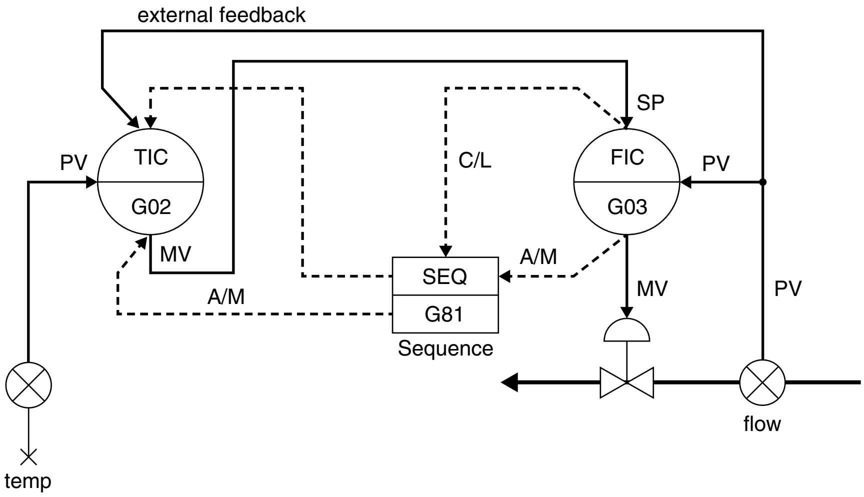


■ CODING LIST ESSENTIALS FOR THE EXAMPLE (1)

GROUP	ITEM	DATA	FUNCTION
02	10	22	Primary loop control block
	56	0322	External feedback connection terminal (secondary loop current SP)
03	10	22	Secondary loop control block
	24	0225	CAS connection terminal (primary loop MV)
30	10	87	Contact distributor block
	11	0303	Input terminal specified to the secondary loop C/L SW status
	12	0310	Destination terminal specified to the secondary loop external feedback SW

■ BLOCK DIAGRAM EXAMPLE (2): USING SEQUENTIAL CONTROL BLOCK

The control output transitions smoothly with automatic tracking when the Cas/Loc control is switched, and the Auto/Man is switched at the secondary loop.



■ OPERATION FOR THE EXAMPLE (2)

How to switch between A/M and C/L:

- Always set the primary loop (TIC) to Auto mode.
- When the secondary loop (FIC) is set to Cas mode:

  Auto mode: Cascade control

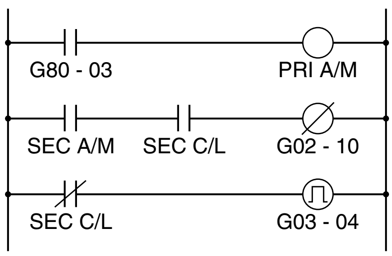
  Manual mode: Manual control of the valve is available. The primary loop MV and the secondary loop SP are tracking the primary loop PV in this state. The MV can be smoothly switched to Auto mode without a bump.
- When the secondary loop (FIC) is set to Loc mode:

  Auto mode: Local control is available. The primary loop MV is tracking the secondary loop PV in this state. The MV can be smoothly switched to Cas mode without a bump.

  Manual mode: Manual control of the valve is available. Turn Loc to Cas before turning to Auto mode.

■ CODING LIST ESSENTIALS FOR THE EXAMPLE (2)

GROUP	ITEM	DATA	FUNCTION
02	10	22	Primary loop control block
	56	0422	External feedback connection terminal (secondary loop PV)
03	10	22	Secondary loop control block
	24	0225	CAS connection terminal (primary loop MV)
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	018003	IN G80 - 03 System's internal SW (always ON)
	13	070211	OT A/M SW (primary loop)
	14	010311	IN A/M SW (secondary loop)
	15	030303	AN C/L SW (secondary loop)
	16	080210	NO G02 - 10 External feedback SW (primary loop)
	17	020303	NI G03 - 03 C/L SW (secondary loop)
	18	110304	SH G03 - 04 SP tracking SW (secondary loop)



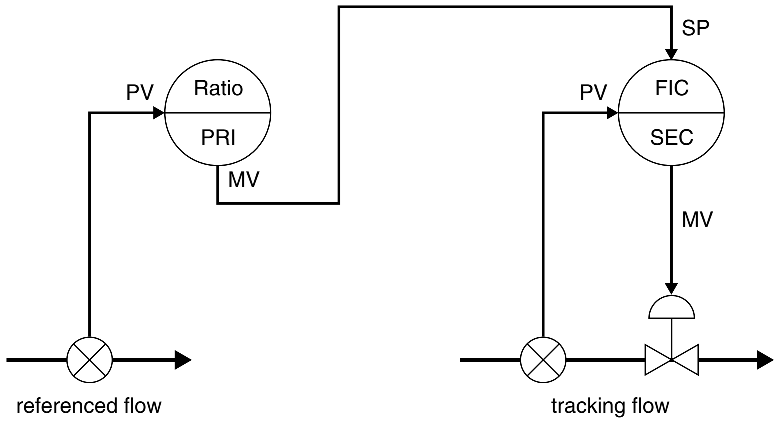
Always setting the primary loop to Auto

Setting the primary loop to Auto (external feedback SW OFF) with the secondary loop set to Auto/Cas modes

4.3.2 RATIO CONTROL

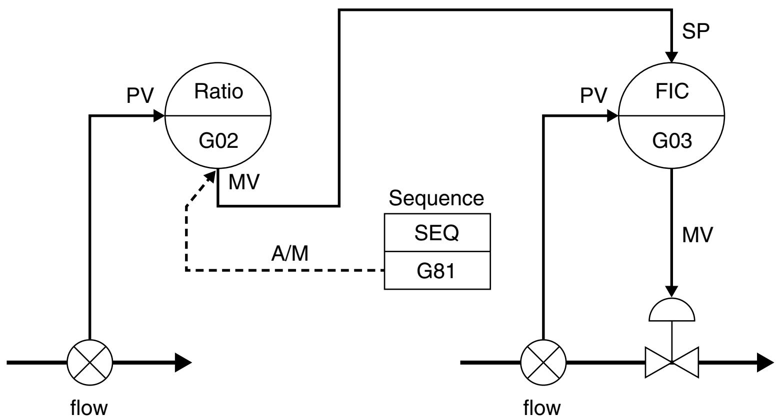
Ratio control attempts to preserve a ratio relationship between two process variables.

■ LOOP CONFIGURATION EXAMPLE



Secondary SP = Ratio x Primary PV

■ BLOCK DIAGRAM

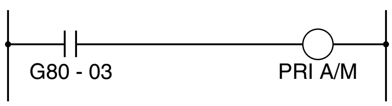


■ OPERATION

- Always set the primary loop (ratio setting) to Auto mode.
- Constant setpoint control and ratio control is selected by the secondary loop C/L SW.

■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	24	Primary loop control block (ratio setter)
03	10	21	Secondary loop control block (PID)
	24	0225	CAS connection terminal (primary loop MV)
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	018003	IN G80 - 03 System's internal SW (always ON)
	13	070211	OT A/M SW (primary loop)

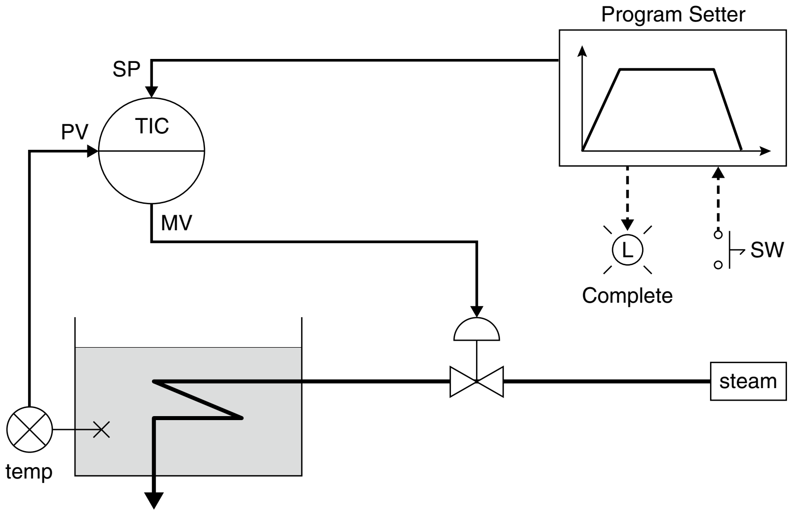


Always setting the primary loop to Auto

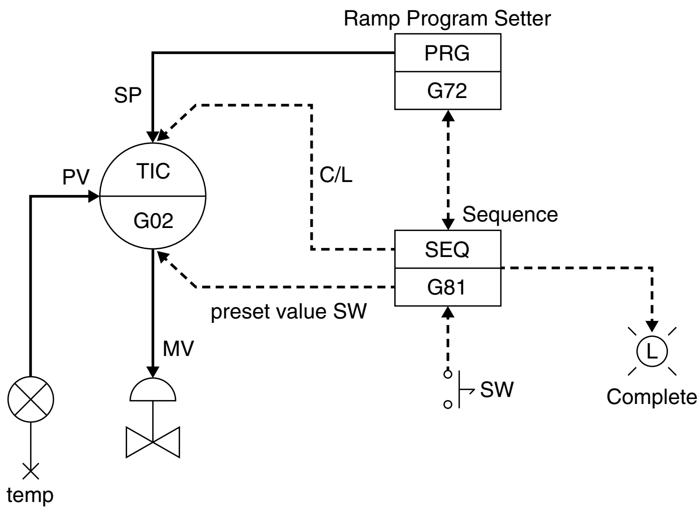
4.3.3 PROGRAM CONTROL

Setpoint is provided as a preset ramp program running over time.

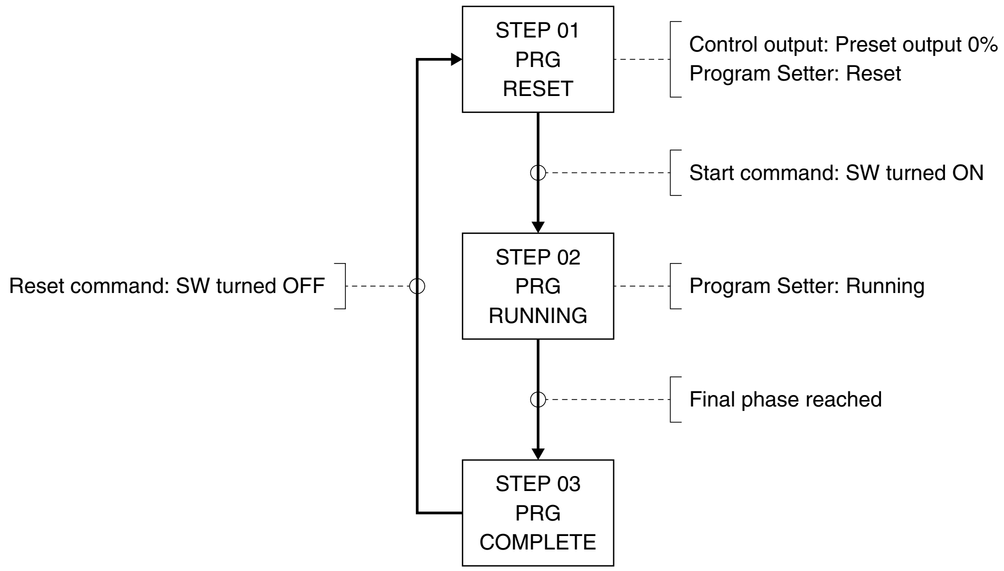
■ LOOP CONFIGURATION EXAMPLE



■ BLOCK DIAGRAM

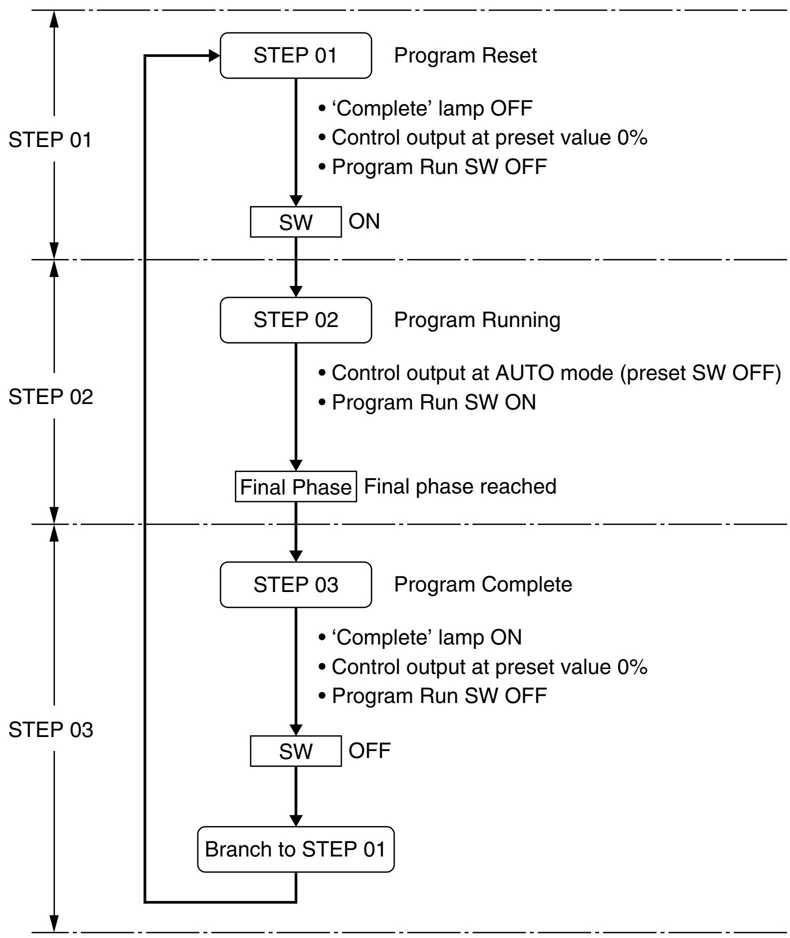


■ OPERATION



■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	21	Control block
	24	7221	CAS connection terminal (program setter output X0)
	53	0.00	Preset value
72	10	69	Ramp program setter block
	12	0	Initial value A0 %
	13	2.00	Ramp rate K1 %/C1
	14	0	K1 time unit C1 sec
	15	50.00	Hold value A1 %
	16	20	Hold time T1
	17	0	T1 time unit P1 sec
	18	-2.00	Ramp rate K2 %/C2
	19	0	K2 time unit C2 sec
	20	0.00	Hold value A2 %
	21	0	Hold time T2
	22	0	T2 time unit P2 sec
	23	0.00	Ramp rate K3 %/C3
81	10	95	Sequential control block
	11	130001	ST STEP 01 (program reset)
	12	100501	OF DO contact Program Complete lamp OFF
	13	090208	ON Preset value selector SW set to Preset
	14	100203	OF C/L SW set to Local
	15	107201	OF Program Run SW OFF
	16	010511	IN SW ON
	17	130002	ST STEP 02 (program running)
	18	100208	OF Preset value selector SW set to Auto
	19	090203	ON C/L SW set to Cascade
	20	097201	ON Program Run SW ON
	21	017211	IN Final phase reached
	22	130003	ST STEP 03 (program complete)
	23	090501	ON DO contact Program Complete lamp ON
	24	090208	ON Preset value selector SW set to Preset
	25	100203	OF C/L SW set to Local
	26	107201	OF Program Run SW OFF
	27	020511	NI SW OFF
	28	120001	BR Return to STEP 01


STEP 01
Program Reset
• 'Complete' lamp OFF
• Control output at preset value 0%
• Program Run SW OFF
SW
ON
STEP 02
Program Running
• Control output at AUTO mode (preset SW OFF)
• Program Run SW ON
Final Phase
Final phase reached
STEP 03
Program Complete
• 'Complete' lamp ON
• Control output at preset value 0%
• Program Run SW OFF
SW
OFF
Branch to STEP 01

4.3.4 OVERRIDE CONTROL

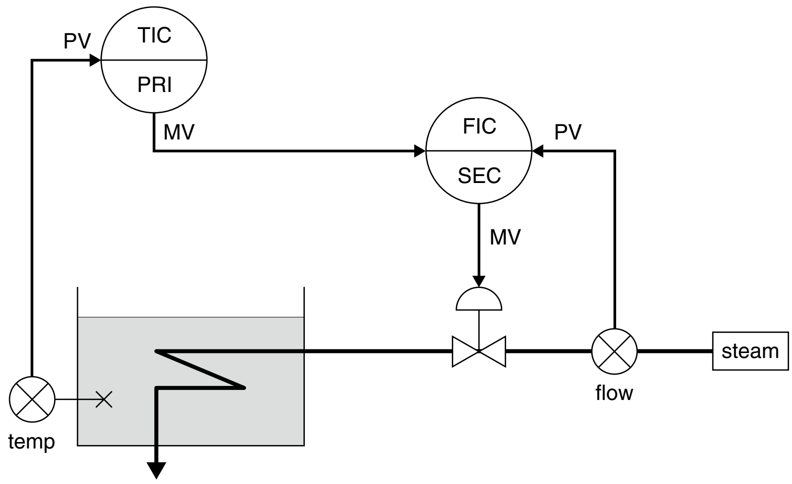
Override control is used to take control of an output from one loop to allow a more important loop to manipulate the output, thus the output from two or more controllers are combined to manipulate a final control element. It is a typical application of external feedback (output tracking) function.

■ LOOP CONFIGURATION EXAMPLE

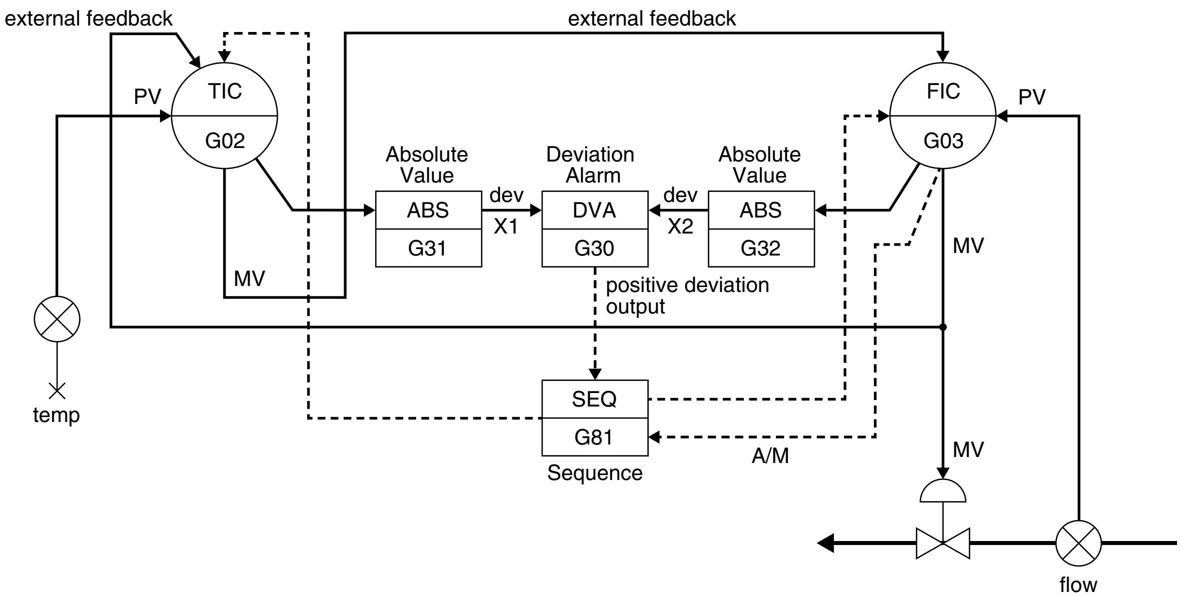
• Temperature control of a tank is the main purpose of the system.

• The FIC is used to maintain steam flow within a preset limit.

• The TIC output is repeated at the FIC output when the TIC takes control.

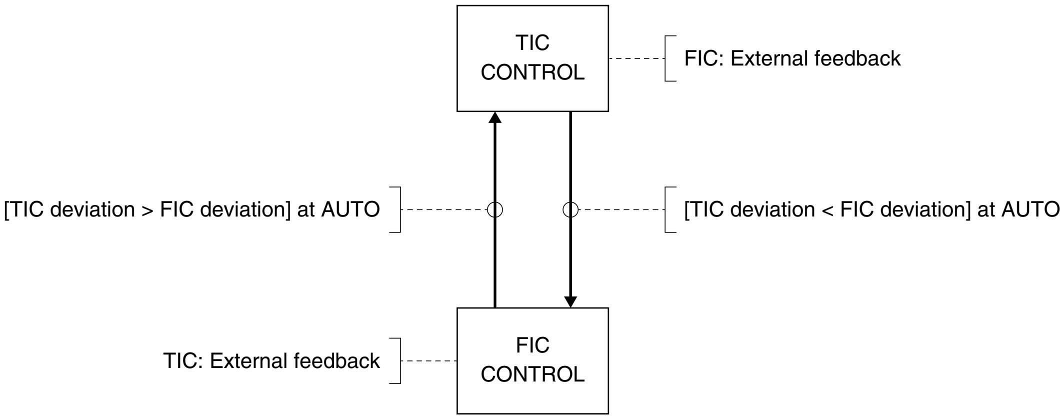


■ BLOCK DIAGRAM



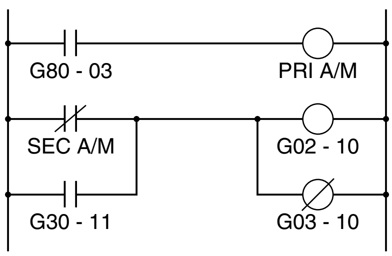
■ OPERATION

Either the TIC or the FIC, the one that has a larger deviation from respective setpoints, overtakes control. When the A/M SW for the FIC loop is set to Manual, the TIC loop output takes in the external feedback (tracking output).



■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	22	Primary loop control block
	56	0325	External feedback connection terminal (secondary loop MV)
03	10	22	Secondary loop control block
	56	0225	External feedback connection terminal (primary loop MV)
30	10	77	Deviation alarm block
	11	3121	X1 connection terminal (absolute value of deviation output from the primary loop)
	12	3221	X2 connection terminal (absolute value of deviation output from the secondary loop)
	13	0.00	High setpoint (%)
	15	0.00	Hysteresis (deadband) (%)
31	10	55	Absolute value block
	11	0223	X1 connection terminal (deviation output from the primary loop)
32	10	55	Absolute value block
	11	0323	X1 connection terminal (deviation output from the secondary loop)
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	018003	IN G80 - 03 System's internal SW (always ON)
	13	070211	OT A/M SW (primary loop)
	14	020311	NI A/M SW (secondary loop)
	15	053011	OR High deviation alarm output (TIC deviation < FIC deviation)
	16	070210	OT G02 - 10 External feedback SW (primary loop)
	17	080310	NO G03 - 10 External feedback SW (secondary loop)



The external feedback SWs are programmed so that they do not turn on at once.

4.3.5 PD/PID SWITCHING

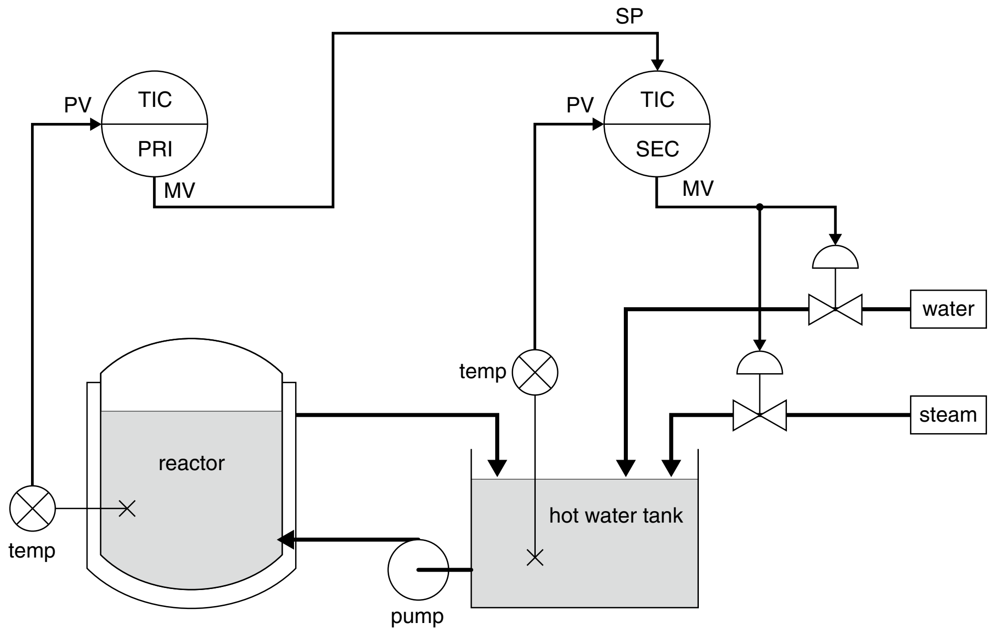
PD control is used while the control loop has a large deviation, and then the control is switched to PID once the deviation has become a small enough value. This method is used mainly to avoid 'integral windup' situation, an excess overshooting that occurs when the integral term accumulates a significant error during initial temperature rise in a batch control system (windup).

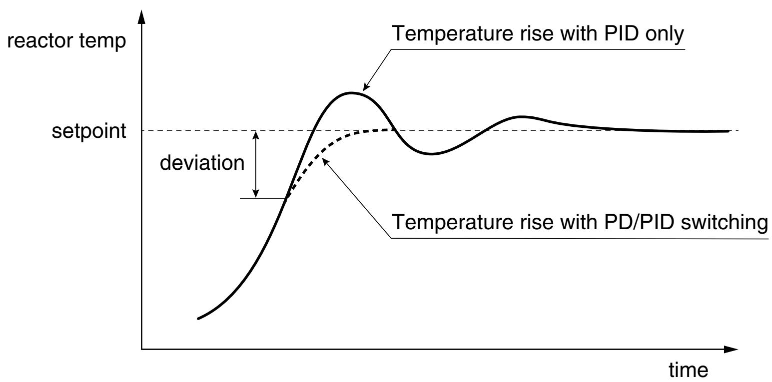
■ LOOP CONFIGURATION EXAMPLE

• Heating control of a batch reactor is given as an example below.

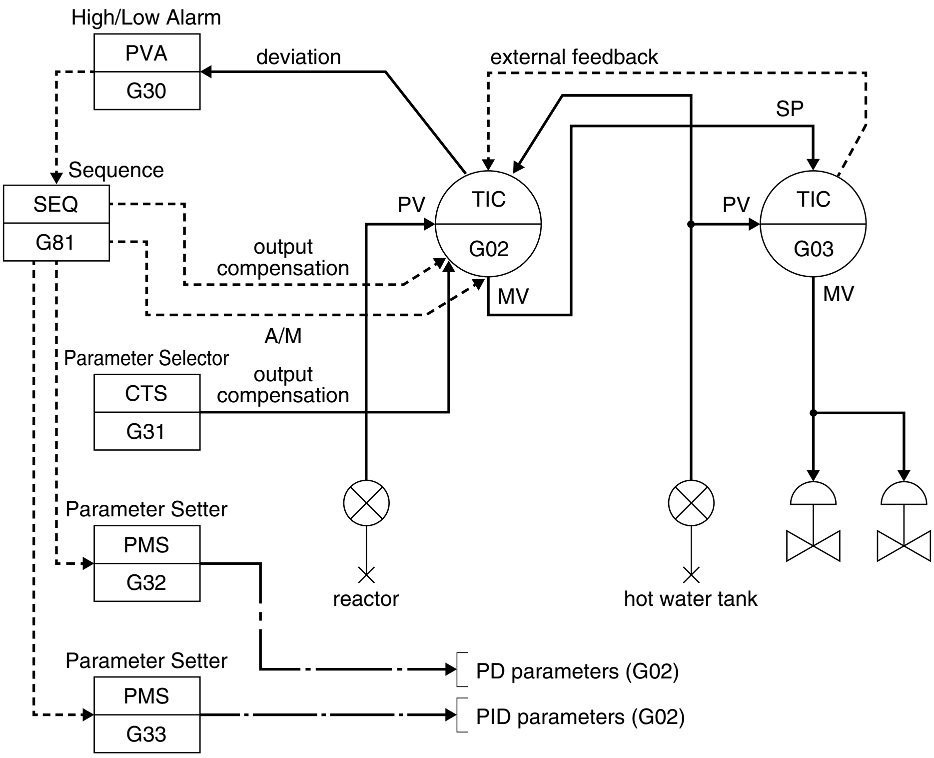
• PD control is used to prevent integral windup while the control loop has a large deviation.

• PD and PID parameters are set independently.





■ BLOCK DIAGRAM



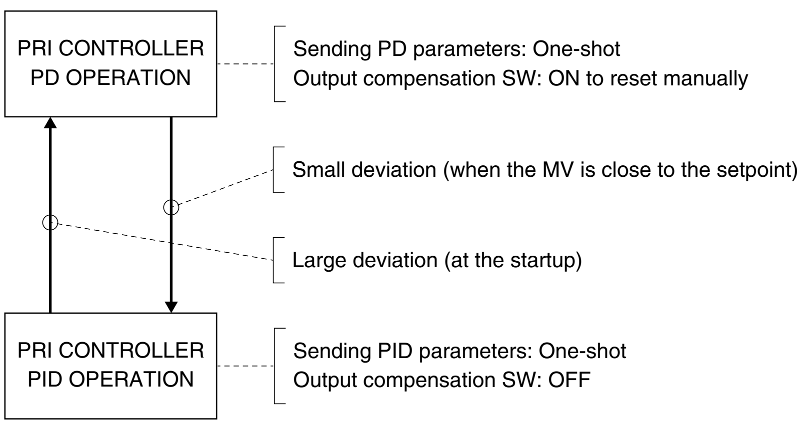
G02 : Control block	(primary loop, reactor temperature)
G03 : Control block	(secondary loop, hot water tank temperature)
G30 : High/Low Alarm	(to detect deviation)
G31 : Parameter Selector	(to manually reset in PD operation)
G32 : Parameter Setter	(for PD operation)
G33 : Parameter Setter	(for PID operation)
G81 : Sequential Control	

[Caution: Use of Parameter Selector Block]

1) Be sure to use OUTPUT SHOT commands for S1 and S2 selector SWs.
2) Parameters can be rewritten for the maximum of one hundred thousand (10^5) times according to the EEPROM rating. For example, it reaches the limit in eleven (11) years if they are rewritten once per hour. Please keep this in consideration when using the Parameter Selector block.

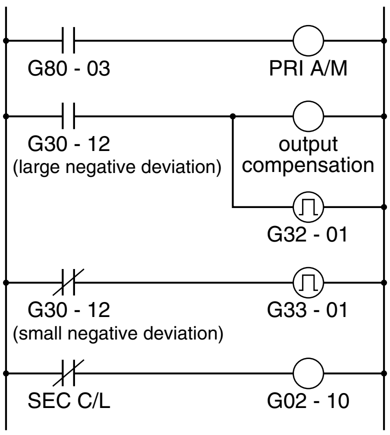
■ OPERATION

- The primary MV output must be set to Auto.
- Apply external feedback to the primary loop MV output while the secondary loop is in Local mode, so that the MV tracks the hot water tank temperature. This ensures smooth transition of MV value when the secondary loop is switched to Cas mode.



■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	22	Primary loop control block
	48	1	Output compensation method set to ‘addition’ (for manual resetting)
	49	3121	Output compensation connection terminal (for manual resetting)
	56	0422	External feedback connection terminal (secondary loop PV)
03	10	22	Secondary loop control block
30	10	76	High/low alarm block
	11	0223	X1 connection terminal (deviation output from the primary loop)
	13	set	Low setpoint (%)
	14	set	Hysteresis (deadband) (%)
31	10	75	Parameter selector block
	11	set	A1 parameter (manual reset value)
32	10	79	Parameter setter block (PD)
	11	0242	G1 connection terminal (to the primary control block PB)
	12	0243	G2 connection terminal (to the primary control block TI)
	13	0244	G3 connection terminal (to the primary control block TD)
	14	set	A1 parameter (PB)
	15	0	A2 parameter (TI : withtout)
	16	set	A3 parameter (TD)
33	10	79	Parameter setter block (PID)
	11	0242	G1 connection terminal (to the primary control block PB)
	12	0243	G2 connection terminal (to the primary control block TI)
	13	0244	G3 connection terminal (to the primary control block TD)
	14	set	A1 parameter (PB)
	15	set	A2 parameter (TI)
	16	set	A3 parameter (TD)
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	018003	IN G80 - 03 System’s internal SW (always ON)
	13	070211	OT A/M SW (primary loop)
	14	013012	IN G30 - 12 (large deviation)
	15	070207	OT G02 - 07 Output compensation SW (primary loop)
	16	113201	SH G32 - 01 Sending PD parameters
	17	023012	NI G30 - 12 (small deviation)
	18	113301	SH G33 - 01 Sending PID parameters
	19	020303	NI C/L SW (secondary loop)
	20	070210	OT G02 - 10 External feedback SW (primary loop)



Always setting the primary loop to Auto

Manual reset is valid at PD control

Sending PD parameters

Sending PID parameters

Turning on the primary loop external feedback SW when the secondary loop is set to Loc mode

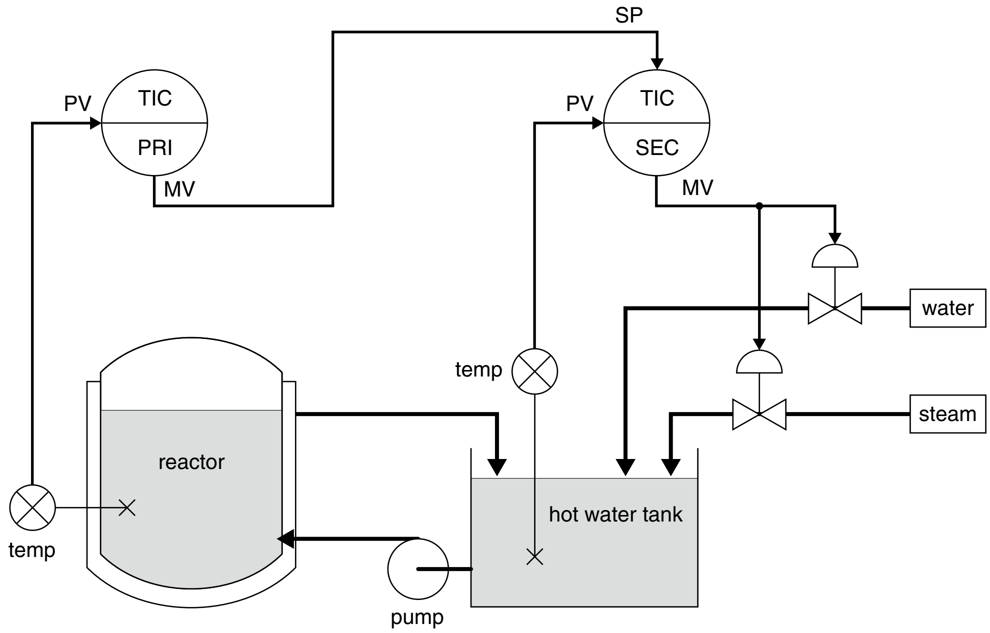
[Parameters]

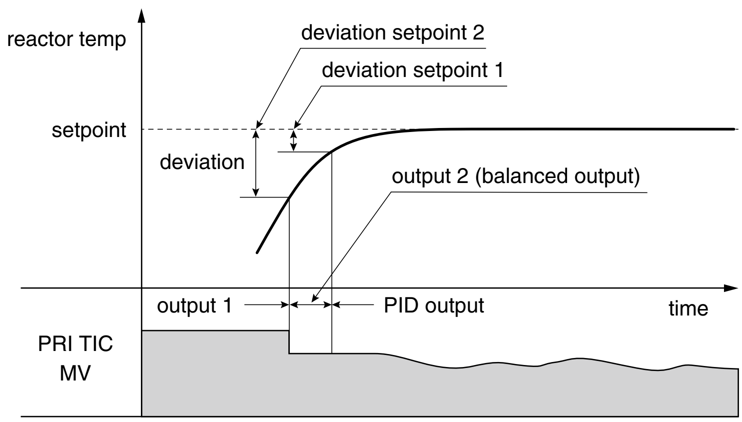
- PID control: Normal setting
- PD control: Set a PB value slightly smaller than and a TD value slightly larger than the respective values for PID.
- Manual reset: Equal to MV value when the deviation equals ‘0.’
- Deviation and deadband set values: Set the above values first and choose appropriate deviation and deadband values so to avoid integral (reset) windup while maintaining the shortest rise time.

4.3.6 BATCH PID CONTROL

The MV output is set to the maximum to quicken initial heating in a batch control process, and then reduced to an expected balanced output value before PID starts taking control. This is a typical control method employed for a batch control process with advantages of minimizing the initial heating time and avoiding an excess overshooting caused by accumulated integral term. It is used also because of the relative simplicity in determining the deviation set value.

■ **LOOP CONFIGURATION EXAMPLE**

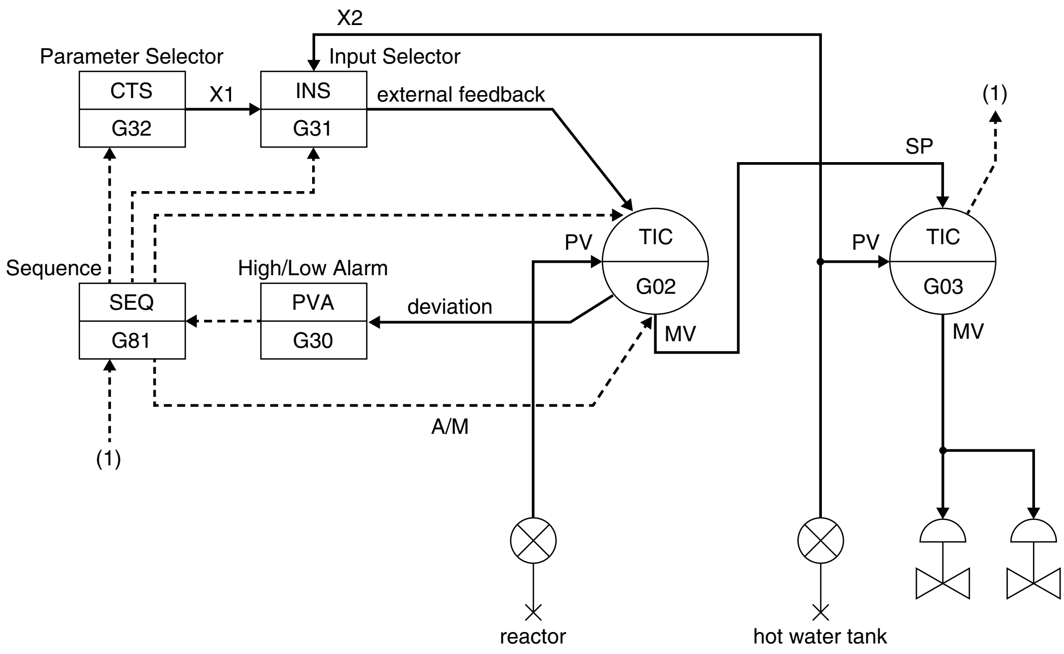




[Parameters]

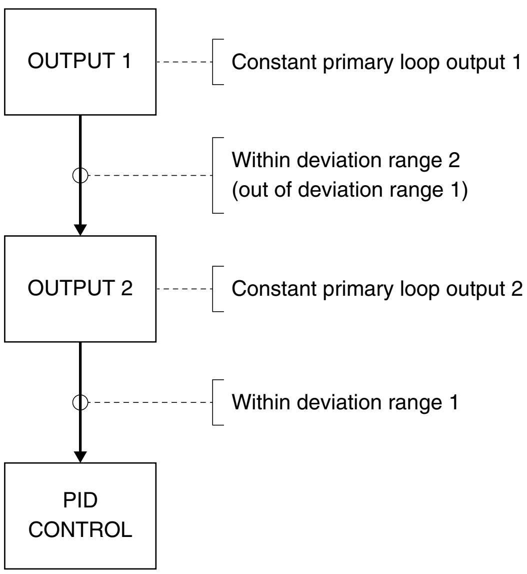
• Deviation setpoints, output values and PID parameters are to be determined by simulation and actual trials.

■ **BLOCK DIAGRAM**



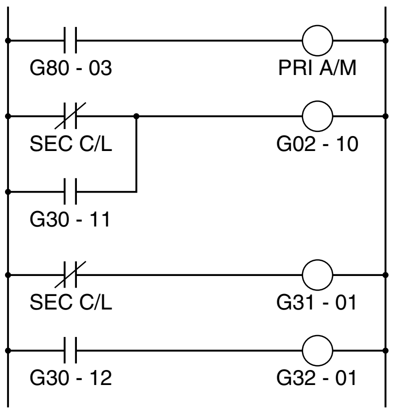
G02 : Control block	(primary loop)
G03 : Control block	(secondary loop)
G30 : High/Low Alarm	(to detect deviation)
G31 : Input Selector	
G32 : Parameter Selector	(output 1 and output 2)
G81 : Sequential Control	

■ **OPERATION**



■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	22	Primary loop control block
	56	3121	External feedback connection terminal (input selector output)
03	10	22	Secondary loop control block
30	10	76	High/low alarm block
	11	0223	X1 connection terminal (deviation output from the primary loop)
	12	set	High setpoint (%) for deviation setpoint 1
	13	set	Low setpoint (%) for deviation setpoint 2
	14	set	Hysteresis (deadband) (%)
31	10	72	Input selector block
	11	3221	X1 connection terminal (parameter selector output)
	12	0422	X2 connection terminal (secondary loop PV)
32	10	75	Parameter selector block
	11	set	A1 parameter (output 1)
	12	set	A2 parameter (output 2)
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	018003	IN G80 - 03 System's internal SW (always ON)
	13	070211	OT A/M SW (primary loop)
	14	020303	NI C/L SW (secondary loop)
	15	063011	NR G30 - 11 Deviation setpoint 1
	16	070210	OT G02 - 10 External feedback SW (primary loop)
	17	020303	NI C/L SW (secondary loop)
	18	073101	OT G31 - 01 Selecting PV
	19	013012	IN G30 - 12 Deviation setpoint 2
	20	073201	OT G32 - 01 Selecting output 2



Always setting the primary loop to Auto

Primary loop set to external feedback when the secondary is at Loc mode or when its MV is out of deviation range 1.

X2 (PV) selected when the secondary loop is set to Loc mode.

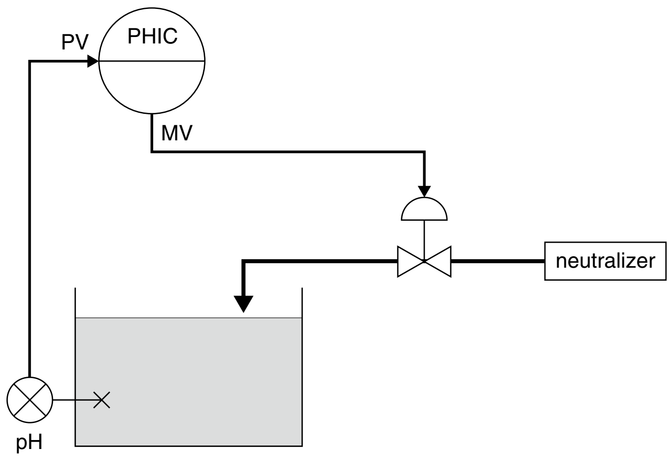
Output 2 selected when the MV is within deviation range 2.

4.3.7 NON-LINEAR PID CONTROL

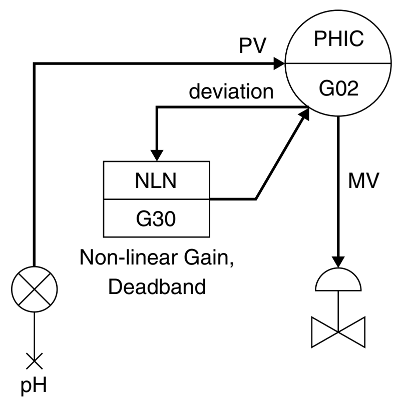
Non-linear PID control is useful to deal with non-linearity problems typically found in pH process control.

■ LOOP CONFIGURATION EXAMPLE: NEUTRALIZATION CONTROL

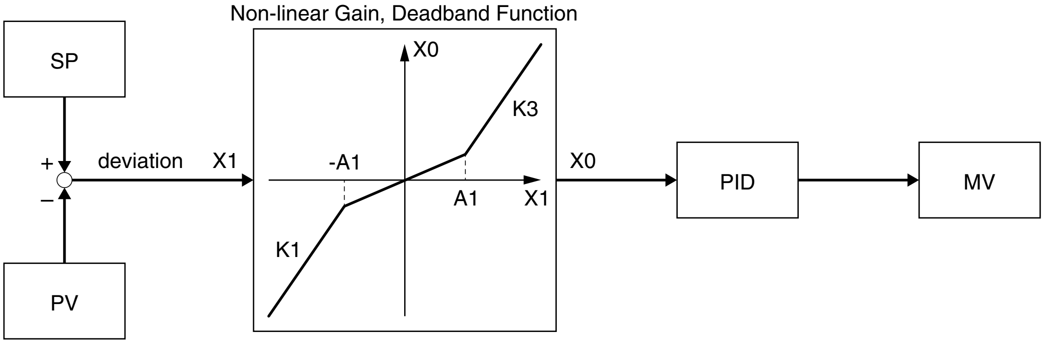
The titration curve around pH 7 with an extreme non-linearity is adjusted to provide a relatively constant gain over entire span by decreasing control gain around the equivalence point by multiplying it with a coefficient.



■ BLOCK DIAGRAM



■ OPERATION



K1 : Gain (set to 1.000)
K2 : Non-linear gain (0.000 ... 1.000)
K3 : Gain (set to 1.000)
A1 : Segment point (0.00 ... 100.00%)

■ CODING LIST ESSENTIALS

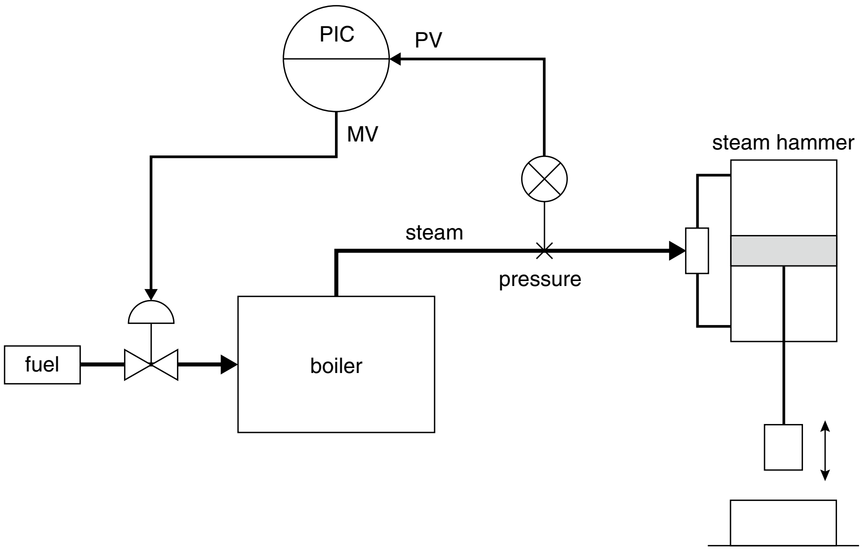
GROUP	ITEM	DATA	FUNCTION
02	10	22	Control block
	37	1	Input compensation SW enabled
	38	3	Input compensation method set to ‘substitution’
	39	3021	Input compensation connection terminal (non-linear gain block output)
30	10	56	Non-linear gain, deadband block
	11	0223	X1 connection terminal (deviation output for input compensation)
	12	1.000	Gain K1
	13	set	Non-linear gain K2 set according to the non-linear process
	14	1.000	Gain K3
	15	set	Segment point A1 set according to the non-linear process

4.3.8 GAP CONTROL

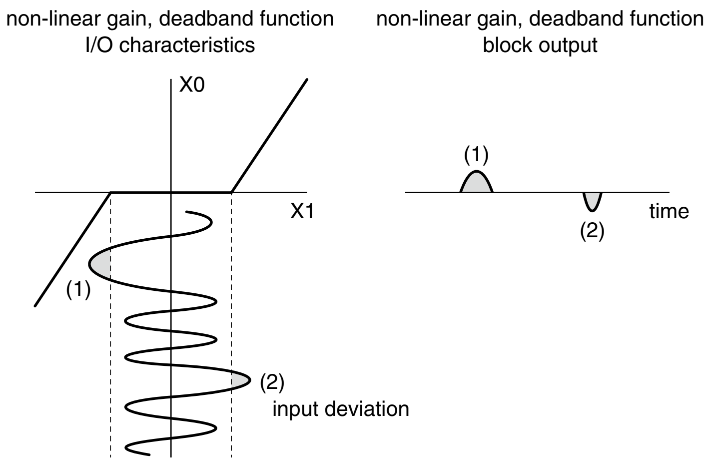
Gap control is a variation of non-linear PID control strategy, with the non-linear gain set to ‘0.’

■ LOOP CONFIGURATION EXAMPLE: STEAM PRESSURE CONTROL FOR A STEAM HAMMER

Steam consumption signal in a steam hammer pulsates widely by piston movements. Attempting to control directly such pressure fluctuation could cause unwanted disturbance to the supply fuel flow. The non-linear gain set to ‘0’ is applied to certain variation range in order to hold the valve position while in this range.



■ OPERATION



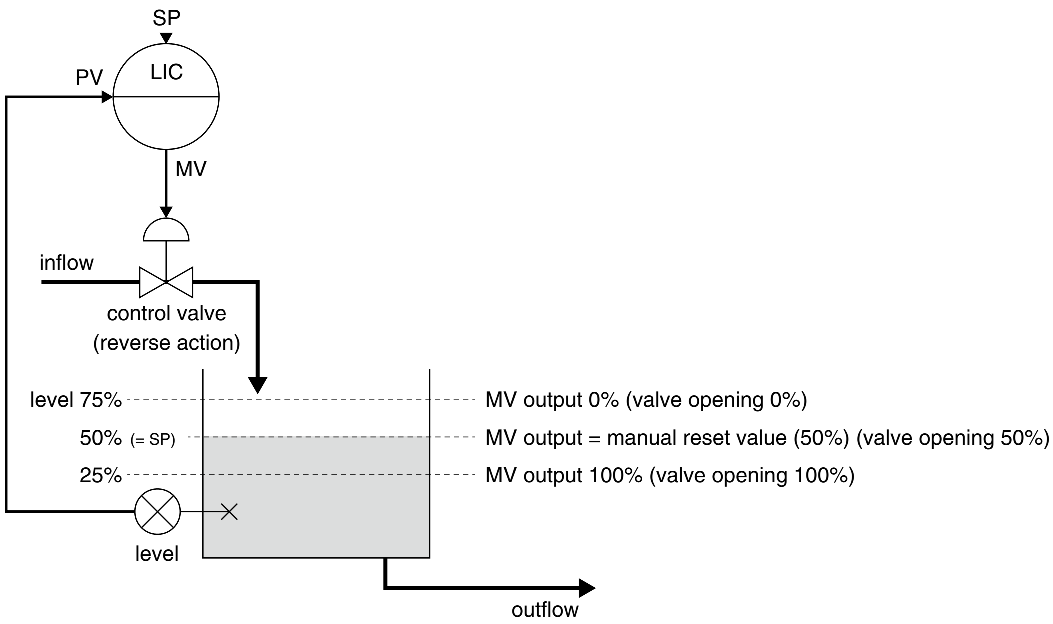
■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	22	Control block
	37	1	Input compensation SW enabled
	38	3	Input compensation method set to ‘substitution’
	39	3021	Input compensation connection terminal (non-linear function block output)
30	10	56	Non-linear gain, deadband block
	11	0223	X1 connection terminal (deviation output for input compensation)
	12	1.000	Gain K1
	13	0.000	Non-linear gain K2 set to hold the valve position
	14	1.000	Gain K3
	15	set	Segment point A1 to specify the hold range

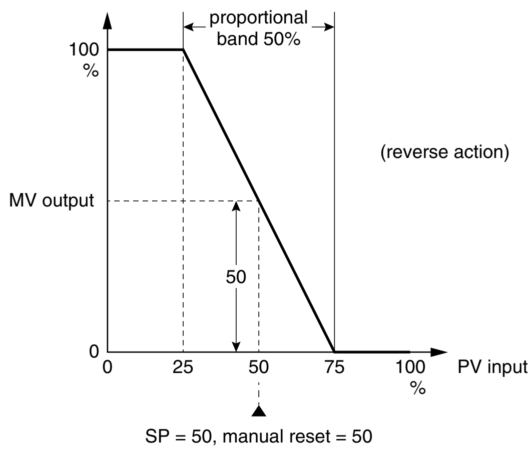
4.3.9 PROPORTIONAL CONTROL

Proportional-only control without integral and derivative terms is widely used. The control method stabilizes the control loop without a risk of cycling as far as a certain deviation in control result is tolerated.

■ LOOP CONFIGURATION EXAMPLE: TANK LEVEL CONTROL



The following graph is an example showing correlation between setpoint (set to 50%), manual reset value (set to 50%) and MV output with the proportional band set to 50%.



The MV output provided when the deviation (SP – PV) equals 0 in a proportional control system is called 'manual reset value.' In the above process, the tank level stays at a constant value when the outflow equals the inflow. The deviation (SP – PV) detected at this point is called 'offset,' where the control is settled out.

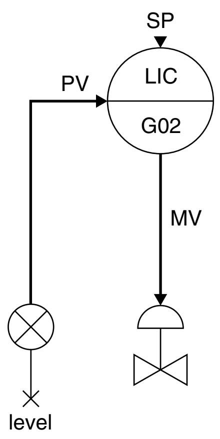
The MV output is expressed with the following equation:

$$MV = \frac{100}{PB}\ e + MR$$

where e = Deviation
MR = Manual reset value

Manual reset value is preset in the Control function block.

■ **BLOCK DIAGRAM**



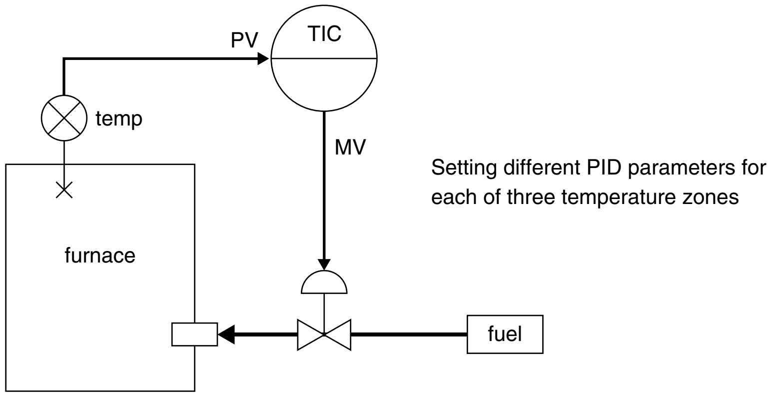
■ **CODING LIST ESSENTIALS**

GROUP	ITEM	DATA	FUNCTION
02	10	22	Control block
	42	set	Proportional band
	43	0.00	Integral time (0.00 = no integral)
	44	0.00	Derivative time (0.00 = no derivative)
	64	set	Manual reset value

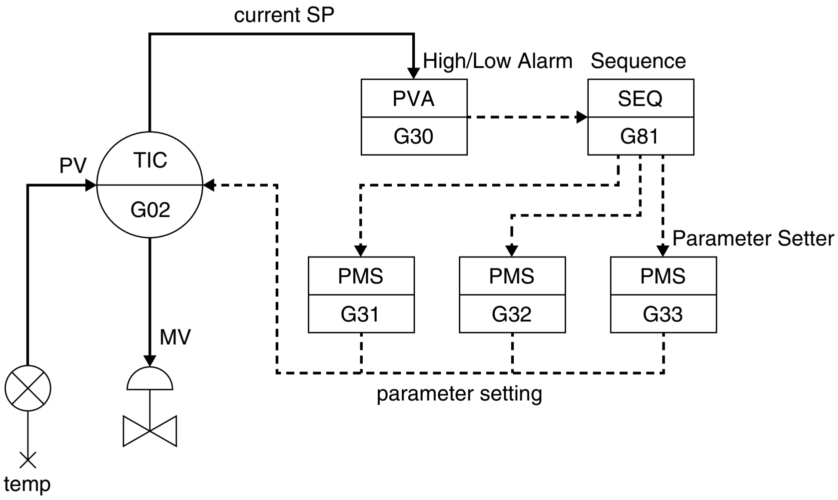
4.3.10 VARIABLE PID CONTROL

Different sets of PID parameters are automatically applied following loop characteristics changes caused by switching sensor's measuring range, control valves or set values (e.g. set values change in accordance with the progress of program steps as in 4.3.3 PROGRAM CONTROL).

■ LOOP CONFIGURATION EXAMPLE: TEMPERATURE CONTROL DIVIDED INTO THREE TEMPERATURE ZONES



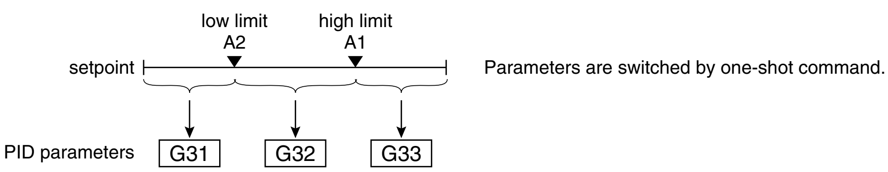
■ BLOCK DIAGRAM



■ OPERATION

The TIC's current SP is supplied to the input of G30 High/Low Alarm block. High and low setpoints divide the set value range in three zones. A Parameter Setter block is applied to each zone.

The high/low setpoints should be provided with a deadband to avoid cycling between parameters.



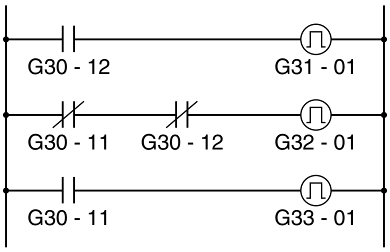
[Caution of using Parameter Setter block]

Parameters in each function block can be rewritten approx. one hundred thousand (100,000) times (according to nominal specification of the EEPROM).

For example, if you rewrite a parameter every one hour, the EEPROM is usable approx. eleven years. Please consider this information carefully when you design an application of this function block.

■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	22	Control block
30	10	76	High/low alarm block
	11	0222	X1 connection terminal (control block current SP)
	12	set	High setpoint A1 (%) for one zone division
	13	set	Low setpoint A2 (%) for another zone division
	14	set	Hysteresis (deadband) A3 (%)
31	10	79	Parameter setter block
	11	0242	PB set value destination
	12	0243	TI set value destination
	13	0244	TD set value destination
	14	set	PB set value applied below the low setpoint
	15	set	TI set value applied below the low setpoint
	16	set	TD set value applied below the low setpoint
32	10	79	Parameter setter block
	11	0242	PB set value destination
	12	0243	TI set value destination
	13	0244	TD set value destination
	14	set	PB set value applied between the alarm setpoints
	15	set	TI set value applied between the alarm setpoints
	16	set	TD set value applied between the alarm setpoints
33	10	79	Parameter setter block
	11	0242	PB set value destination
	12	0243	TI set value destination
	13	0244	TD set value destination
	14	set	PB set value applied above the high setpoint
	15	set	TI set value applied above the high setpoint
	16	set	TD set value applied above the high setpoint
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	013012	IN G30 - 12 Low alarm
	13	113101	SH G31 - 01 Sending G31 parameters
	14	023011	NI G30 - 11 Not low alarm and
	15	043012	NA G30 - 12 Not high alarm
	16	113201	SH G32 - 01 Sending G32 parameters
	17	013011	IN G30 - 11 High alarm
	18	113301	SH G33 - 01 Sending G33 parameters



Sending G31 parameters when the SP is at the low limit or lower.

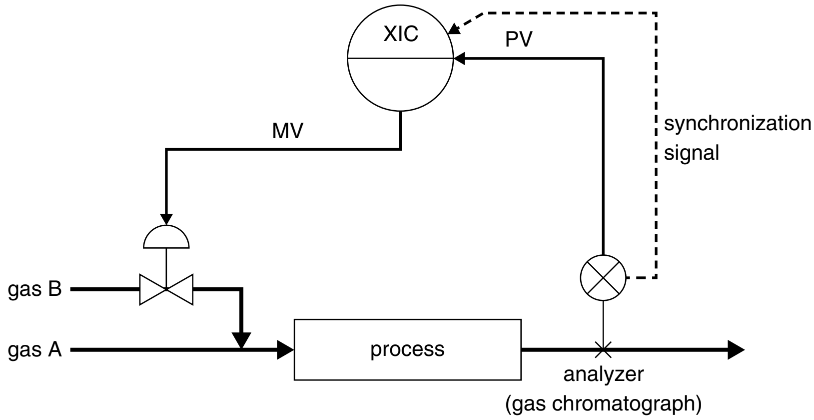
Sending G32 parameters when the SP is between the low and high limits.

Sending G33 parameters when the SP is at the high limit or higher.

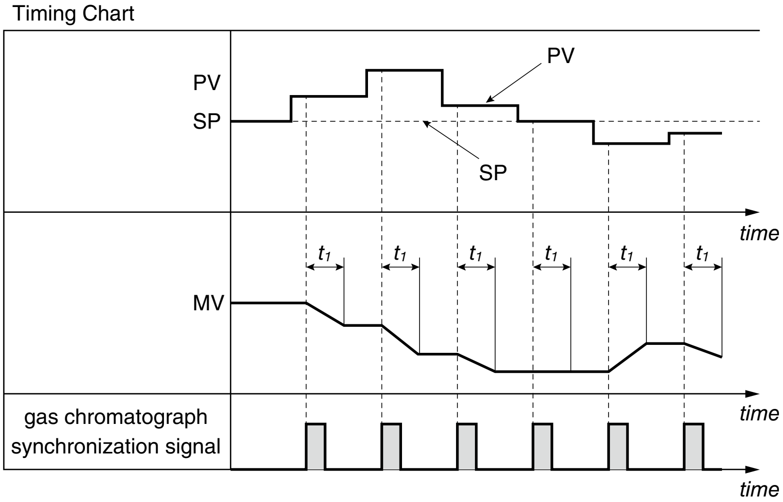
4.3.11 SAMPLING CONTROL

Sampling control is used to deal with intermittent PV signals by using integral action and output hold function. It is typically applied to analyzers using gas chromatography or to processes with a large dead time.

■ LOOP CONFIGURATION EXAMPLE: END POINT CONTROL WITH A GAS CHROMATOGRAPH



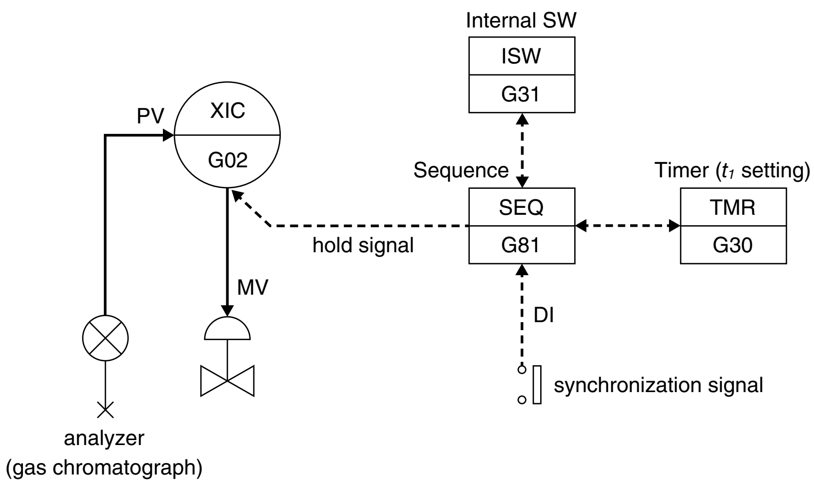
Timing Chart



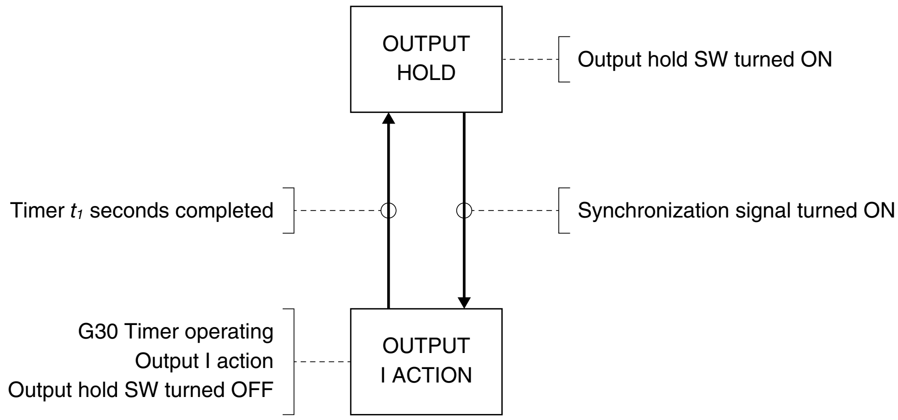
Integral term is applied for 't_1' seconds when the synchronization signal is turned on, and then the MV signal is held. Since the hold function is cancelled after a new PV is given and stabilized, bumpless output tracking cancels changes in the proportional term.

MV output volume by every sampling is determined by the combination of proportional band and integral time.

■ BLOCK DIAGRAM

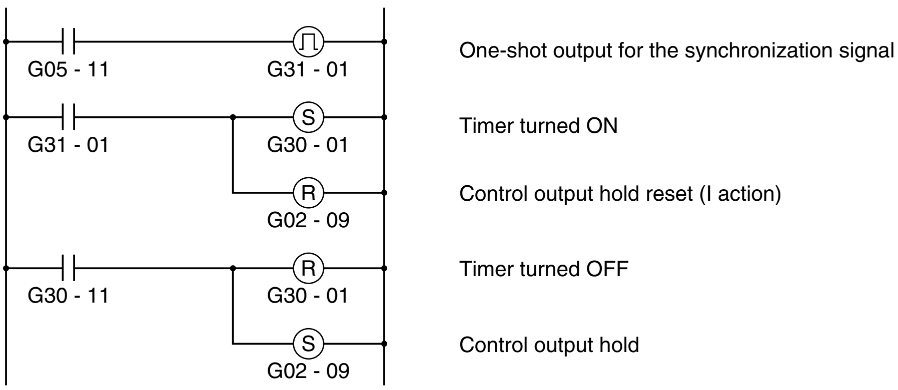


■ OPERATION



■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	22	Control block
30	10	91	Timer block
	11	10	Time setting (t_1)
	12	0	Time unit (seconds)
31	10	93	Internal switch block
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	010511	IN DI (synchronization signal)
	13	113101	SH Internal switch (input signal converted into one-shot signal)
	14	013101	IN Internal switch
	15	093001	ON G30 - 01 Count SW ON
	16	100209	OF G02 - 09 Output hold SW OFF
	17	013011	IN G30 - 11 Timer complete status ON
	18	103001	OF G30 - 01 Count SW OFF
	19	090209	ON G02 - 09 Output hold SW ON



[Parameters]

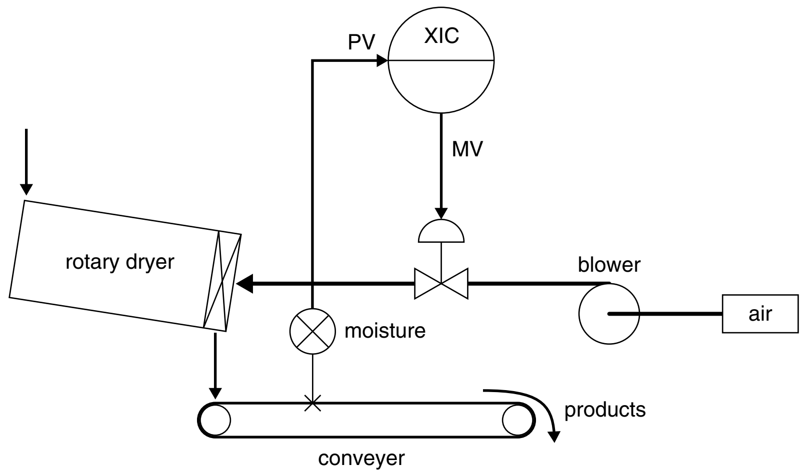
- Smaller the PB and/or the TI/t_1 is, larger is the loop gain. These parameters must be carefully chosen by observing the process to avoid output cycling.
- Set the TD to '0.'
- Set 't' value to '10' seconds.

4.3.12 DEAD TIME COMPENSATION

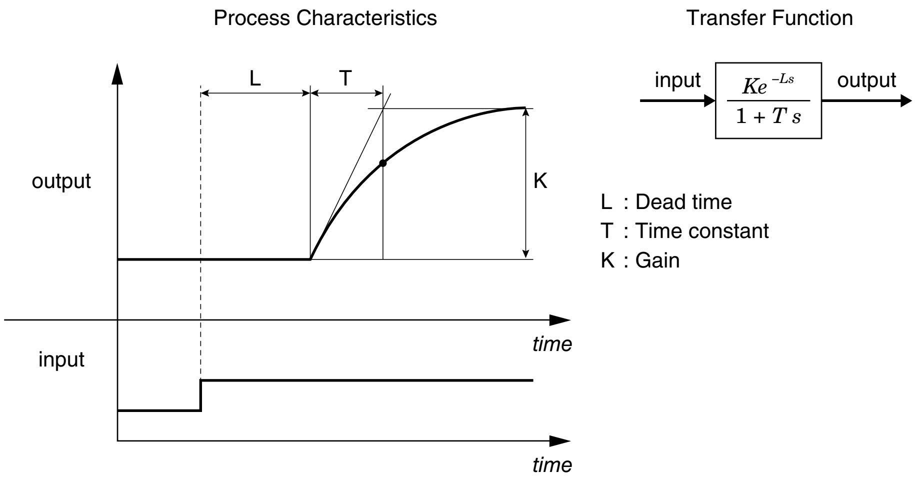
Dead time compensation (Smith controller) is used when a large dead time exists and remains relatively stable in the process.

■ LOOP CONFIGURATION EXAMPLE: MOISTURE CONTROL AT THE ROTARY DRYER OUTLET

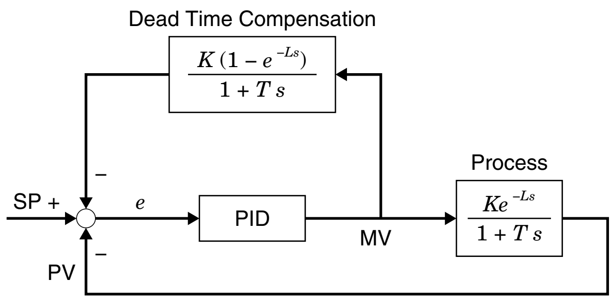
Moisture sensor output changes slowly in a certain time period after the blower air supply volume is changed.



The diagram below is an approximation of process transfer function using dead time and first order lag elements by observing its response to a step input.



The dead time 'L' could cause hunting problem when simple PID control is applied, but it can be avoided by adding the dead time compensation block that is used to subtract a calculated compensation value from the feedback input.



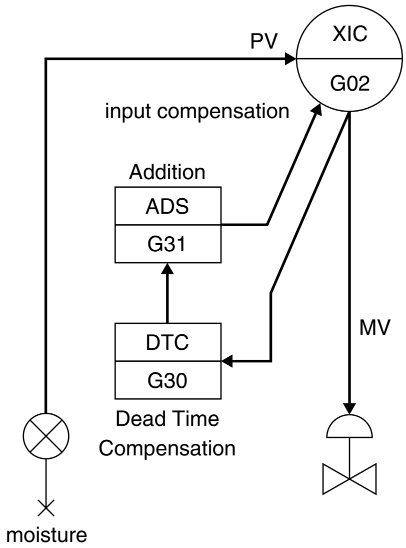
[Rationale]

Dead time compensation cancels the dead time term e^{-Ls} in the following equation expressing the process from PID output (MV) to deviation input (e):

$$e(s) = SP(s) - MV(s)\left(\frac{K(1-e^{-Ls})}{1+Ts} + \frac{Ke^{-Ls}}{1+Ts}\right) = SP(s) - MV(s)\left(\frac{K}{1+Ts}\right)$$

s : Laplace operator

■ BLOCK DIAGRAM



G31 Addition function block is used to multiply the input compensation signal by Gain K.

■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	22	Control block
	37	1	Input compensation SW enabled
	38	1	Input compensation method set to 'addition' (Choose 'subtraction' when the control direction is set to 'direct.')
	39	3121	Input compensation connection terminal
30	10	67	Dead time compensation block
	11	0225	X1 connection terminal (control block MV output)
	12	set	Time constant TC
	13	set	Sampling cycle H
	14	8	Number of samples to be calculated N (dead time = H x N)
31	10	51	Addition/subtraction block
	11	3021	X1 connection terminal (dead time compensation block output)
	14	set	Gain K1

[Parameters]

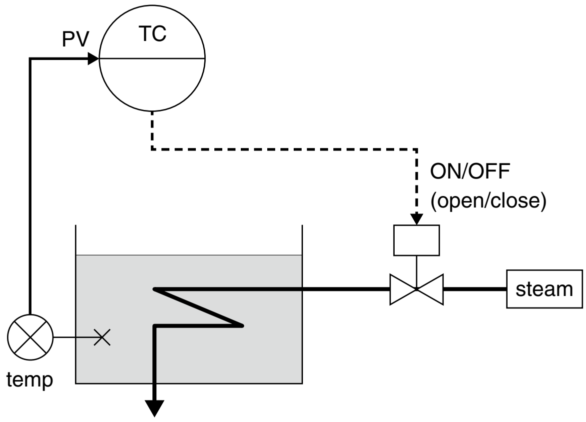
- Dead time, time constant and gain values are to be determined by observing actual process behavior.
- Set the MV output to Man mode and apply a step signal. Observe the PV response to the process to determine the parameters.
- Dead time L = H x N (Set N to '8' (maximum value) to determine H value.)

4.3.13 ON/OFF CONTROL

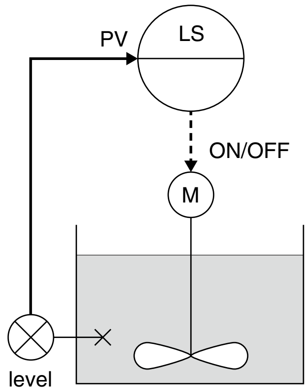
High/low alarm block is used to achieve ON/OFF control or interlocking.

■ LOOP CONFIGURATION EXAMPLES

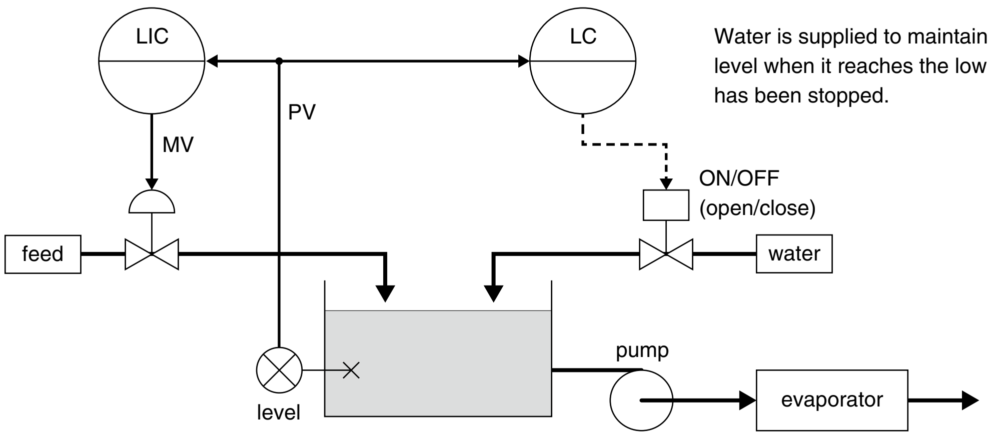
■ Example (1): Temperature control



■ Example (2): Interlocking to prevent idle running of an agitator

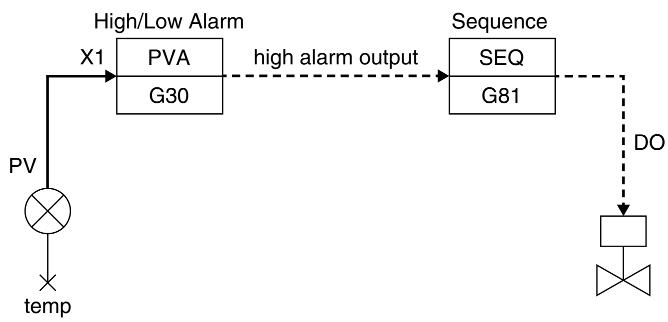


■ Example (3): Maintaining the minimum liquid level in a tank



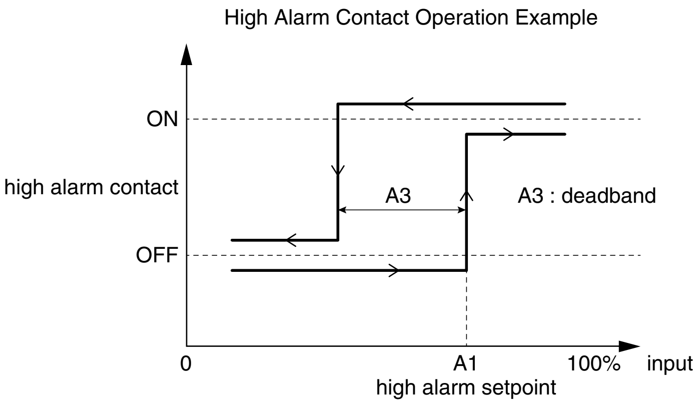
Water is supplied to maintain the minimum liquid level when it reaches the low limit after the feed has been stopped.

■ BLOCK DIAGRAM FOR THE EXAMPLE (1)



■ OPERATION FOR THE EXAMPLE (1)

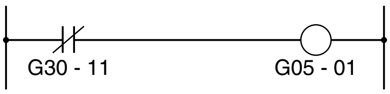
High/low alarm block has two trip points with a deadband used to prevent ON/OFF cycling around the setpoint.



ON when the PV increases above the setpoint A1.
OFF when the PV decreases by A3 below A1.

■ CODING LIST ESSENTIALS FOR THE EXAMPLE (1)

GROUP	ITEM	DATA	FUNCTION
30	10	76	High/low alarm block
	11	0421	X1 connection terminal (field terminal PV)
	12	set	High setpoint A1
	13	set	Low setpoint A2
	14	set	Deadband A3
81	10	95	Sequential control block
	11	023011	NI G30 - 11 When high alarm output OFF
	12	070501	OT DO (field terminal) (valve open)

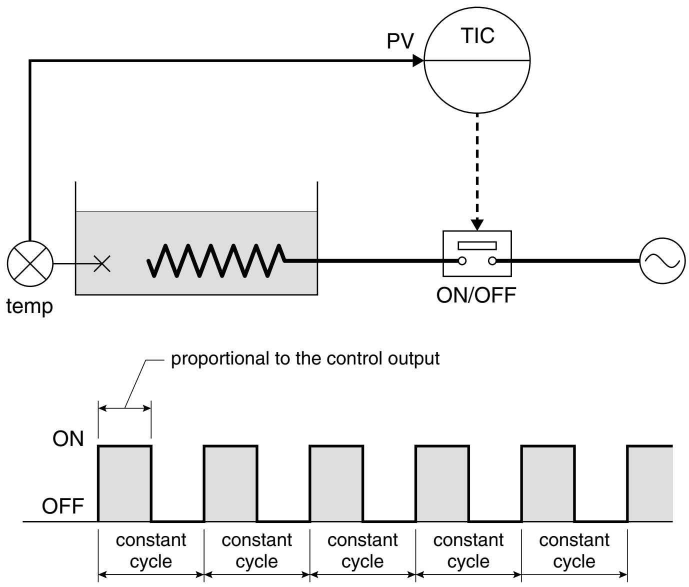


Assigning high alarm output to a contact output

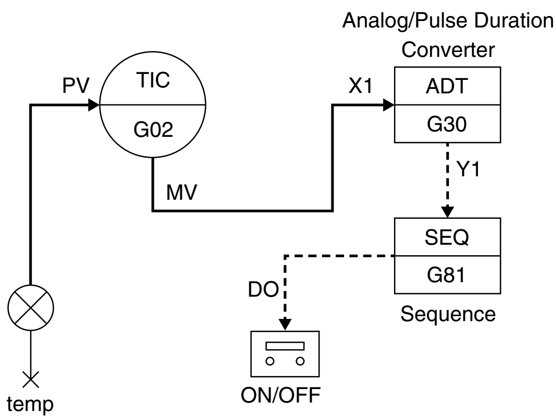
4.3.14 TIME-PROPORTIONING ON/OFF CONTROL

Output is turned on and off within a certain time interval in the ratio of MV signal.

■ LOOP CONFIGURATION EXAMPLE: TEMPERATURE CONTROL BY NICHROME WIRE HEATER

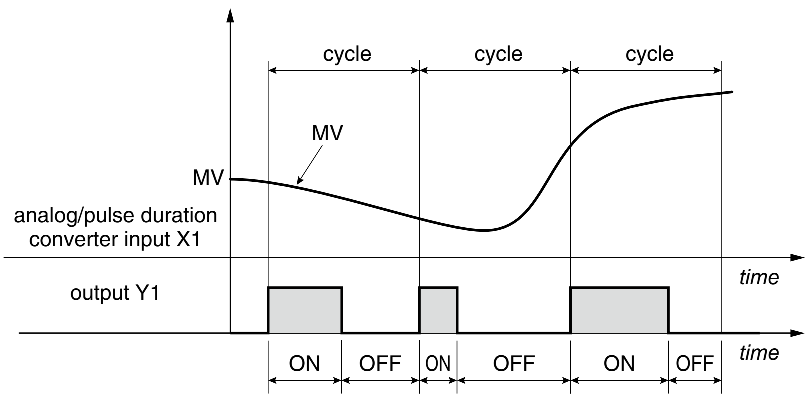


■ BLOCK DIAGRAM



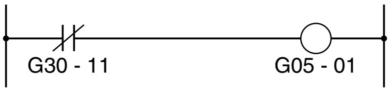
■ OPERATION

Analog/pulse duration converter block provides pulse width modulation output (status signals) in proportion to the analog input signal.



■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	22	Control block
30	10	82	Analog/pulse duration converter block
	11	0225	X1 connection terminal (control block MV output)
	12	30	Pulse cycle time CT (0...1000 seconds)
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	013011	IN G30 - 11 Pulse duration contact output Y1
	13	070501	OT DO (field terminal) output ON

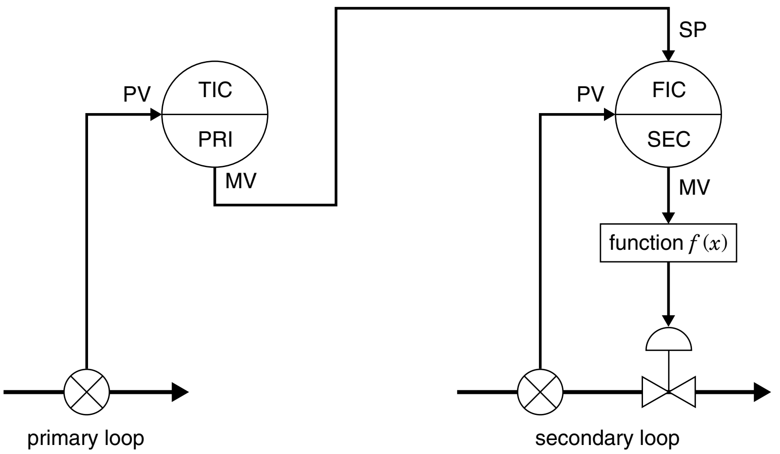


Assigning ON cycle to a contact output

4.3.15 LOOP GAIN COMPENSATION TO DEAL WITH SET VALUE CHANGE

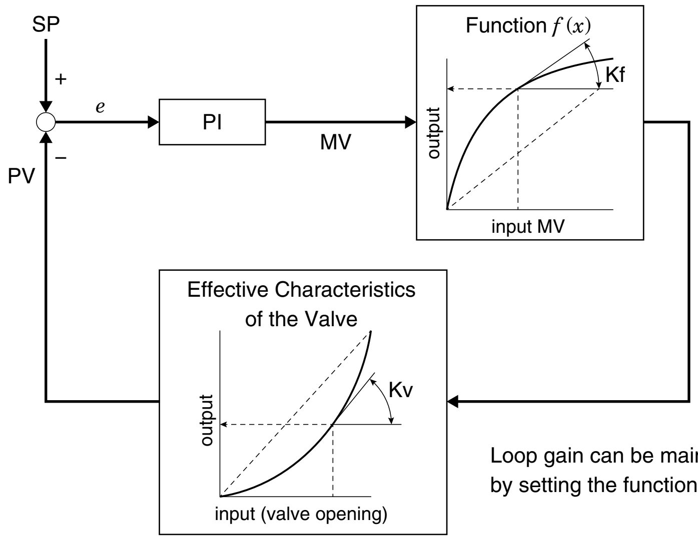
Loop gain varies depending upon process conditions and valve positions. Loop gain compensation attempts to maintain the gain to a constant level.

■ LOOP CONFIGURATION EXAMPLE: TEMPERATURE CONTROL LOOP IN CASCADE CONTROL



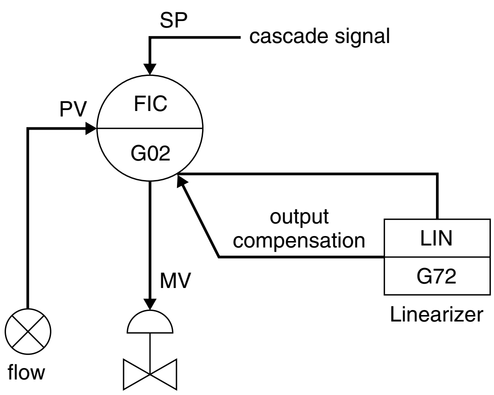
Loop gain change could occur in the secondary loop of a proportional control system.
It is also observed in a constant setpoint control system when the setpoint is changed by a large degree.

Loop gain changes when the FIC loop setpoint is changed with a control valve that has non-linear characteristics. Linearizer block is used to compensate such changes.



Loop gain can be maintained at a constant value by setting the function to give [Kf · Kv ≈ 1].

■ BLOCK DIAGRAM



■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	22	Control block
	47	1	Output compensation SW enabled
	48	3	Output compensation method set to 'substitution'
	49	7221	Output compensation connection terminal (linearizer block output)
72	10	58	Linearizer block
	11	0224	X1 connection terminal (control block PID output)
	21	set	A1 Input 1
	22	set	B1 Output 1
	:	:	:
	:	:	: Linearization data
	:	:	:
	:	:	:
	36	set	B8 Output 8

[Linearization Data]

1) Manually operate the valve to determine a valve characteristics curve that correlates valve position and flow.
2) Divide the valve position axis into eight (8) divisions (do not need to be equal ones).
3) Read the gradient (gain) of the point closest to 0% (A1) and draw a line in its inverse gradient from 0% point to acquire the B1 point.
4) Read the gradient of the A2 and draw a line in its inverse gradient from the B1 to acquire the B2.
5) Acquire all points in the same manner.

[Caution: Use of Output Compensation]

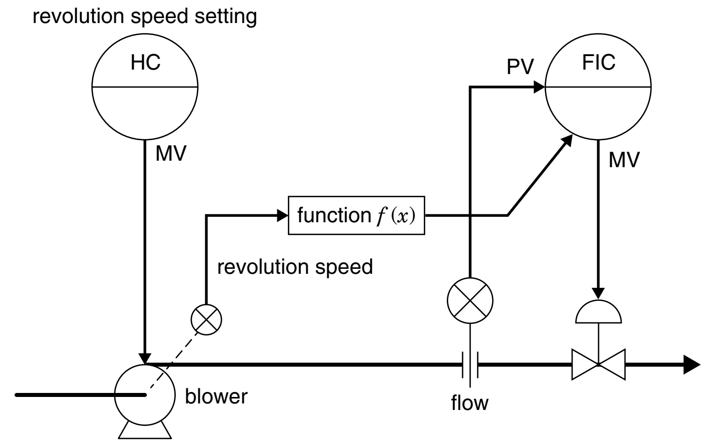
The MV output bumps when the control is switched from Man to Auto mode due to the 'substitution' type output compensation employed by the controller.

4.3.16 LOOP GAIN COMPENSATION TO DEAL WITH PROCESS GAIN CHANGE

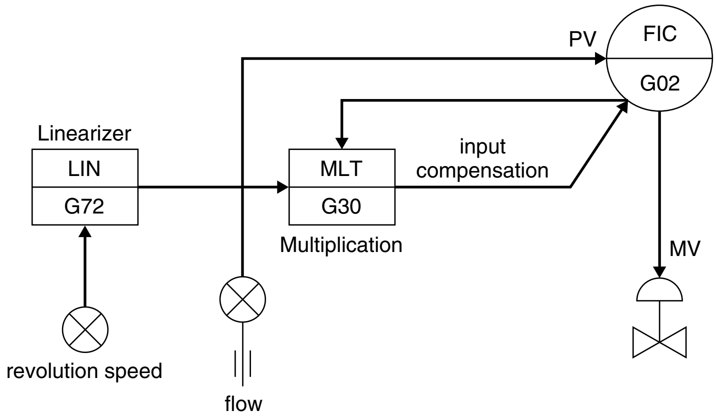
Loop gain varies depending upon process conditions and valve positions. Loop gain compensation attempts to maintain the gain to a constant level.

■ LOOP CONFIGURATION EXAMPLE: BLOWER OUTFLOW CONTROL

Loop gain changes with the blower outflow due to its revolution speed change. The revolution speed signal is supplied to maintain the loop gain to a constant level.



■ BLOCK DIAGRAM

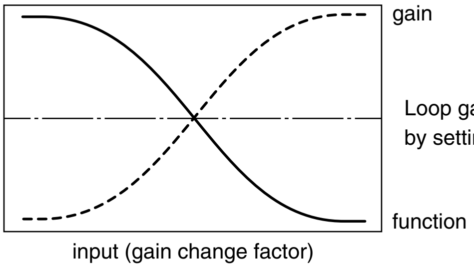


■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	22	Control block
	37	1	Input compensation SW enabled
	38	3	Input compensation method set to ‘substitution’
	39	3021	Input compensation connection terminal (multiplication block output)
30	10	52	Multiplication block
	11	7221	X1 connection terminal (linearizer block output)
	12	0223	X2 connection terminal (control block deviation output)
	13	1.000	Gain K1
72	10	58	Linearizer block
	11	0423	X1 connection terminal (field terminal Ai 1)

[Linearization Data]

Set the output to 100% at the minimum gain within the input range (gain change factor). Set inverse to the gain at other input points.



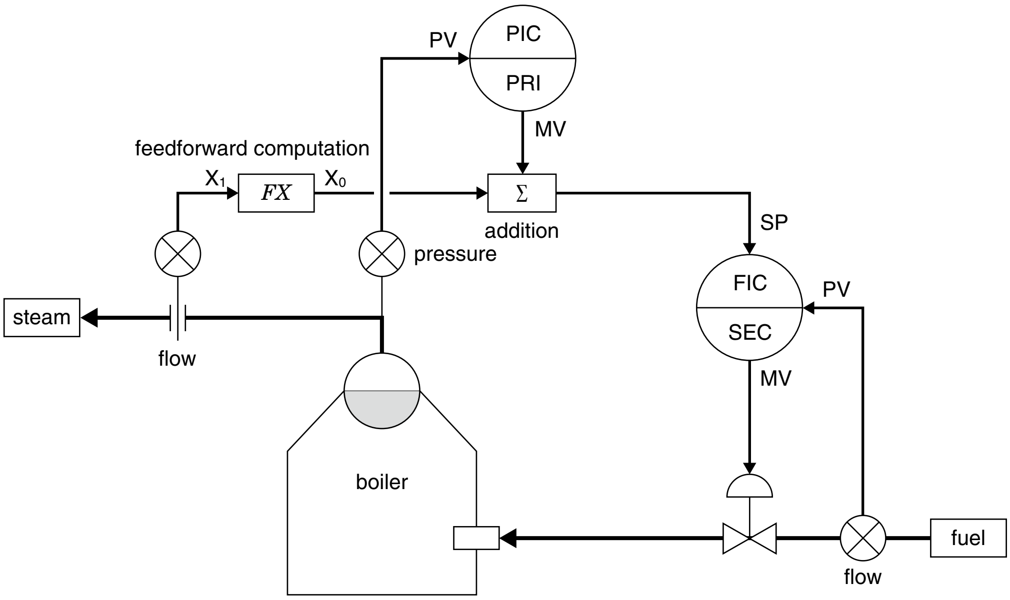
Loop gain can be maintained at a constant value by setting the function to give [(gain)·(function) = 1].

4.3.17 FEEDFORWARD CONTROL (ADDITION/SUBTRACTION)

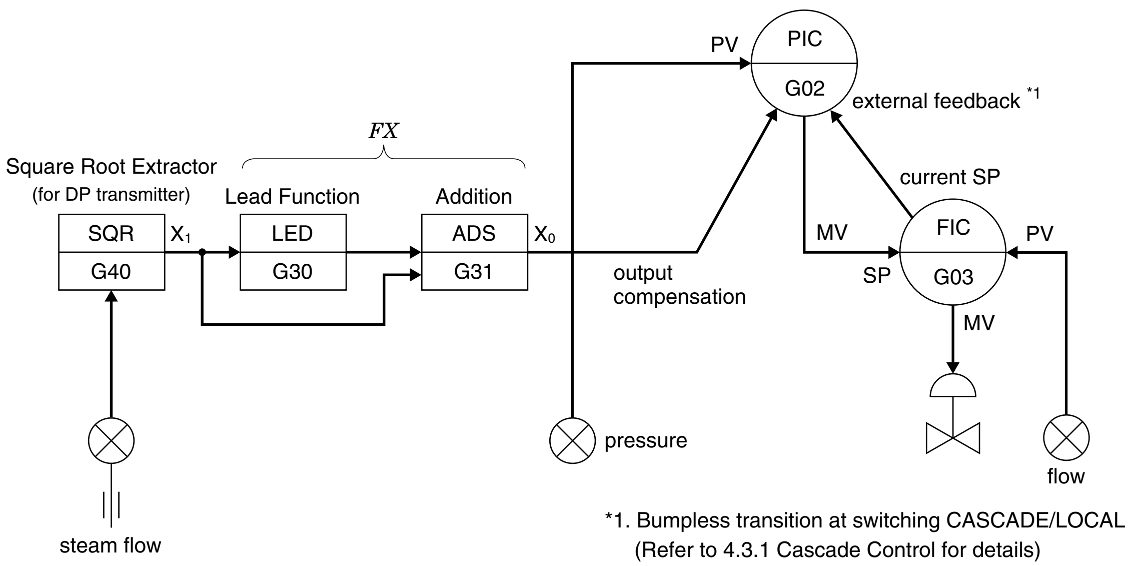
Feedforward control attempts to measure disturbance to the control loop and to directly change MV output to prevent the appearance of any deviation beforehand.

■ LOOP CONFIGURATION EXAMPLE (1): BOILER PRESSURE CONTROL

Upset in master steam flow is a major disturbance factor in the boiler pressure control (master control). The steam flow is measured and added to the PIC control output.



■ BLOCK DIAGRAM FOR THE EXAMPLE (1)



*1. Bumpless transition at switching CASCADE/LOCAL
(Refer to 4.3.1 Cascade Control for details)

■ OPERATION FOR THE EXAMPLE (1)

Feedforward signal (steam flow) is multiplied with an inexact differential coefficient and applied with an 'addition' type output compensation.

$$X_0 = \underbrace{K_1 \cdot X_1 + K_2 \cdot \underbrace{\left(\frac{1}{1 + Ts} \right) \cdot X_1}_{\text{LED}}}_{\text{ADS}}$$

where $K_1 = -K_2$

■ CODING LIST ESSENTIALS FOR THE EXAMPLE (1)

GROUP	ITEM	DATA	FUNCTION
02	10	22	Control block
	47	1	Output compensation SW enabled
	48	1	Output compensation method set to 'addition'
	49	3121	Output compensation connection terminal (addition/subtraction block output)
03	10	22	Control block
	24	0225	CAS connection terminal (primary loop MV)
30	10	65	Lead computation block
	11	0423	X1 connection terminal (field terminal Ai 1)
	12	set	Time constant T
31	10	51	Addition/subtraction block
	11	0423	X1 connection terminal (field terminal Ai 1, same for G30)
	12	3021	X2 connection terminal (lead computation block output)
	14	set	Gain K1
	15	set	Gain K2
	17	0.00	Bias A0

[Parameters]

• Parameters are to be determined by simulation runs.

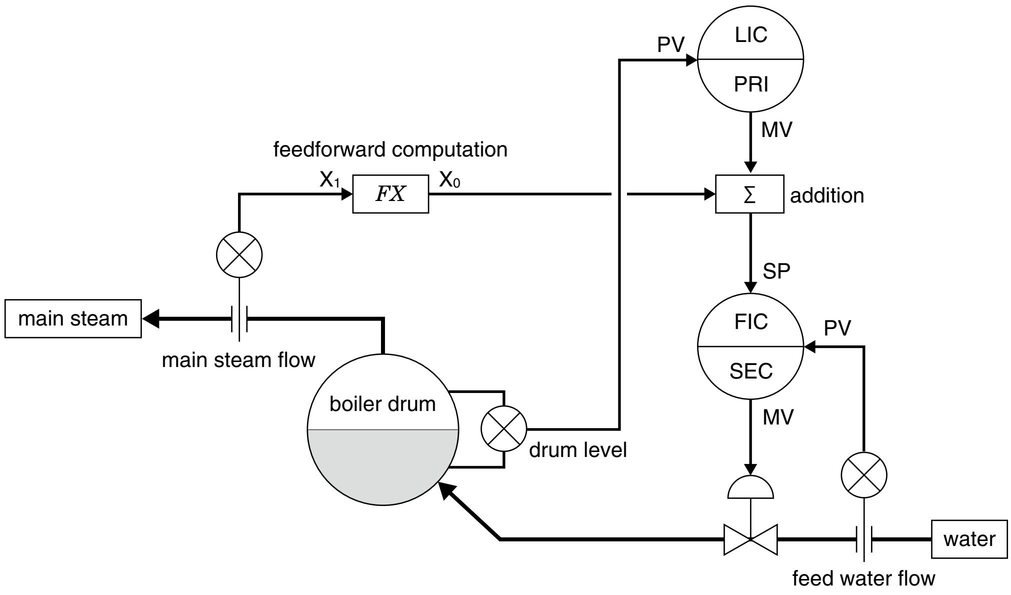
• Time constant T = Approx. 5 times the response time of the control loop

• Choose K1 and K2 values applicable when the PV fluctuates the least.

■ LOOP CONFIGURATION EXAMPLE (2): BOILER DRUM LEVEL CONTROL (THREE-ELEMENT CONTROL)*

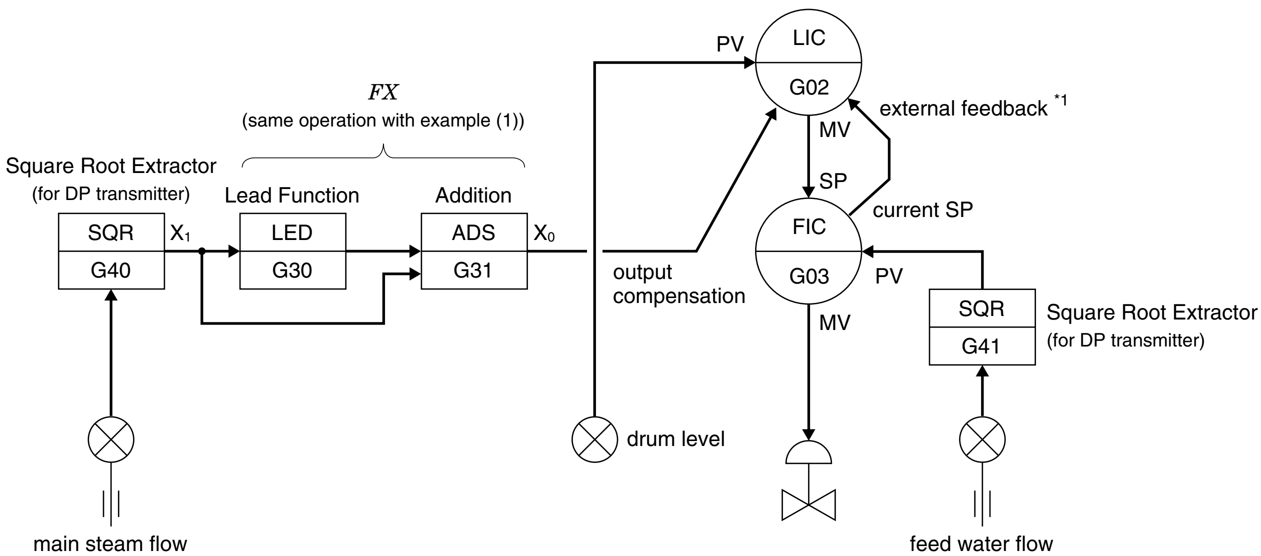
The purpose of boiler feed water flow control is to maintain the drum level to a constant level. In order to achieve this goal, the drum level control loop (LIC) is cascaded into the feed water flow control loop (FIC).

Violent fluctuations in the main steam flow causes a large disturbance to the drum level. In order to eliminate it, the main steam flow is measured and added to the feed water setpoint (feedforward control).



*Involves three elements: drum level, feed water flow and main steam flow

■ BLOCK DIAGRAM FOR THE EXAMPLE (2)



*1. Bumpless transition at switching CASCADE/LOCAL
(Refer to 4.3.1 Cascade Control for details)

■ CODING LIST ESSENTIALS FOR THE EXAMPLE (2)

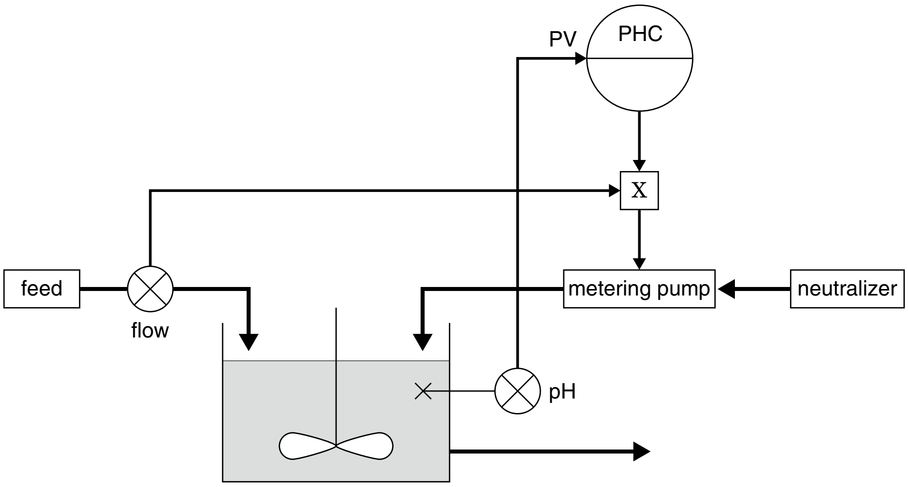
GROUP	ITEM	DATA	FUNCTION
02	10	22	Control block
	47	1	Output compensation SW enabled
	48	1	Output compensation method set to ‘addition’
	49	3121	Output compensation connection terminal (addition/subtraction block output)
	56	0322	External feedback connection terminal (secondary loop current SP)
	58	0, 1	Switching 0 / 1 by sequential control (‘1’ for LOCAL, ‘0’ for CASCADE at secondary loop)
03	10	22	Control block
	15	4121	PV connection terminal (G41 square root extractor block output)
	24	0225	CAS connection terminal (primary loop MV)
30	10	65	Lead computation block
	11	4021	X1 connection terminal (G40 square root extractor block output)
	12	set	Time constant T
31	10	51	Addition/subtraction block
	11	4021	X1 connection terminal (G40 square root extractor block output, same for G30)
	12	3021	X2 connection terminal (lead computation block output)
	14	set	Gain K1
	15	set	Gain K2
	17	0.000	Bias A0
40	10	54	Square root extractor block
	11	0423	X1 connection terminal (field terminal Ai 1)
	12	10.000	Gain K1
	13	3.000	Low-end cutout A1
41	10	54	Square root extractor block
	11	0422	X1 connection terminal (field terminal Pv 2)
	12	10.000	Gain K1
	13	3.000	Low-end cutout A1

4.3.18 FEEDFORWARD CONTROL (MULTIPLICATION/DIVISION)

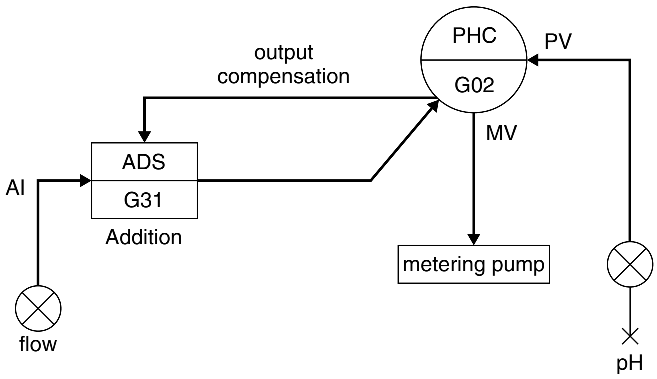
Feedforward control attempts to measure disturbance to the control loop and to directly change MV output to prevent the appearance of any deviation beforehand.

■ LOOP CONFIGURATION EXAMPLE: pH CONTROL

Ratio control is used for the feed flow and the neutralizer flow through a metering pump. The ratio setting is changed by the PHC output. Same principle can be applied with a FIC loop instead of the metering pump.



■ BLOCK DIAGRAM



■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
02	10	22	Control block
	47	1	Output compensation SW enabled
	48	3	Output compensation method set to ‘substitution’
	49	3021	Output compensation connection terminal (multiplication block output)
30	10	52	Multiplication block
	11	0423	X1 connection terminal (field terminal Ai 1)
	12	0224	X2 connection terminal (control block PID output)
	13	1.000	Gain K1

5. COMPUTATIONAL FUNCTION BLOCKS

5.1 MATH FUNCTIONS

Gain and bias calculation methods for normalization equation are somewhat complicated and prone to mistakes. The purpose of this section is to explain the procedures in their simplest form.

5.1.1 NORMALIZATION

I/O signal ranges, gains and biases must be scaled to the normalized range of 0...1 when they are used in math function blocks.

Addition/subtraction is used as an example to explain the procedure to calculate normalized gains and biases based on engineering unit variables. They are calculated by substituting the formulae correlating Y_n and X_n into an engineering unit function equation.

Normalization equation

$X_0 = K_1X_1 + K_2X_2 + K_3X_3 + A_0$ ....Equation (1)

where X_0, X_1, X_2, X_3 : Variables (normalized to 0...1 range)
K_1, K_2, K_3 : Gains (normalized to 0...1 range)
A_0 : Bias (normalized to 0...1 range)

Engineering unit function equation

$Y_0 = G_1Y_1 + G_2Y_2 + G_3Y_3 + B_0$ ....Equation (2)

where Y_0, Y_1, Y_2, Y_3 : Variables
(engineering unit; Y_n varies between Y_{n0}...Y_{n1} when X_n varies between 0...1)
G_1, G_2, G_3 : Gains
B_0 : Bias (engineering unit)

Substitute the following Y_n - X_n correlation formulae into the equation (2).

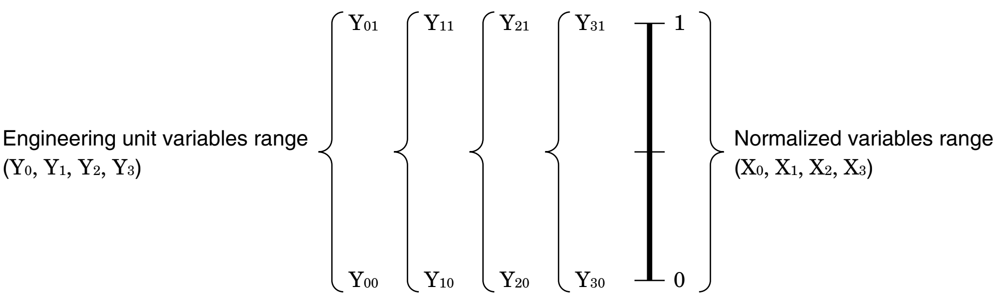
$Y_0 = (Y_{01} - Y_{00})\, X_0 + Y_{00}$

$Y_1 = (Y_{11} - Y_{10})\, X_1 + Y_{10}$

$Y_2 = (Y_{21} - Y_{20})\, X_2 + Y_{20}$

$Y_3 = (Y_{31} - Y_{30})\, X_3 + Y_{30}$

where Y_{01} : Y_0 value when $X_0 = 1$
Y_{00} : Y_0 value when $X_0 = 0$
Y_{11} : Y_1 value when $X_1 = 1$
Y_{10} : Y_1 value when $X_1 = 0$
Y_{21} : Y_2 value when $X_2 = 1$
Y_{20} : Y_2 value when $X_2 = 0$
Y_{31} : Y_3 value when $X_3 = 1$
Y_{30} : Y_3 value when $X_3 = 0$



$$(Y_{01} - Y_{00})\, X_0 + Y_{00} = G_1\,\{(Y_{11} - Y_{10})\, X_1 + Y_{10}\} + G_2\,\{(Y_{21} - Y_{20})\, X_2 + Y_{20}\} + G_3\,\{(Y_{31} - Y_{30})\, X_3 + Y_{30}\} + B_0 \;.......\; (2)'$$

$$X_0 = \frac{G_1\,(Y_{11} - Y_{10})}{Y_{01} - Y_{00}}\, X_1 + \frac{G_2\,(Y_{21} - Y_{20})}{Y_{01} - Y_{00}}\, X_2 + \frac{G_3\,(Y_{31} - Y_{30})}{Y_{01} - Y_{00}}\, X_3 + \frac{G_1Y_{10} + G_2Y_{20} + G_3Y_{30} - Y_{00} + B_0}{Y_{01} - Y_{00}} \;.......\; (3)$$

Gains and biases are calculated by the following equations based on the equation (3).

$$K_1 = \frac{G_1\,(Y_{11} - Y_{10})}{Y_{01} - Y_{00}} \quad \text{.......... Equation (4)}$$

$$K_2 = \frac{G_2\,(Y_{21} - Y_{20})}{Y_{01} - Y_{00}} \quad \text{.......... Equation (5)}$$

$$K_3 = \frac{G_3\,(Y_{31} - Y_{30})}{Y_{01} - Y_{00}} \quad \text{.......... Equation (6)}$$

$$A_0 = \frac{G_1Y_{10} + G_2Y_{20} + G_3Y_{30} - Y_{00} + B_0}{Y_{01} - Y_{00}} \quad \text{.......... Equation (7)}$$

■ NORMALIZATION PROCEDURE

1) Formulate an engineering unit function equation.
   Transform the user's own process equation into one with each term corresponding the normalization equation.
2) Determine 0% and 100% engineering unit values for each of inputs and outputs.
3) Formulate a normalization equation.
   Calculate gains K_0, K_1, K_2 and biases A_0, A_1 and A_2. Formulate the normalization equation using these parameters.
4) Recalculation for confirmation
   Enter a simulated value (e.g. 0.5 for 50%) into the normalization equation and calculate the output. Then enter an equivalent engineering unit value into the engineering unit function equation and calculate its output. Gains and biases are proved correct if these two results are consistent.

5.1.2 ADDITION/SUBTRACTION

Three-input addition or subtraction function is available. For four or more inputs, combine multiple blocks. For two inputs, leave the connection terminal for unused input blank so that it is ignored.

■ EXAMPLE (1): ADDING THREE FLOW RATES

Engineering unit function equation

$Y_0 = Y_1 + Y_2 + Y_3$ ....(Equation 8)

Engineering unit variables range

$Y_0 = 0 \ldots 400\ m^3/h$
$Y_1 = 0 \ldots 200\ m^3/h$
$Y_2 = 0 \ldots 100\ m^3/h$
$Y_3 = 0 \ldots 300\ m^3/h$

Normalized gains and biases (equations (4), (5), (6) and (7))

$K_1 = 200 / 400 = 0.500$
$K_2 = 100 / 400 = 0.250$
$K_3 = 300 / 400 = 0.750$
$A_0 = 0$

Normalization equation

$X_0 = 0.5X_1 + 0.25X_2 + 0.75X_3$ ....(Equation 9)

Confirming parameter ranges

Confirm that K_1, K_2 and K_3 are respectively within the range between -10.000 and +10.000. Confirm also that each term in the equation does not overflow, remaining within the range between -3.2768 and +3.2767, when X_1, X_2 and X_3 are equal to 1.

Recalculation

Normalization equation at $X_1 = X_2 = X_3 = 0.5$ is given according to the equation (9):

$X_0 = 0.25 + 0.125 + 0.375 = 0.75$

Actual flow rates at 50% are given respectively as:

$Y_1 = 100\ m^3/h$
$Y_2 = 50\ m^3/h$
$Y_3 = 150\ m^3/h$

Engineering unit function equation at 50% flow is given according to the equation (8):

$Y_0 = 100 + 50 + 150 = 300\ m^3/h$

Normalized Y_0 equals 0.75 (300 / 400), corresponding to the result with the normalization equation.

■ EXAMPLE (2): AVERAGING THREE TEMPERATURE MEASUREMENTS

Engineering unit function equation

$Y_0 = (Y_1 + Y_2 + Y_3) / 3 = 0.333Y_1 + 0.333Y_2 + 0.333Y_3$ .... (Equation 10)

Engineering unit variables range

$Y_0 = 100 ... 500\ °C$
$Y_1 = 0 ... 500\ °C$
$Y_2 = 100 ... 600\ °C$
$Y_3 = 200 ... 600\ °C$
$G_1 = G_2 = G_3 = 0.333$
$B_0 = 0$

Normalized gains and biases (equations (4), (5), (6) and (7))

$K_1 = 0.333\ (500 - 0) / (500 - 100) = 0.416$
$K_2 = 0.333\ (600 - 100) / (500 - 100) = 0.416$
$K_3 = 0.333\ (600 - 200) / (500 - 100) = 0.333$
$A_0 = (0.333 \times 0 + 0.333 \times 100 + 0.333 \times 200 - 100) / (500 - 100) = 0$

Normalization equation

$X_0 = 0.416X_1 + 0.416X_2 + 0.333X_3$ .... (Equation 11)

Confirming parameter ranges

Confirm that K_1, K_2 and K_3 are respectively within the range between -10.000 and +10.000. Confirm also that each term in the equation does not overflow, remaining within the range between -3.2768 and +3.2767, when X_1, X_2 and X_3 are equal to 1.

Recalculation

Normalization equation at $X_1 = X_2 = X_3 = 0.5$ is given according to the equation (11):

$X_0 = 0.416 \times 0.5 + 0.416 \times 0.5 + 0.333 \times 0.5 = 0.583$

Actual temperature measurements at 50% are given respectively as:

$Y_1 = 500 \times 0.5 = 250\ °C$
$Y_2 = (600 - 100) \times 0.5 + 100 = 350\ °C$
$Y_3 = (600 - 200) \times 0.5 + 200 = 400\ °C$

Engineering unit function equation at 50% temperature is given according to the equation (10):

$Y_0 = (250 + 350 + 400) / 3 = 333.3\ °C$

Normalized Y_0 is given as $X_0 = (333.3 - 100) / (500 - 100) = 0.583$, corresponding to the result with the normalization equation.

■ EXAMPLE (3): TEMPERATURE COMPENSATION FOR LIQUID DENSITY MEASUREMENT

User's process function equation

$\gamma_0 = \gamma_t + \alpha\,(t_0 - t) = \gamma_t - \alpha t + \alpha t_0$

where γ_0 : Compensated density (1.0 ... 1.3 kg/l)
γ_t : Uncompensated density (1.0 ... 1.3 kg/l)
α : Temperature compensation coefficient (0.0012 kg/l)
t_0 : Reference temperature (50 °C)
t : Measured temperature (0 ... 100 °C)

Engineering unit function equation

$Y_0 = Y_1 + G_2Y_2 + B_0$ ....(Equation 12)

where $Y_0 = \gamma_0$
$Y_1 = \gamma_t$
$G_2 = -\alpha$
$Y_2 = t$
$B_0 = \alpha t_0$

Engineering unit variables range

$Y_0 = 1.0 \ldots 1.5$
$Y_1 = 1.0 \ldots 1.5$
$Y_2 = 0 \ldots 100$
$G_2 = -0.0012$
$B_0 = 0.0012 \times 50 = 0.06$

Normalized gains and biases (equations (4), (5) and (7))

$K_1 = (1.5 - 1.0) / (1.5 - 1.0) = 1$
$K_2 = -0.0012\,(100 - 0) / (1.5 - 1.0) = -0.24$
$A_0 = (1 - 0.0012 \times 0 + 0.06 - 1 \times 1) / (1.5 - 1.0) = 0.12$

Normalization equation

$X_0 = X_1 - 0.24X_2 + 0.12$ ....(Equation 13)

Confirming parameter ranges

Confirm that K_1 and K_2 are respectively within the range between -10.000 and +10.000. Confirm also that each term in the equation does not overflow, remaining within the range between -3.2768 and +3.2767, when X_1 and X_2 are equal to 1.

Recalculation

Normalization equation at $X_1 = X_2 = 0.5$ is given according to the equation (13):

$X_0 = 0.5 - 0.24 \times 0.5 + 0.12 = 0.5$

Actual measurements at 50% are given respectively as:

$Y_1 = 1.25$
$Y_2 = 50$

Engineering unit function equation at 50% is given according to the equation (12):

$Y_0 = 1.25 - 0.0012 \times 50 + 0.06 = 1.25$

Normalized Y_0 is given as $X_0 = (1.25 - 1.0) / (1.5 - 1.0) = 0.5$, corresponding to the result with the normalization equation.

5.1.3 MULTIPLICATION

Two-input multiplication function is available. For three or more inputs, combine multiple blocks.

Normalization equation

$X_0 = (K_1X_1 + A_1)(K_2X_2 + A_2) + A_0$ .... Equation (1)

where X_0, X_1, X_2 : Variables (normalized to 0...1 range)
K_1, K_2 : Gains (normalized to 0...1 range)
A_0, A_1, A_2 : Bias (normalized to 0...1 range)

Engineering unit function equation

$Y_0 = (G_1Y_1 + B_1)(G_2Y_2 + B_2) + B_0$ .... Equation (2)

where Y_0, Y_1, Y_2 : Variables
(engineering unit; Y_n varies between $Y_{n0}...Y_{n1}$ when X_n varies between 0...1)
G_1, G_2 : Gains
B_0, B_1, B_2 : Bias (engineering unit)

Gains and biases

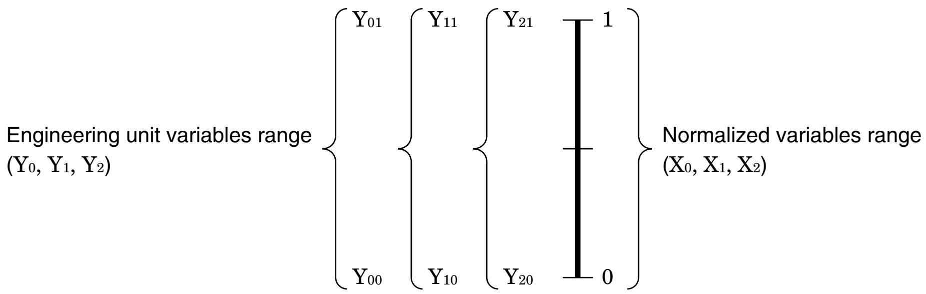
$$K_1 = \frac{G_1(Y_{11} - Y_{10})}{Y_{01} - Y_{00}}$$ .... Equation (3)

$$K_2 = G_2(Y_{21} - Y_{20})$$ .... Equation (4)

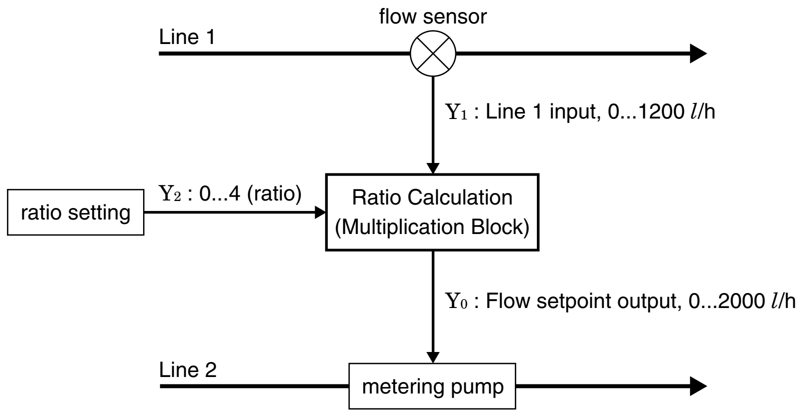
$$A_0 = \frac{B_0 - Y_{00}}{Y_{01} - Y_{00}}$$ .... Equation (5)

$$A_1 = \frac{G_1Y_{10} + B_1}{Y_{01} - Y_{00}}$$ .... Equation (6)

$$A_2 = G_2Y_{20} + B_2$$ .... Equation (7)



■ EXAMPLE (1): RATIO CALCULATION IN A FLOW CONTROL PROCESS



Engineering unit function equation

$Y_0 = Y_1 \times Y_2$ .... Equation (8)

The above equation is equivalent to the following one that matches the construction of the equation (2):

$Y_0 = (1Y_1 + 0)\ (1Y_2 + 0) + 0$

Gains and biases are therefore given as follows:

$G_1 = G_2 = 1$
$B_0 = B_1 = B_2 = 0$

Engineering unit variables range

$Y_0 = 0\ ...\ 2000\ l/h \quad \rightarrow Y_{00} = 0, Y_{01} = 2000$
$Y_1 = 0\ ...\ 1200\ l/h \quad \rightarrow Y_{10} = 0, Y_{11} = 1200$
$Y_2 = 0\ ...\ 4\ (ratio) \quad \rightarrow Y_{20} = 0, Y_{21} = 4$

Normalized gains and biases (equations (3), (4), (5), (6) and (7))

$K_1 = 1200 / 2000 = 0.6$
$K_2 = 4$
$A_0 = A_1 = A_2 = 0$

Normalization equation

$X_0 = 0.6X_1 \times 4X_2$ .... Equation (9)

Recalculation

Normalization equation at $X_1 = X_2 = 0.5$ is given according to the equation (9):

$X_0 = 0.6 \times 0.5 \times 4 \times 0.5 = 0.6$

Actual flow rates at 50% are given respectively as follows:

$Y_1 = 600\ l/h$
$Y_2 = 2$

Engineering unit function equation at 50% flow is given according to the equation (8):

$Y_0 = 600 \times 2 = 1200\ l/h$

Normalized Y_0 equals 0.6 (1200 / 2000), corresponding to the result with the normalization equation.

5.1.4 DIVISION

Two-input division function is available. For three or more inputs, combine multiple blocks.

Normalization equation

$$X_0 = \frac{K_1X_1 + A_1}{K_2X_2 + A_2} + A_0 \quad \text{.......... Equation (1)}$$

where X_0, X_1, X_2 : Variables (normalized to 0...1 range)
K_1, K_2 : Gains (normalized to 0...1 range)
A_0, A_1, A_2 : Bias (normalized to 0...1 range)

Engineering unit function equation

$$Y_0 = \frac{G_1Y_1 + B_1}{G_2Y_2 + B_2} + B_0 \quad \text{.......... Equation (2)}$$

where Y_0, Y_1, Y_2 : Variables
(engineering unit; Y_n varies between Y_{n0}...Y_{n1} when X_n varies between 0...1)
G_1, G_2 : Gains
B_0, B_1, B_2 : Bias (engineering unit)

Gains and biases

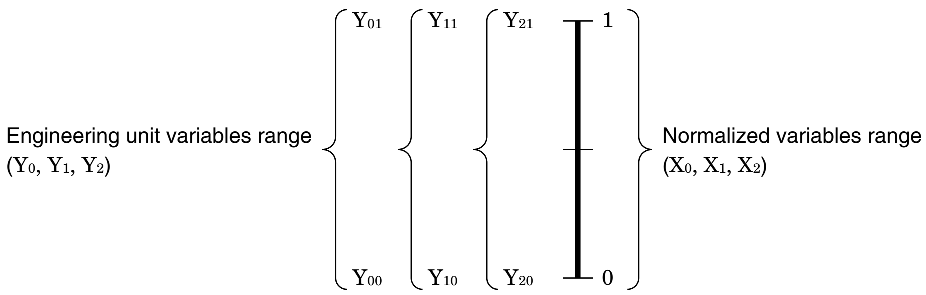
$$K_1 = \frac{G_1 (Y_{11} - Y_{10})}{Y_{01} - Y_{00}} \quad \text{.......... Equation (3)}$$

$$K_2 = G_2 (Y_{21} - Y_{20}) \quad \text{.......... Equation (4)}$$

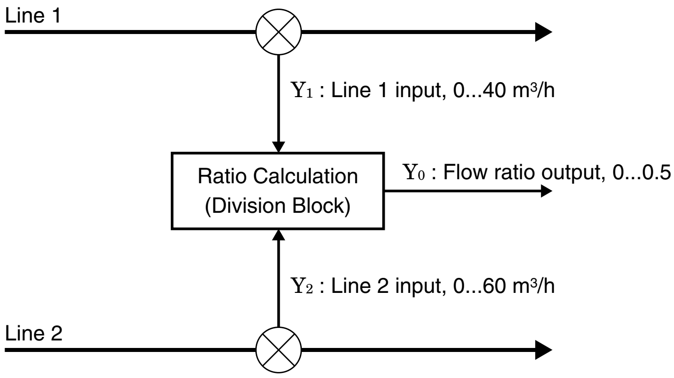
$$A_0 = \frac{B_0 - Y_{00}}{Y_{01} - Y_{00}} \quad \text{.......... Equation (5)}$$

$$A_1 = \frac{G_1Y_{10} + B_1}{Y_{01} - Y_{00}} \quad \text{.......... Equation (6)}$$

$$A_2 = G_2Y_{20} + B_2 \quad \text{.......... Equation (7)}$$



■ EXAMPLE (1): FLOW RATIO CALCULATION



Engineering unit function equation

$Y_0 = Y_1 \div Y_2$ .... Equation (8)

The above equation is equivalent to the following one that matches the construction of the equation (2):

$$Y_0 = \frac{1Y_1 + 0}{1Y_2 + 0} + 0$$

Gains and biases are therefore given as follows:

$G_1 = G_2 = 1$
$B_0 = B_1 = B_2 = 0$

Engineering unit variables range

$Y_0 = 0 ... 0.5$ (ratio) $\rightarrow Y_{00} = 0, Y_{01} = 0.5$
$Y_1 = 0 ... 40$ m³/h $\rightarrow Y_{10} = 0, Y_{11} = 40$
$Y_2 = 0 ... 60$ m³/h $\rightarrow Y_{20} = 0, Y_{21} = 60$

Normalized gains and biases (equations (3), (4), (5), (6) and (7))

$K_1 = 40 / 0.5 = 80$
$K_2 = 60$
$A_0 = A_1 = A_2 = 0$

Normalization equation

$X_0 = 80X_1 / 60X_2 = 4X_1 / 3X_2$ .... Equation (9)

[Note]
Reduce fractions so that gains and biases are within the selectable ranges: -10.000 to +10.000 for gains, -1.1500 to +1.1500 for biases.

Recalculation

Normalization equation at $X_1 = 0.5$ and $X_2 = 1$ is given according to the equation (9):

$X_0 = 4 \times 0.5 / 3 \times 1 = 2/3$

Actual flow rates are given respectively as:

$Y_1 = 20$ m³/h
$Y_2 = 60$ m³/h

Engineering unit function equation is given according to the equation (8):

$Y_0 = 20 / 60 = 1/3$

Normalized Y_0 equals 2/3 (1/3 ÷ 0.5), corresponding to the result with the normalization equation.

■ EXAMPLE (2): TEMPERATURE RATIO CALCULATION

Temperature ratio calculation is typically used for psychrometers.

Engineering unit function equation

$$Y_0 = \frac{Y_1 + 10}{Y_2 - 20} \quad \text{.......... Equation (10)}$$

The above equation is equivalent to the following one that matches the construction of the equation (2):

$$Y_0 = \frac{1Y_1 + 10}{1Y_2 - 20} + 0$$

Gains and biases are therefore given as follows:

$G_1 = G_2 = 1$
$B_0 = 0, B_1 = 10, B_2 = -20$

Engineering unit variables range

$Y_0 = 1.0 \dots 1.5$ (ratio) $\rightarrow Y_{00} = 1.0, Y_{01} = 1.5$
$Y_1 = 50 \dots 80$ °C $\rightarrow Y_{10} = 50, Y_{11} = 80$
$Y_2 = 50 \dots 100$ °C $\rightarrow Y_{20} = 50, Y_{21} = 100$

Normalized gains and biases (equations (3), (4), (5), (6) and (7))

$K_1 = (80 - 50) / (1.5 - 1.0) = 60$
$K_2 = 100 - 50 = 50$
$A_0 = -1.0 / (1.5 - 1.0) = -2$
$A_1 = (50 + 10) / (1.5 - 1.0) = 120$
$A_2 = 50 - 20 = 30$

Normalization equation

$$X_0 = \frac{60X_1 + 120}{50X_2 + 30} - 2 = \frac{0.6X_1 + 1.2}{0.5X_2 + 0.3} - 2 \quad \text{.......... Equation (11)}$$

[Note]
Reduce fractions so that gains and biases are within the selectable ranges: -10.000 to +10.000 for gains, -1.1500 to +1.1500 for biases.

Recalculation

Normalization equation at $X_1 = X_2 = 0.5$ is given according to the equation (11):

$$X_0 = \frac{0.6 \times 0.5 + 1.2}{0.5 \times 0.5 + 0.3} - 2 = \frac{1.5}{0.55} - 2 = 0.727$$

Actual temperature measurements are given respectively as follows:

$Y_1 = (80 - 50) \times 0.5 + 50 = 65$ °C
$Y_2 = (100 - 50) \times 0.5 + 50 = 75$ °C

Engineering unit function equation is given according to the equation (10):

$Y_0 = (65 + 10) / (75 - 20) = 75 / 55 = 1.364$

Normalized Y_0 is given as $X_0 = (1.364 - 1) / (1.5 - 1.0) = 0.728$, corresponding to the result with the normalization equation, with only a tolerable error in the last digit of the fraction.

5.2 PROGRAM SETTING

Two methods to create program patterns set over time are available: trapezoidal ramp program and line chart program. The trapezoidal ramp program is realized with Program Setter block, while the line chart program is realized with combined Linearizer and Accumulator blocks.

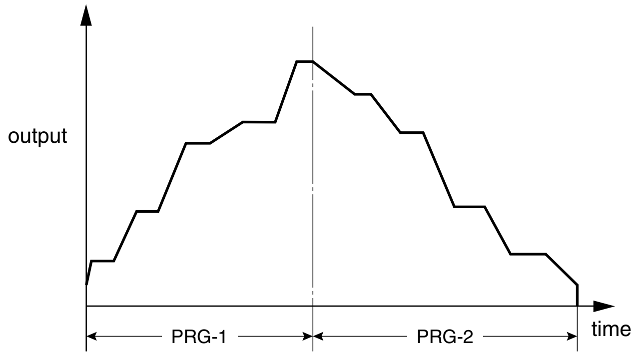
5.2.1 RAMP PROGRAM WITH FIVE OR LESS NUMBER OF RAMPS

Simple ramp program with a maximum of five ramps is realized by utilizing one Program Setter block. Refer to Section 4.3.3 PROGRAM CONTROL for an actual application example.

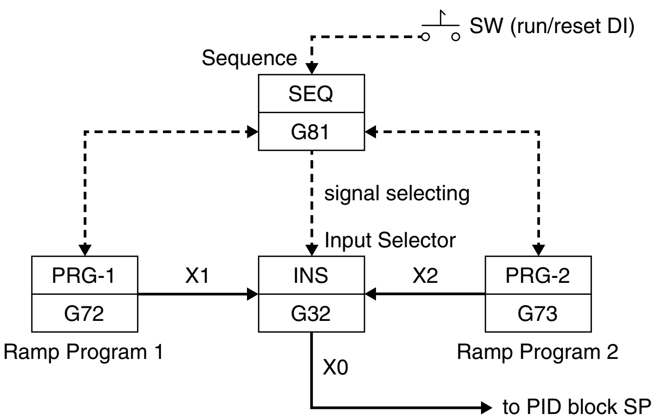
5.2.2 RAMP PROGRAM WITH SIX TO TEN RAMPS

Two Program Setter blocks are combined to deal with six to ten ramps. Two programs are switched in turn.

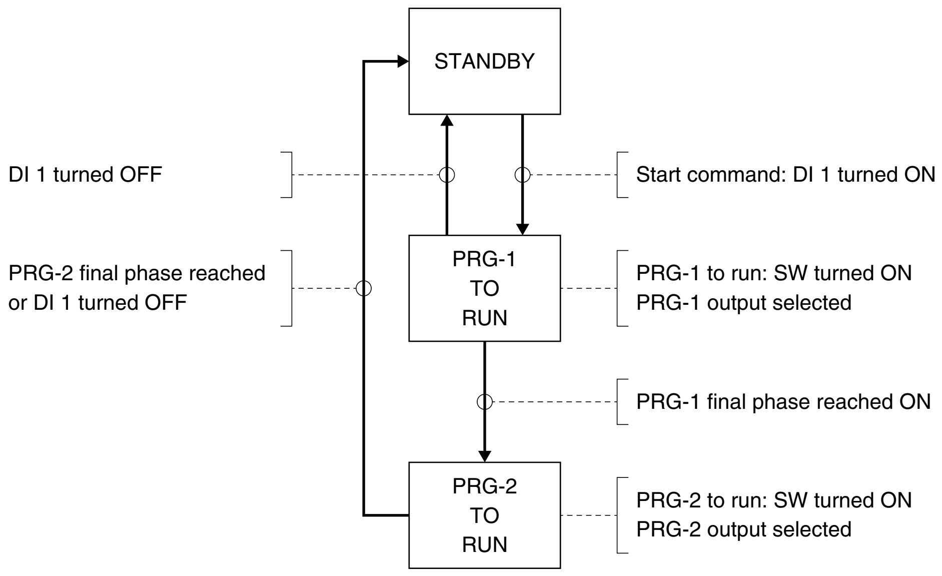
■ **RAMP PROGRAM EXAMPLE**



■ **BLOCK DIAGRAM**

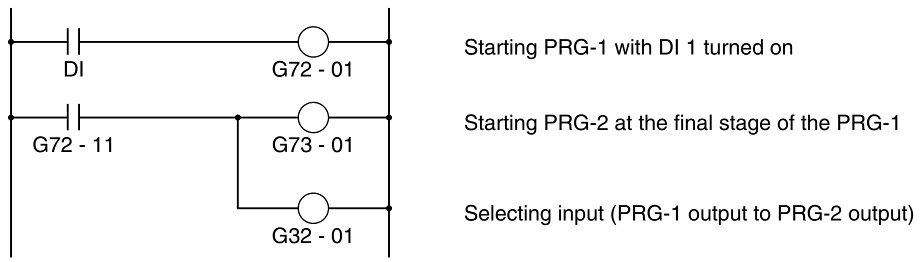


■ OPERATION



■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
32	10	72	Input selector block
	11	7221	X1 connection terminal (PRG-1 output)
	12	7321	X2 connection terminal (PRG-2 output)
72	10	69	Program setter block (PRG-1)
73	10	69	Program setter block (PRG-2)
	11	7221	X1 connection terminal (PRG-1 output)
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	010511	IN DI (start signal)
	13	077201	OT G72 - 01 PRG-1 to run SW ON
	14	017211	IN G72 - 11 PRG-1 final phase reached output ON
	15	077301	OT G73 - 01 PRG-2 to run SW ON
	16	073201	OT G32 - 01 PRG-2 output selected



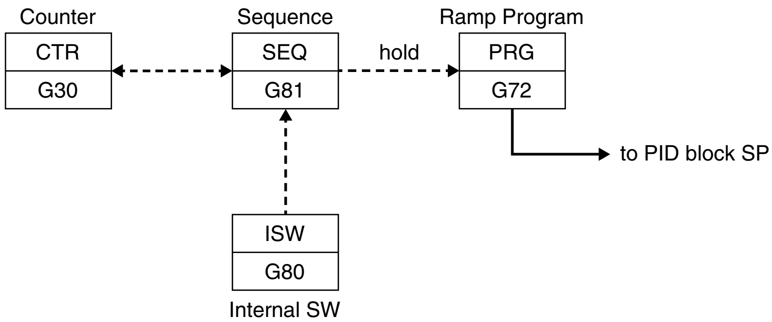
5.2.3 RAMP PROGRAM WITH EXTENDED TIME SPAN

Single batch program continuing for several tens of days can be realized by use of hold switches to halt and resume the program periodically. Parameters used in the program must be multiplied by appropriate conversion factors defined by the degree of time span expansion (clock pulse rate).

■ CLOCK PULSE RATE V.S. CONVERSION FACTOR

CLOCK PULSE RATE	HOLD TIME (T) CONVERSION FACTOR	RAMP RATE (K) CONVERSION FACTOR
ON for 1 second / OFF for 9 seconds	Tn x 10	Kn x 0.1
ON for 1 second / OFF for 99 seconds	Tn x 100	Kn x 0.01

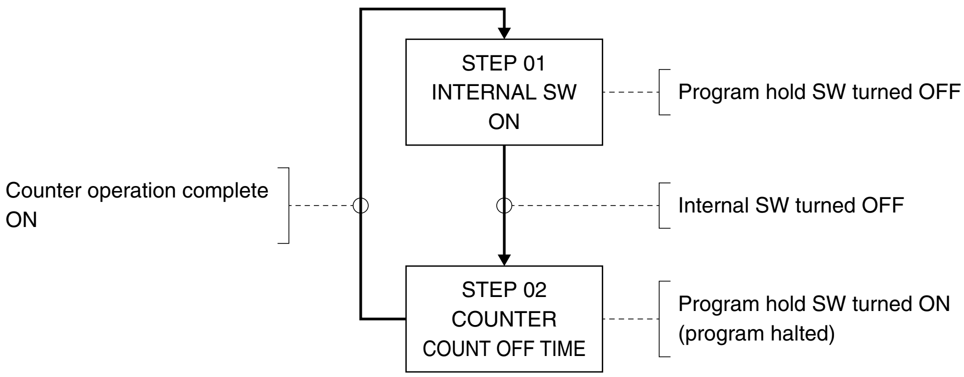
■ BLOCK DIAGRAM



■ OPERATION

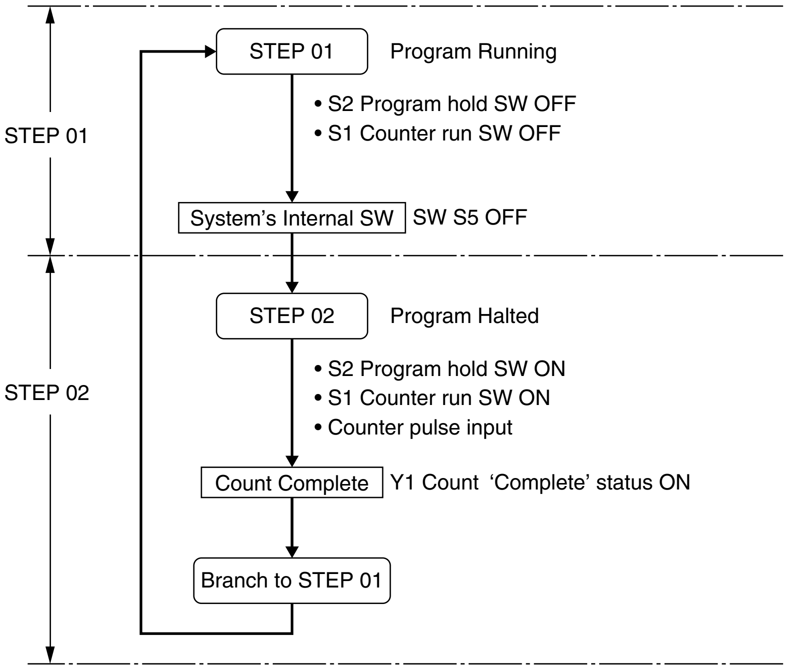
Clock cycle of Timer block is not synchronized with the Controller's computation cycle. Counter block is used instead of Timer to count pulses generated by System's Internal Switch block (Switch S5, G80) which repeats ON-OFF cycles every second. The internal switch is described in Sequential Control block.

The following explanations do not include the sequence to start/reset the ramp program.



■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
30	10	92	Counter block
	11	9	Count set to '9'
72	10	69	Program setter block
81	10	95	Sequential control block
	11	130001	ST STEP 01
	12	107202	OF G72 - 02 PRG hold SW OFF
	13	103001	OF G30 - 01 Counter run SW OFF
	14	028005	NI G80 - 05 System's internal SW S5 OFF
	15	130002	ST STEP 02
	16	097202	ON G72 - 02 PRG hold SW ON
	17	093001	ON G30 - 01 Counter run SW ON
	18	018005	IN G80 - 05 System's internal SW S5 ON
	19	073002	OT G30 - 02 Counter pulse input SW ON
	20	013011	IN G30 - 11 Counter complete status ON
	21	120001	BR BR 01 Branch to STEP 01

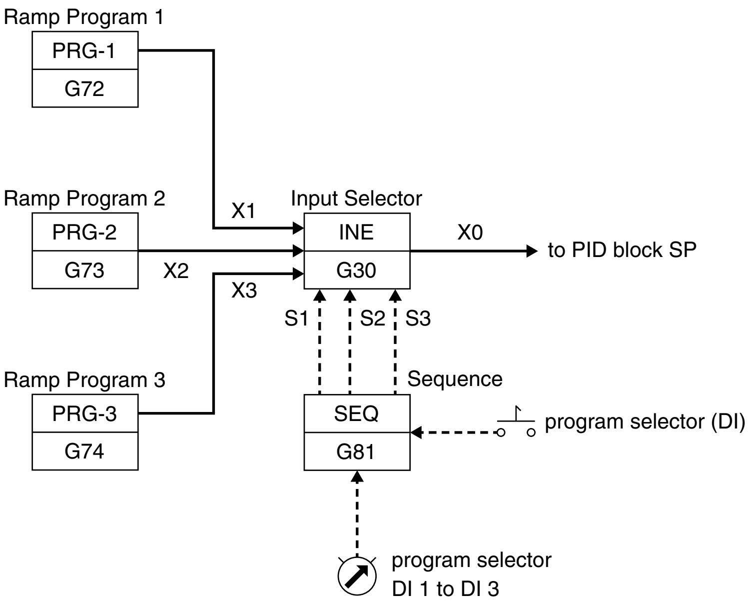


5.2.4 SWITCHING AMONG MULTIPLE RAMP PROGRAMS

The example below explains how to switch among multiple predefined ramp programs by using external switches.

■ BLOCK DIAGRAM EXAMPLE: THREE PROGRAMS

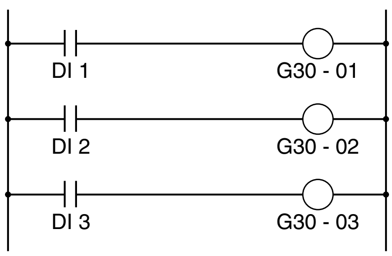
Up to 8 programs can be switched using 8-point Input Selector Block with the following configurations.



Control sequence to start Program Setter blocks is not described in thie example.

■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
31	10	8 5	Input selector block
	11	7 2 2 1	X1 connection terminal (PRG-1 output)
	12	7 3 2 1	X2 connection terminal (PRG-2 output)
	13	7 4 2 1	X3 connection terminal (PRG-3 output)
72	10	6 9	Program setter block (PRG-1)
73	10	6 9	Program setter block (PRG-2)
74	10	6 9	Program setter block (PRG-3)
81	10	9 5	Sequential control block
	11	1 3 0 0 0 0	ST STEP 00
	12	0 1 0 5 1 1	IN G05 - 11 When DI 1 is ON
	13	0 7 3 0 0 1	OT G30 - 01 Select X1 (PRG-1)
	14	0 1 0 5 1 2	IN G05 - 12 When DI 2 is ON
	15	0 7 3 0 0 2	OT G30 - 02 Select X2 (PRG-2)
	16	0 1 0 5 1 3	IN G05 - 13 When DI 3 is ON
	17	0 7 3 0 0 3	OT G30 - 03 Select X3 (PRG-3)



Input X1 to output by DI 1

Input X2 to output by DI 2

Input X3 to output by DI 3

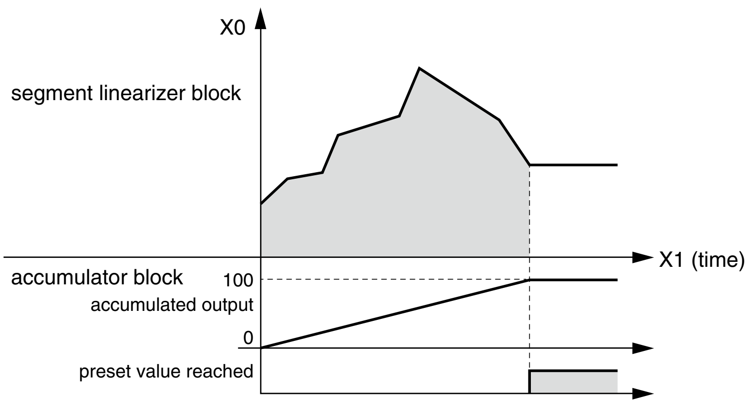
5.2.5 LINE CHART PROGRAM

Line chart program is realized by combining Accumulator and Linearizer blocks. Input axis of the linearizer's line chart graph is applied with time, and its output axis is applied with set values. Time signal, provided from accumulated output at the accumulator block, is determined with Parameter Selector block output multiplied by the counter rate in the accumulator block.

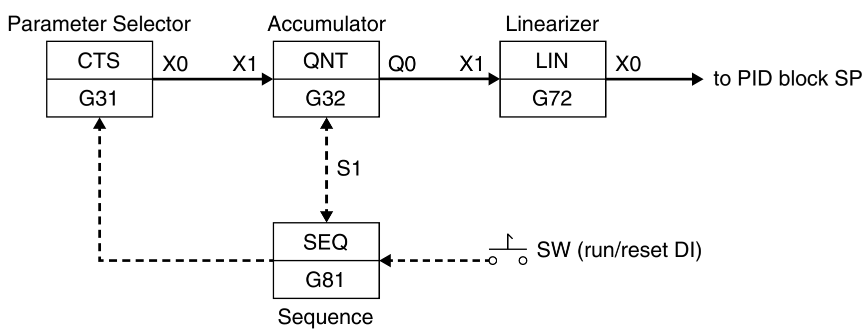
[Application Considerations]

1) Total batch operation time can be expanded or contracted easily with a fixed program pattern by changing only one parameter: either the counter rate in the accumulator block or the full-scale time parameter in the parameter selector block.
2) Each time index corresponds to one output value. No need of calculating ramp rates.
3) No limitation in ramp rate setting. This method is especially accurate when the ramp rate is very small.
4) Set value cannot be adjusted automatically to match with a measured value at the start of bach operation.
5) For an additional time adjustment during the operation, connect Addition/Subtraction block to the accumulator output and add or subtract time counts using a bias setting.

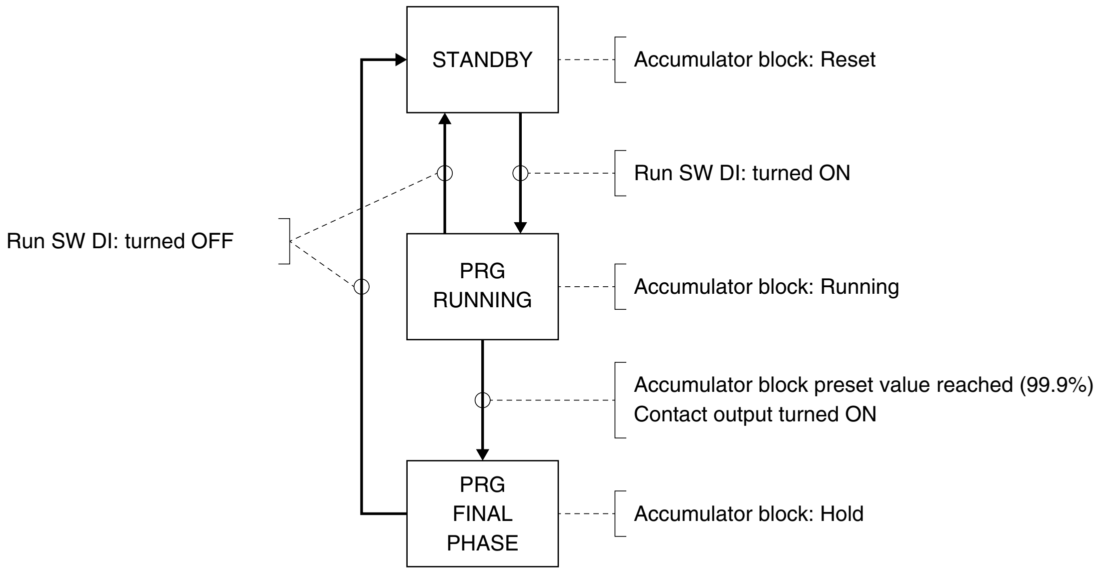
■ LINE CHART PROGRAM EXAMPLE



■ BLOCK DIAGRAM

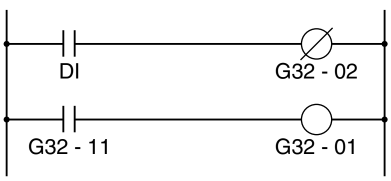


■ OPERATION



■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
31	10	75	Parameter selector block
	11	set	A1 parameter to set the full-scale time span
32	10	68	Accumulator block
	11	3121	X1 connection terminal (parameter selector output)
	12	9990	Preset value
	13	10000.00	Counter rate K
	14	1	Time unit set to ‘minute’
72	10	58	Linearizer block
	11	3221	X1 connection terminal (accumulator output)
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	013001	IN DI (field terminal) turned ON
	13	083202	NO G32 - 02 Accumulator reset SW OFF
	14	013211	IN G32 - 11 Accumulated output > 99.90%
	15	073201	OT G32 - 01 Accumulator block HOLD



Starting accumulation

Turning interrupt SW on and holding output at preset value

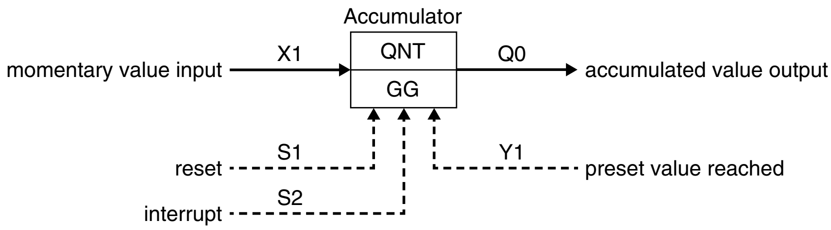
5.3 ACCUMULATOR

5.3.1 GENERAL DESCRIPTION

Accumulator block is used for continuous accumulation of analog input signals or for preset counter purpose.

■ OPERATION

- Counter is automatically reset when the accumulated value reaches 10000 counts.
- Fractions exceeding 10000 counts are added after the counter is reset.
- When the counter reaches the preset value, the ‘preset value reached’ output Y1 is turned on. The Y1 is not reset automatically after the count has reached 10000, until the reset SW S1 is turned on.
- Turn on the interrupt SW S2 in order to halt counting.
- Accumulated value output is provided at Q0.



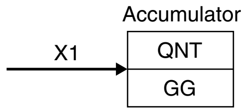
■ COUNTER RATE

Counter rate K represents the accumulated output value per time unit (second, minute, hour or day) provided when the input is fixed at 100%.

For example, in order to have 150 counts per hour with the range 0...150 m^3/h (1 count per 1 m^3), set the K (ITEM 13) to 150 and the time unit (ITEM 14) to ‘2’ (hour). In order to have 1500 counts per hour (1 count per 0.1 m^3), set the K to 1500.

5.3.2 APPLICATION EXAMPLES

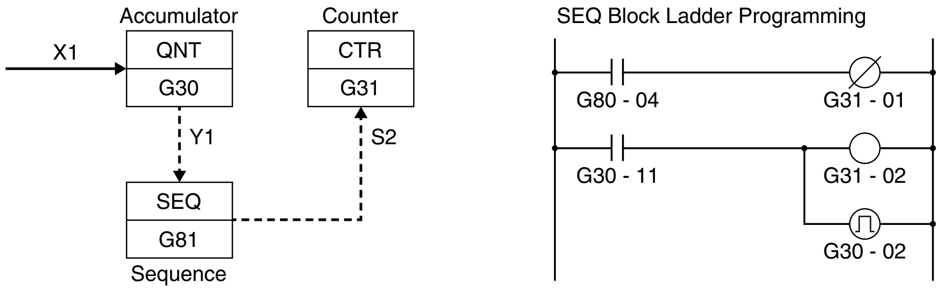
■ TYPICAL USAGE



Accumulator block is utilized with a counter rate setting.

■ ACCUMULATING MORE THAN 10000 COUNTS

Combine Accumulator block with Counter block. Set the counter rate K so that the preset value of the accumulator is equivalent to the least significant digit of the counter.



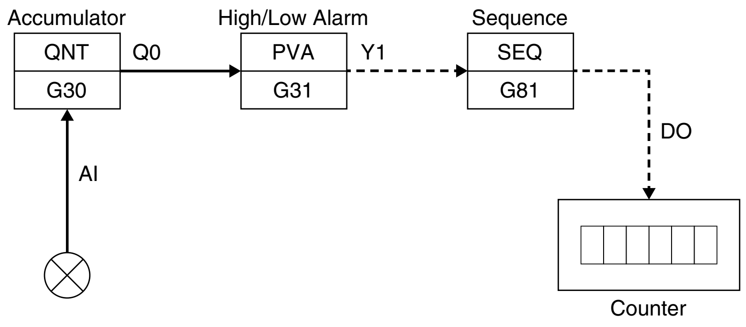
■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
30	10	68	Accumulator block
	12	10000	Preset value
31	10	92	Counter block
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	018004	IN G80 - 04 System's internal SW (always 0)
	13	083101	NO G31 - 01 Counter run SW always ON
	14	013011	IN G30 - 11 Accumulator preset value reached
	15	073102	OT G31 - 02 1 pulse output to the counter
	16	113002	SH G30 - 02 Reset and restart

5.3.3 DRIVING AN EXTERNAL COUNTER

Accumulated analog input signal is provided as pulse outputs to drive an external counter.

■ BLOCK DIAGRAM



■ OPERATION

- Accumulator's counter is automatically reset when the accumulated value reaches 10000 counts.
- Fractions exceeding 10000 counts are added after the counter is reset.
- One-shot output is provided to drive an external counter when the counter is reset by watching the Q0 (accumulated value output) with High/Low Alarm block.

■ CODING LIST ESSENTIALS

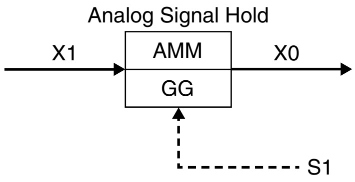
GROUP	ITEM	DATA	FUNCTION
30	10	68	Accumulator block
	13	set	Counter rate K
31	10	76	High/low alarm block
	11	3021	X1 connection terminal (accumulator output)
	12	100.00	High alarm setpoint A1
	14	0.00	Deadband (hysteresis) A3
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	013111	IN G31 - 11 Accumulator output
	13	110501	SH DO

5.4 SIGNAL MEMORY

5.4.1 GENERAL DESCRIPTION

Analog signal is held temporarily by utilizing Analog Signal Hold block or Input Selector block.

■ ANALOG SIGNAL HOLD BLOCK



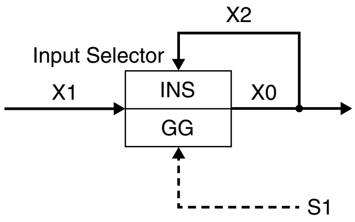
Analog Signal Hold block (Model No. 83, abbreviation code AMM) is used to track or hold input values according to a preset condition.

Maximum, minimum or momentary value memory is selectable in ITEM 12: Hold mode setting.

X0 = X1 when S1 is at ‘1.’

OUTPUT SHOT command in the sequential control block is used to reset.

■ INPUT SELECTOR BLOCK



Input Selector block (Model No. 72, abbreviation code INS) can be also used to hold input values.

Connect X0 output terminal to X2 input terminal (ITEM 12: X2 connection terminal set to ‘GG21’).

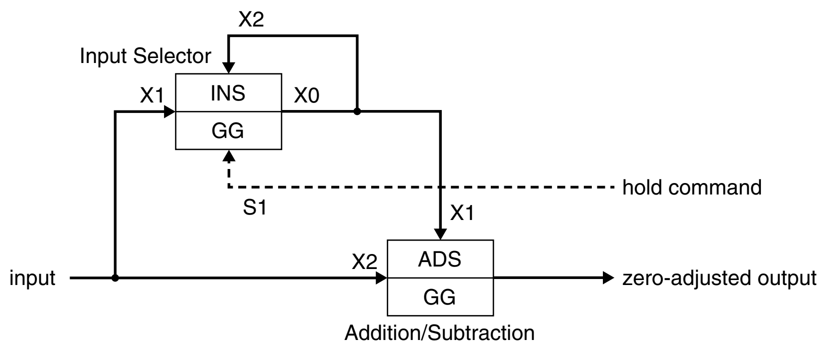
X0 = X1 when S1 is at ‘0’ (without signal memory).

X0 = X2 when S1 is at ‘1’ (signal memory)

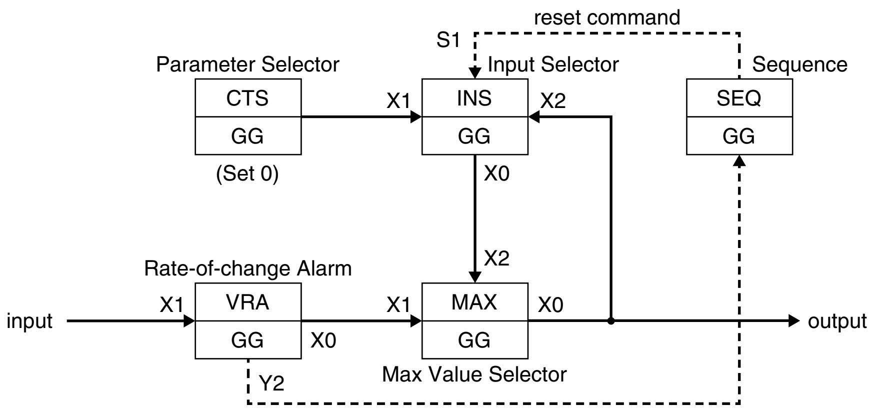
5.4.2 APPLICATION EXAMPLES

■ ZERO ADJUSTMENT

Actual measured signal is captured and stored at the moment when ‘0’ is indicated on an external meter (INS: Input Selector). The stored signal is provided as offset to compensate newly measured signals (ADS: Addition/Subtraction).



■ STORING THE MAXIMUM RATE-OF-CHANGE



In the above example, Maximum Value Selector (MAX) is used to store positive rate-of-change. Choose Minimum Value Selector (MIN) to store negative rate-of-change.

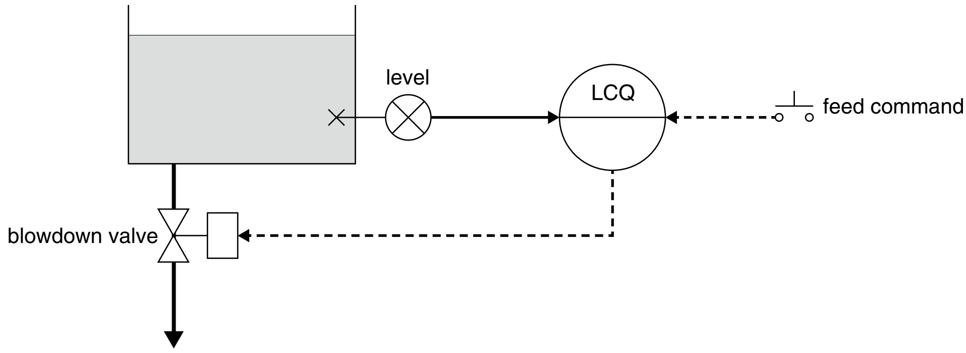
5.5 BATCH PROCESS CONTROL

5.5.1 LOSS-IN-WEIGHT FEEDING

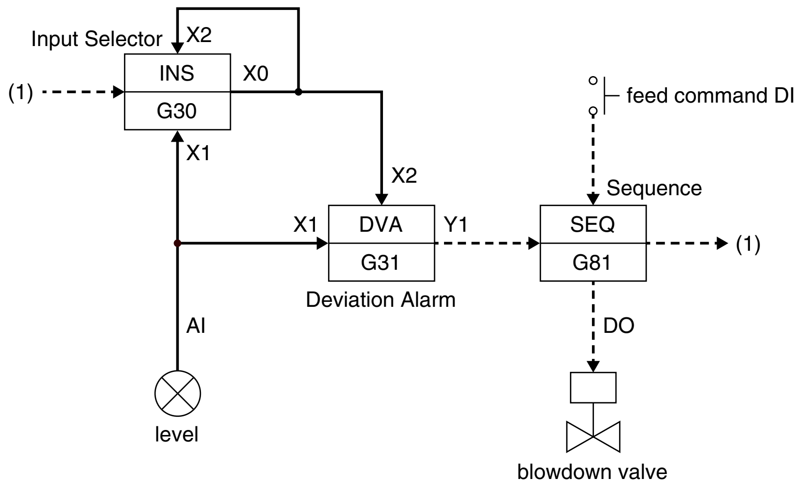
The principle of loss-in-weight feeding is to control the feed of material out of a hopper or a tank by extracting a preset volume from a measured present volume (level or weight).

■ LOOP CONFIGURATION EXAMPLE

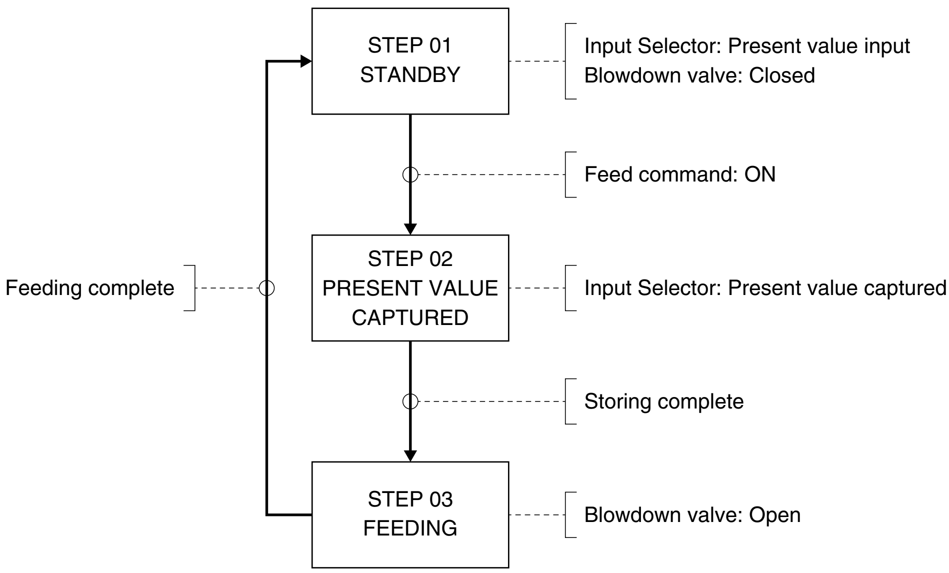
The valve opens by Start signal and closes when deviation (extracted volume) alarm trips.



■ BLOCK DIAGRAM

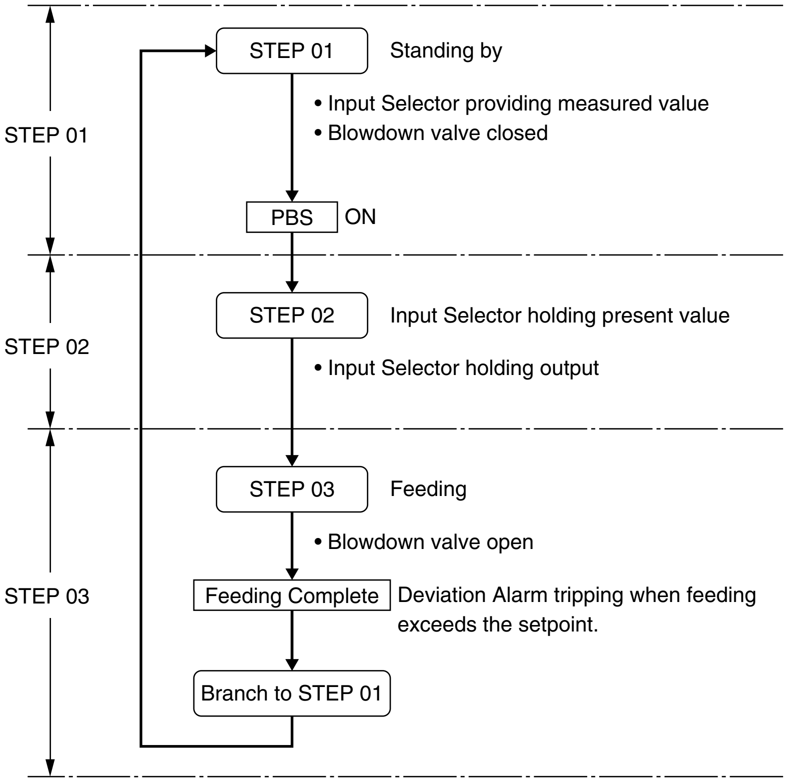


■ OPERATION



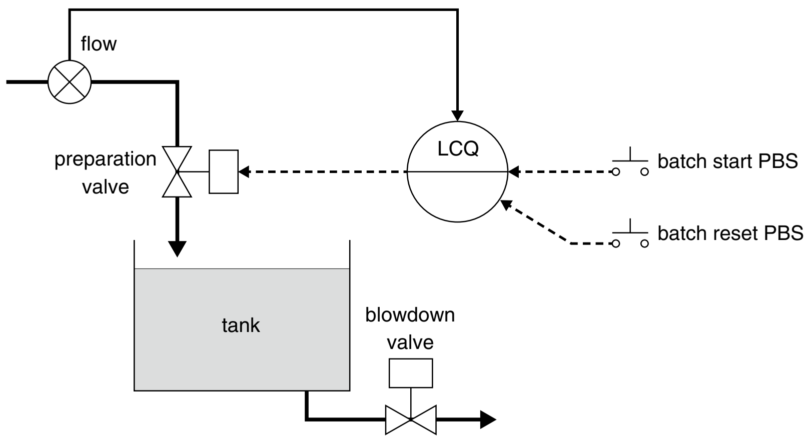
■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
30	10	7 2	Input selector block
	11	0 4 2 3	X1 connection terminal (field terminal AI)
	12	3 0 2 1	X2 connection terminal (output X0)
31	10	7 7	Deviation alarm block
	11	0 4 2 3	X1 connection terminal (present volume: field terminal AI)
	12	3 0 2 1	X2 connection terminal (stored volume: input selector output X0)
	13	s e t	High deviation setpoint (feed volume)
81	10	9 5	Sequential control block
	11	1 3 0 0 0 1	ST STEP 01
	12	1 0 3 0 0 1	OF G30 - 01 Input selector measured output
	13	1 0 0 5 0 1	OF DO Valve closed
	14	0 1 0 5 1 1	IN DI Feed command ON
	15	1 3 0 0 0 2	ST STEP 02
	16	0 9 3 0 0 1	ON G30 - 01 Input selector output held
	17	1 3 0 0 0 3	ST STEP 03
	18	0 9 0 5 0 1	ON DO Valve open
	19	0 1 3 1 1 1	IN G31 - 11 (Y1) When the deviation is larger than the set value
	20	1 2 0 0 0 1	BR BR 01 Branch to STEP 01

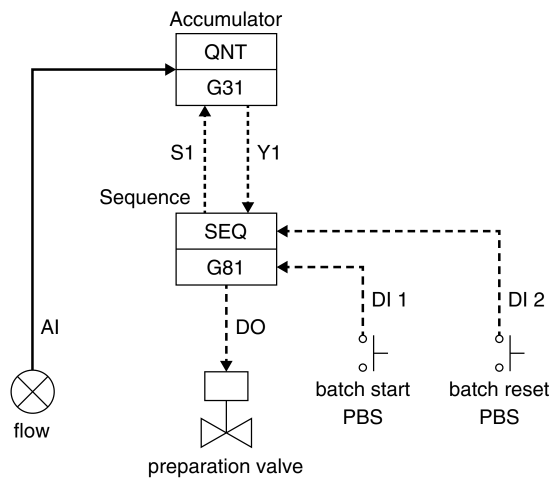


5.5.2 FLOW BATCH CONTROL

■ LOOP CONFIGURATION EXAMPLE: FIXED QUANTITY PREPARATION



■ BLOCK DIAGRAM



DI 1 and DI 2 are assigned to G30 Internal SW block as an example.

■ OPERATION

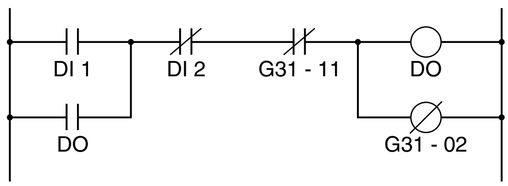
• Feeding starts when the start PBS is pressed.

• When the feeding reaches the preset value, the valve is closed and the feed value is reset.

• When the reset PBS is pressed during feeding, the valve is closed and the feed value is reset.

■ CODING LIST ESSENTIALS

GROUP	ITEM	DATA	FUNCTION
81	10	95	Sequential control block
	11	130000	ST STEP 00
	12	013001	IN DI 1 Start PBS pressed
	13	050501	OR DO Hold by feed output
	14	043002	NA DI 2 Valve close command when reset command PBS is pressed
	15	043111	NA G31 - 11 Valve close command when preset value is reached
	16	070501	OT DO Feed output
	17	083102	NO G31 - 02 Feed value reset when the valve is closed



Holding DO by DI 1

Cancelling holding DO and resetting accumulated value by DI 2

6. SEQUENTIAL CONTROL BLOCK

6.1 GENERAL DESCRIPTIONS

A sequential control block uses switches and status signals from other blocks to condition and control various discrete signals. All ON/OFF signals must be controlled via sequential control blocks.

16 types of commands are available for use in relay sequence or in step sequence descriptions. They are registered in 12 sequential control blocks.

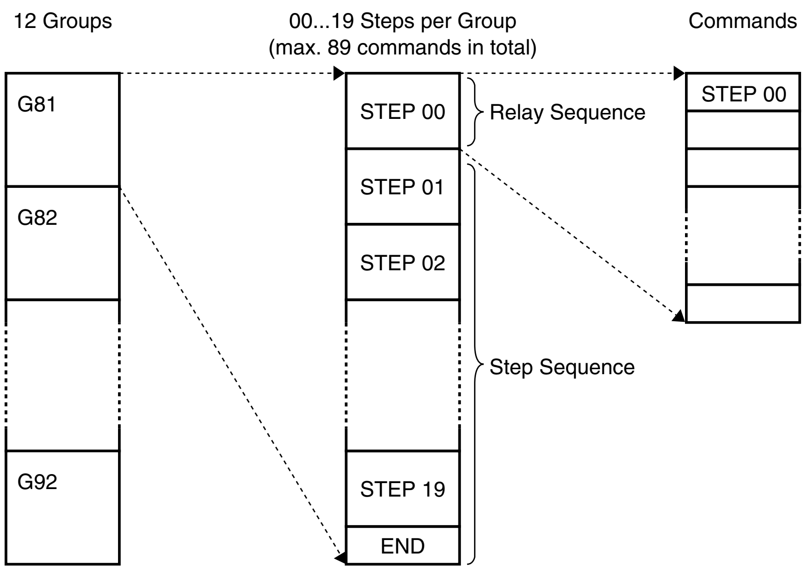
[Caution]

In this manual, switch or status '1' is described 'ON' and '0' is 'OFF.'

6.1.1 CONFIGURATION OF SEQUENTIAL CONTROL BLOCKS

■ GENERAL CONFIGURATIONS

12 sequential control blocks (groups) are available per controller module. Each block can contain 89 commands at the maximum. Each block is divided into 20 steps (00 to 19), and can be connected with BRANCH command to realize a series of sequence commands. A specific step in one block can be launched by a command from another block.



■ COMMANDS TO CONTROL THE BLOCK

[S1 : Run SW]

- With S1 turned on, Steps 00 and 01 start operating.
- With S1 turned off, the operation is stopped and returns to Step 01.
- With cold start setting, only Steps 00 and 01 in Group 81 operate while all other groups are deactivated.

[S2 : Cancel 'Go to Next Step' SW]

- With S2 turned on, the operation is stopped. Output is held.
- Step 00 continues running.
- With S2 turned off, the operation starts at the step where it has been stopped.

[Y1 : Step Timer Complete]

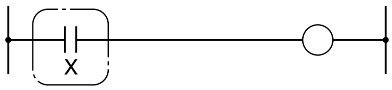
- Set timer command in the step to 'step watch timer' mode.
- In this mode, when the step operation is complete, the output Y1 turns to '1.'
- The signal is used to detect errors of controlled hardware device when the control process does not go to next step after a certain time period.

6.1.2 SEQUENTIAL CONTROL COMMANDS

GENERAL COMMAND FORMAT C C G G N N — Example: 020101

- N N: Terminal No.
- G G: Group No.
- C C: Command Code

■ CODE 01 : INPUT .... Abbr. : IN



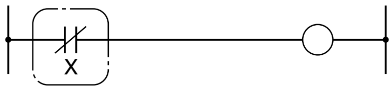
INPUT X

The first N.O. contact in a row.
Condition is true when the contact X in the ladder diagram to the left is turned on or at '1,' and the output '1' is provided.

Command : 0 1 G G N N

- N N: X terminal No.
- 0 1: INPUT

■ CODE 02 : INPUT NOT.. Abbr. : NI



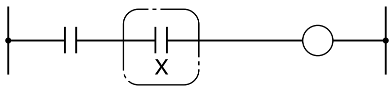
INPUT NOT X

The first N.C. contact in a row.
Condition is true when the contact X in the ladder diagram to the left is turned off or at '0,' and the output '1' is provided.

Command : 0 2 G G N N

- N N: X terminal No.
- 0 2: INPUT NOT

■ CODE 03 : AND .... Abbr. : AD



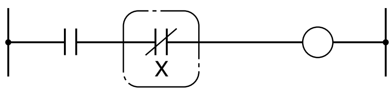
AND X

A N.O. contact connected in series with the first contact in a row.
Condition is true when the contact X in the ladder diagram to the left is turned on or at '1,' and the output '1' is provided.

Command : 0 3 G G N N

- N N: X terminal No.
- 0 3: AND

■ CODE 04 : AND NOT.. Abbr. : NA



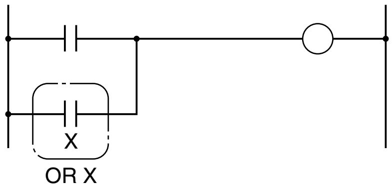
AND NOT X

A N.C. contact connected in series with the first contact in a row.
Condition is true when the contact X in the ladder diagram to the left is turned off or at '0,' and the output '1' is provided.

Command : 0 4 G G N N

- N N: X terminal No.
- 0 4: AND NOT

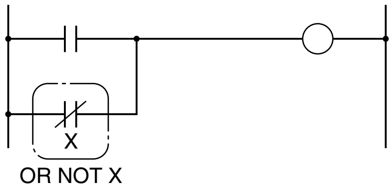
■ **CODE 05 : OR** .... **Abbr.: OR**



A N.O. contact connected in parallel with the first contact in a row. Condition is true when the contact X in the ladder diagram to the left is turned on or at ‘1,’ and the output ‘1’ is provided.

Command : `0 5 G G N N`
- G G N N — X terminal No.
- 0 5 — OR

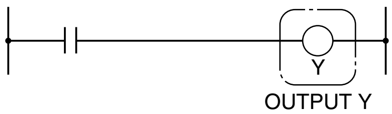
■ **CODE 06 : OR NOT** .... **Abbr. : NR**



A N.C. contact connected in parallel with the first contact in a row. Condition is true when the contact X in the ladder diagram to the left is turned off or at ‘0,’ and the output ‘1’ is provided.

Command : `0 6 G G N N`
- G G N N — X terminal No.
- 0 6 — OR NOT

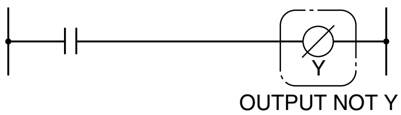
■ **CODE 07 : OUTPUT** .... **Abbr. : OT**



A coil in a relay circuit.
The contact Y is turned on or at ‘1’ when the circuit is closed, and off or at ‘0’ when it is open.

Command : `0 7 G G N N`
- G G N N — Y terminal No.
- 0 7 — OUTPUT

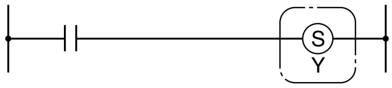
■ **CODE 08 : OUTPUT NOT** .... **Abbr. : NO**



A coil in a relay circuit.
The contact Y is turned on or at ‘1’ when the circuit is open, and off or at ‘0’ when it is closed.
There is no actual relay device that operates in this manner.

Command : `0 8 G G N N`
- G G N N — Y terminal No.
- 0 8 — OUTPUT NOT

■ **CODE 09 : OUTPUT ON** .... **Abbr. : ON**

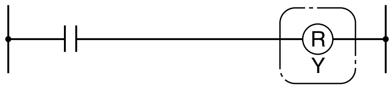


OUTPUT ON Y

A set coil in a latching relay circuit.
The contact Y is turned on or at '1' when the circuit is closed, and remains on when it is back open.
OUTPUT OFF command (below) is used to turn it off.

Command : 0 9 G G N N
- G G N N — Y terminal No.
- 0 9 — OUTPUT ON

■ **CODE 10 : OUTPUT OFF** .... **Abbr. : OF**

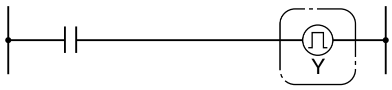


OUTPUT OFF Y

A reset coil in a latching relay circuit.
The contact Y is turned off or at '0' when the circuit is closed.

Command : 1 0 G G N N
- G G N N — Y terminal No.
- 1 0 — OUTPUT OFF

■ **CODE 11 : OUTPUT SHOT** .... **Abbr. : SH**



OUTPUT SHOT Y

A coil in a relay circuit that turns on for one computation cycle when the circuit is closed.
It must be open again before providing another one-shot output.

Command : 1 1 G G N N
- G G N N — Y terminal No.
- 1 1 — OUTPUT SHOT

■ CODE 12 : BRANCH.. Abbr. : BR

Command to jump to a specified step of a specified group No. when the condition is true.
Used also to connect between groups when more than one group is needed to describe a program.

```
Command :  1 2 G G S S
           |   |   |
           |   |   └────────── STEP No.
           |   └────────────── Destination GROUP No.
           |                     • Operation SW S1 of the destination group must be turned on before moving
           |                       to the group.
           |                     • Specify GROUP '00' to jump within the group.
           └────────────────── BRANCH command
```

■ CODE 13 : STEP.. Abbr. : ST

Declaration of a step.

STEP 00 : Runs continuously after Operation SW S1 of the group is turned on.
STEP 01 : Runs once when Operation SW S1 is turned on.
STEP 02 ... 19 : Runs by BRANCH command or when the condition to move to the step is true.
(Does not run by SW S1.)

```
Command :  1 3 0 0 S S
           |   |   |
           |   |   └────────── STEP No. (00...19)
           |   └────────────── Always '00'
           └────────────────── STEP command
```

■ CODE 14 : TIMER... Abbr. : TM

Timer operation is identical for any ITEM in the step.
Step watch timer does not automatically prompt the program operation to the next step.
The timer output Y1 is turned on when the set time has been elapsed.
Use the Y1 to handle any error procedure in a sequential control block assigned to another GROUP.

```
Command :  1 4 U N N N
           |   |   |
           |   |   └────────── Time (0...999 seconds)
           |   └────────────── Timer type
           |                     0 : ON delay timer (moved to the following step upon the time elapse)
           |                     1 : Step watch timer (Y1 = 1 upon the time elapse)
           └────────────────── STEP timer
```

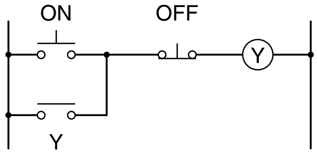
6.2 RELAY SEQUENCE

6.2.1 GENERAL DESCRIPTIONS

Software relay circuits have the following differences from actual relay circuits. They must be carefully considered when you build software logic sequence programs, but on the other part this means new possibilities of configuring virtual circuits which are not possible by actual relays.

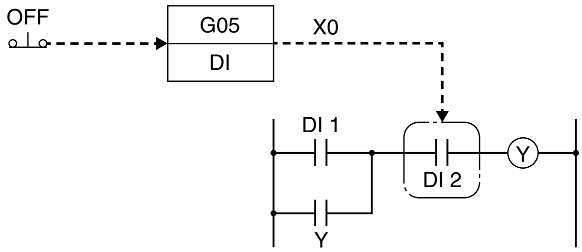
1) In every computation cycle, external input is taken in, processed through commands in the order of function block numbers and ITEM numbers, and provided as output at once at the end of the cycle. An upstream block utilizing a downstream block result can process such command only in a next cycle.
2) If one switching device is operated multiple times in one cycle, operation result at the most downstream block prevails.
3) One contact or coil can be used multiple times as conditions. There is no limitation applicable with actual mechanical relays.
4) Relay circuit operations using common power supply lines, such as interlocking circuit or shutdown circuit, are not possible with the software relay circuits. Build such circuits separately in downstream blocks.
5) N.C. contact in an actual relay circuit may be expressed as N.O. contact in the software function block. (See the example below.)

■ **RELAY CIRCUIT**



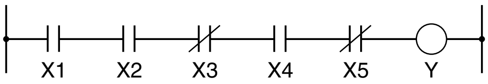
■ **FUNCTION BLOCK**

All external inputs are replaced with status outputs via Field Terminal or Communication Terminal blocks. N.C. PBS input is handled as N.O. contact in the function block descriptions.



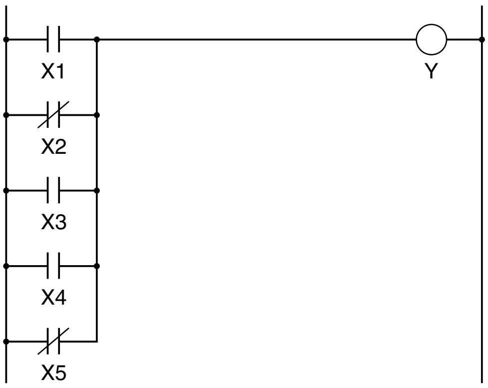
6.2.2 LADDER COMMAND DESCRIPTIONS

■ AND (NOT)



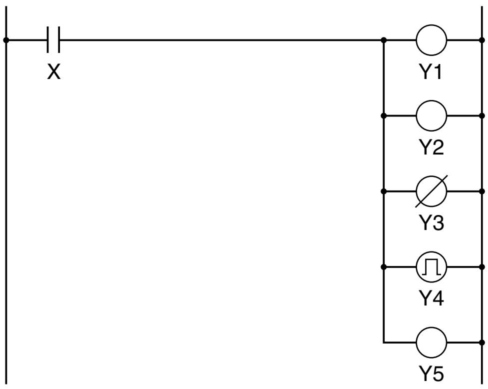
INPUT	X1
AND	X2
AND NOT	X3
AND	X4
AND NOT	X5
OUTPUT	Y

■ OR (NOT)



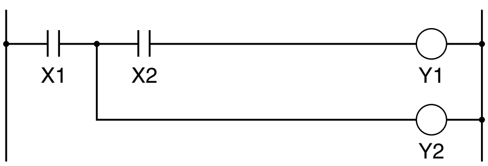
INPUT	X1
OR NOT	X2
OR	X3
OR	X4
OR NOT	X5
OUTPUT	Y

■ MULTIPLE OUTPUTS



INPUT	X
OUTPUT	Y1
OUTPUT	Y2
OUTPUT NOT	Y3
OUTPUT SHOT	Y4
OUTPUT	Y5

■ OUTPUT BRANCHING IN THE MIDDLE OF A ROW

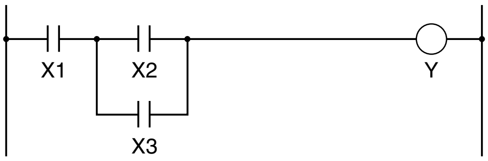


INPUT	X1
OUTPUT	Y2
AND	X2
OUTPUT	Y1

■ OR (NOT) + AND (NOT)

INPUT	X1
OR	X2
AND	X3
OUTPUT	Y

■ AND (NOT) + OR (NOT)



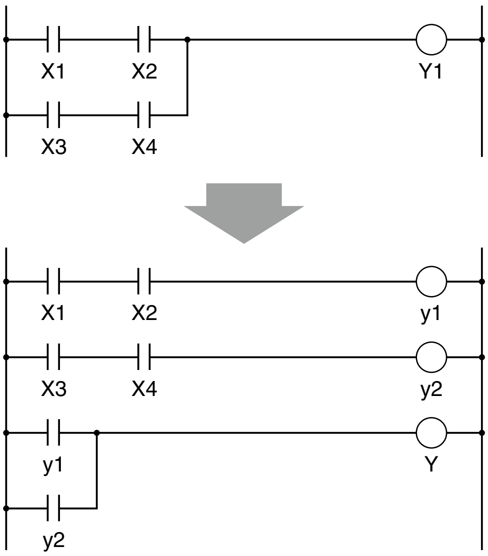
Two circuits are connected via AND command without input.

INPUT	X1
INPUT	X2
OR	X3
AND	0000
OUTPUT	Y

The following alternative command description with AND/OR in a reversed order is also valid.

INPUT	X2
OR	X3
AND	X1
OUTPUT	Y

■ TWO AND (NOT) CIRCUITS WITH OR CONNECTION



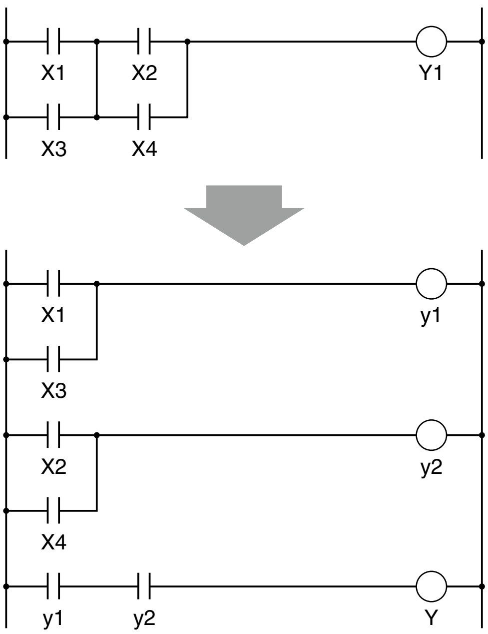
Two AND circuits are connected via OR command without input.

INPUT	X1
AND	X2
INPUT	X3
AND	X4
OR	0000
OUTPUT	Y

The following command description using internal switches y1 and y2 is equivalent to the above.

INPUT	X1
AND	X2
OUTPUT	y1
INPUT	X3
AND	X4
OUTPUT	y2
INPUT	y1
OR	y2
OUTPUT	Y

■ TWO OR (NOT) CIRCUITS WITH AND CONNECTION



Two OR circuits are connected via AND command without input.

INPUT	X1
OR	X3
INPUT	X2
OR	X4
AND	0000
OUTPUT	Y

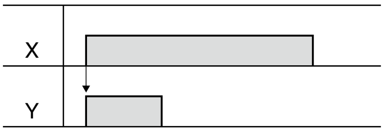
The following command description using internal switches y1 and y2 is equivalent to the above.

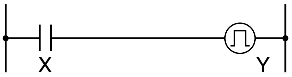
INPUT	X1
OR	X3
OUTPUT	y1
INPUT	X2
OR	X4
OUTPUT	y2
INPUT	y1
AND	y2
OUTPUT	Y

6.2.3 FREQUENTLY USED CIRCUIT CONFIGURATIONS

■ ONE-SHOT OUTPUT

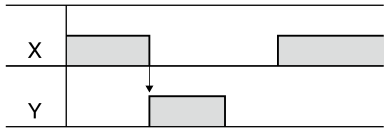
• One-shot output at an input rising

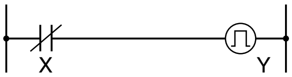




INPUT	X
OUTPUT SHOT	Y

• One-shot output at an input sinking

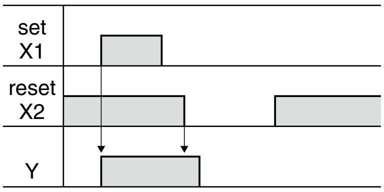


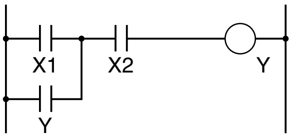


INPUT NOT	X
OUTPUT SHOT	Y

■ LATCHING CIRCUIT

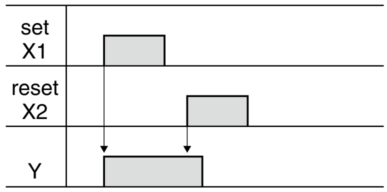
• N.O. reset input

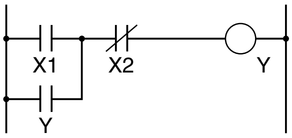




INPUT	X1
OR	Y
AND	X2
OUTPUT	Y

• N.C. reset input

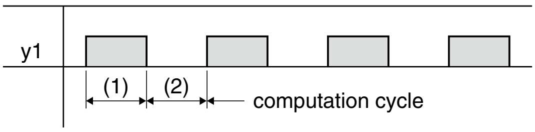


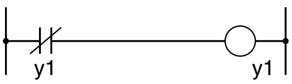


INPUT	X1
OR	Y
AND NOT	X2
OUTPUT	Y

■ FLASHING CIRCUIT

• ON-OFF by computation cycle (0.5 sec. ON - 0.5 sec. OFF with 0.5 sec. computation cycle)



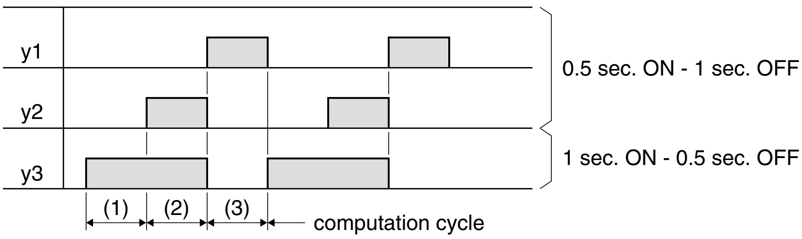


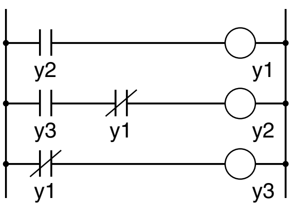
INPUT NOT	y1
OUTPUT	y1

[OPERATION]

- Output y1 turns on when Input y1 is off at the first (1) cycle.
- Output y1 turns off when Input y1 is on at the second (2) cycle.
- This program does not function normally with a mechanical contact.

• 1 sec. ON - 0.5 sec. OFF or 0.5 sec. ON - 1 sec. OFF (with 0.5 sec. computation cycle)



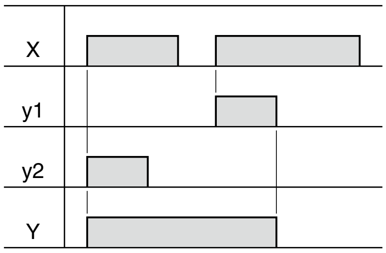


INPUT	y2
OUTPUT	y1
INPUT	y3
AND NOT	y1
OUTPUT	y2
INPUT NOT	y1
OUTPUT	y3

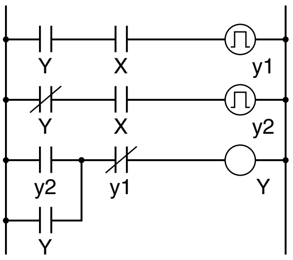
[OPERATION]

- Output y3 turns on at the first (1) cycle.
- Output y2 turns on when Input y3 is on at the second (2) cycle.
- Output y1 turns on when Input y2 is on at the third (3) cycle, and the y2 and y3 turn off as a result.
- A downstream command result changes in turn its upstream command condition by every computation cycle.

■ FLIP-FLOP CIRCUIT



• Y turns on/off once while X turns on/off twice.



INPUT	Y
AND	X
OUTPUT SHOT	y1
INPUT NOT	Y
AND	X
OUTPUT SHOT	y2
INPUT	y2
OR	Y
AND NOT	y1
OUTPUT	Y

[OPERATION]

- With contact X turned on, one-shot output y2 is provided to latch contact Y.
- With contact X turned off and on again, contact Y is on and one-shot output y1 is provided to reset contact Y.
- Contact Y turns once while contact X turns twice.

6.3 STEP SEQUENCE

6.3.1 GENERAL DESCRIPTIONS

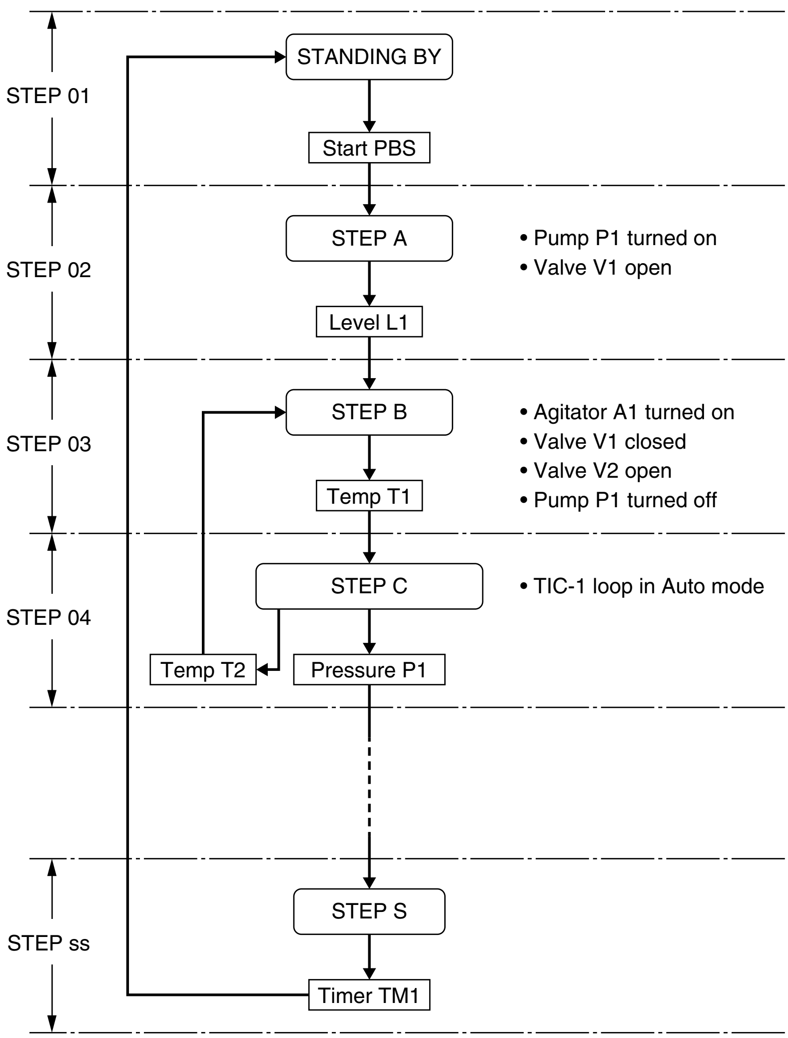
In addition to relay (ladder) sequence type programming, the ‘step sequence’ type programming similar to sequential function chart is available.

It is especially effective in describing a batch control process that needs exact conditioning to go to a next step in a batch.

The following five (5) types of commands are available:

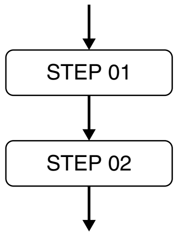
OUTPUT ON	:	Once turned on, the output remains on until a next OFF command is received.
OUTPUT OFF	:	Once turned off, the output remains off until a next ON command is received.
BRANCH	:	Activates a specified step in a specified block.
STEP	:	Declares STEP number.
TIMER	:	Step timer which runs only within a step without using an external timer device. ‘ON-delay’ timer or ‘step watch’ timer is selectable.

■ **EXAMPLE OF STEP SEQUENCE DESCRIPTION IN A BATCH PROCESS**



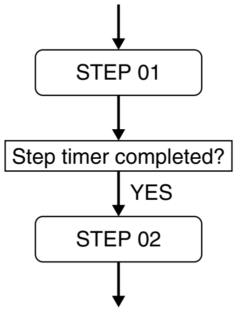
6.3.2 STEP COMMAND DESCRIPTIONS

■ **Advancing steps by the timing of computation cycles**



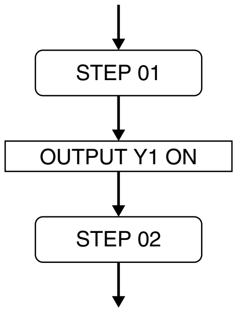

```
STEP 01
STEP 02
```

■ **Moving to the next step when the step timer is completed**



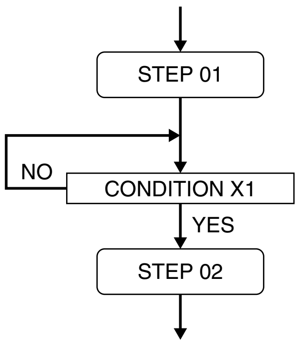

```
STEP 01
TIMER 0 100 (setting at 100 seconds)
STEP 02
```

■ **Moving to the next step after the previous step has provided output for one computational cycle**



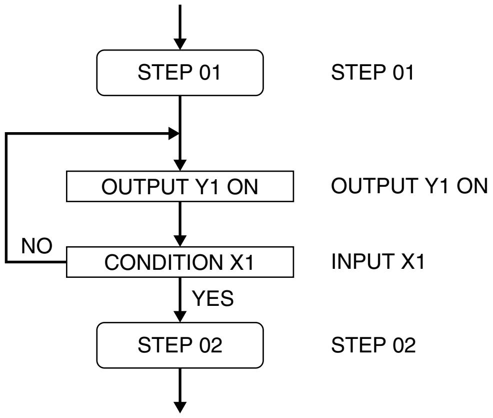

```
STEP 01
OUTPUT Y1 ON
STEP 02
```

■ **Moving to the next step when the condition is valid**

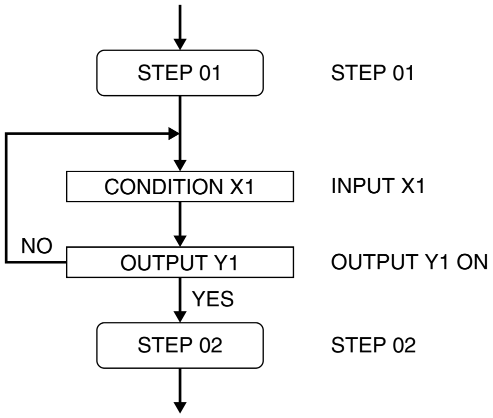



```
STEP 01
INPUT X1
STEP 02
```

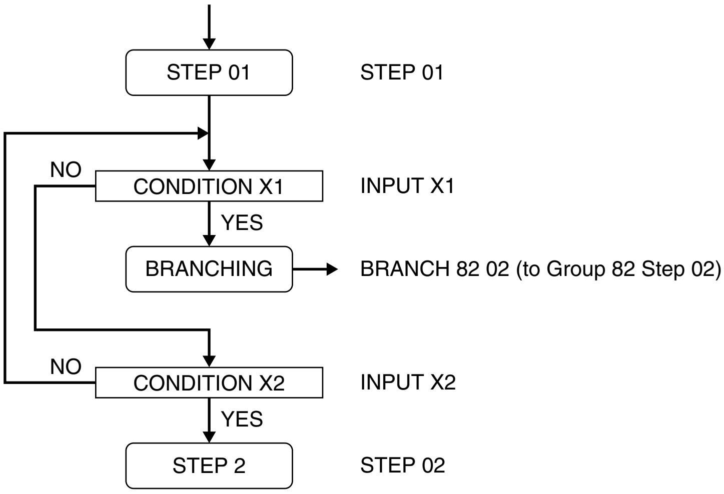
■ **Moving to the next step when the condition is valid after the previous step has provided output**



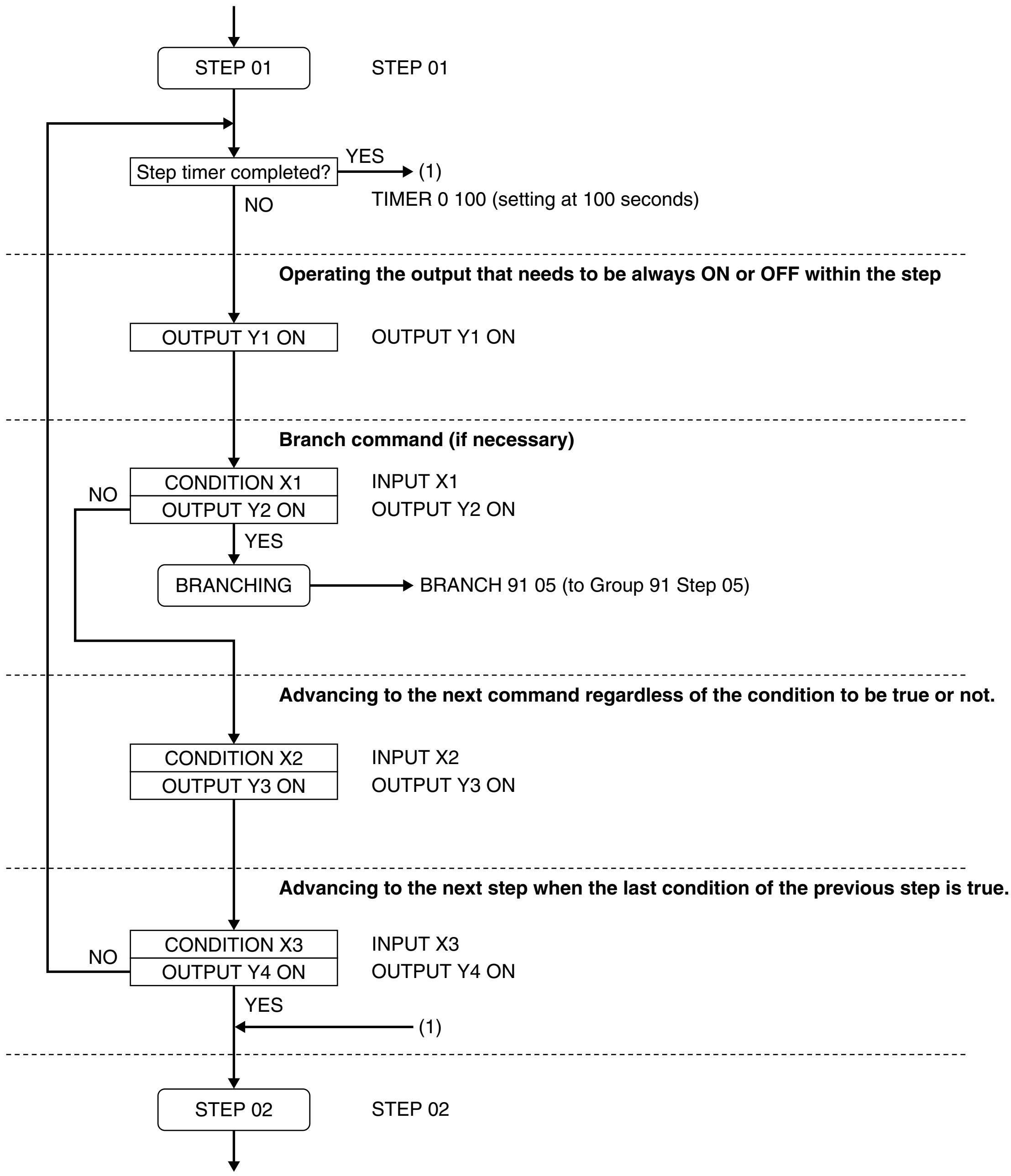
■ **Moving to the next step after the previous step has provided output when the condition was valid**



■ **Branching**



■ **Overall sequence**



6.4 TIMER AND COUNTER BLOCKS

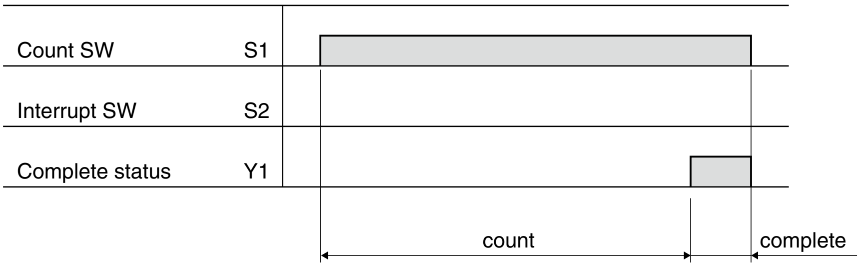
Timer and Counter are similar in functions. Timer counts internal clock pulses while Counter counts external pulse signals.

6.4.1 TIMER

Timer block has Count SW (S1), Interrupt SW (S2) and Complete status output (Y1) to control precise counting operation.

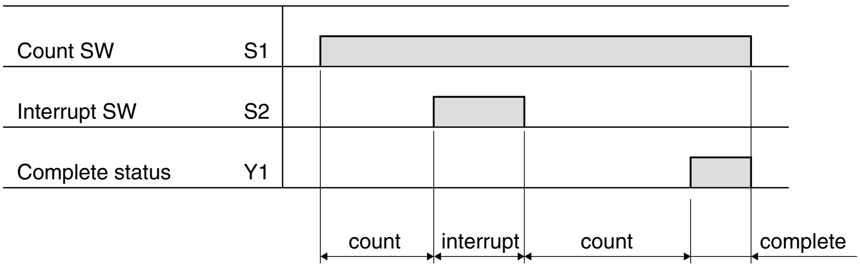
- Counting is reset and off when S1 is off.
- S2 is used to temporarily stop time counting. Counting is off when S2 is on.
- Y1 is turned on when the preset time has been elapsed (counted).

■ WITHOUT COUNT INTERRUPTION



- The timer starts counting when the S1 is turned on.
- The Y1 is turned on when the preset time has been elapsed.
- When the S1 is turned off, the Y1 is also reset to off.
- The S2 always remains off.

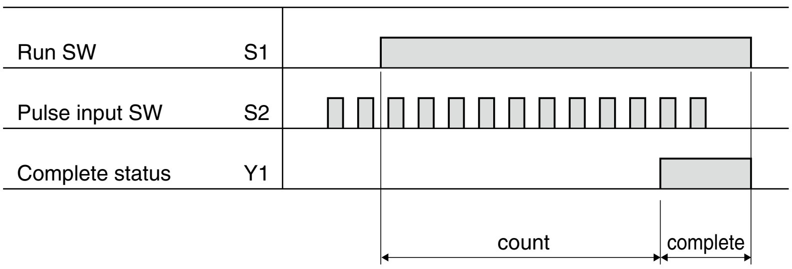
■ WITH COUNT INTERRUPTION



- Turn on the S2 to interrupt counting.

6.4.2 COUNTER

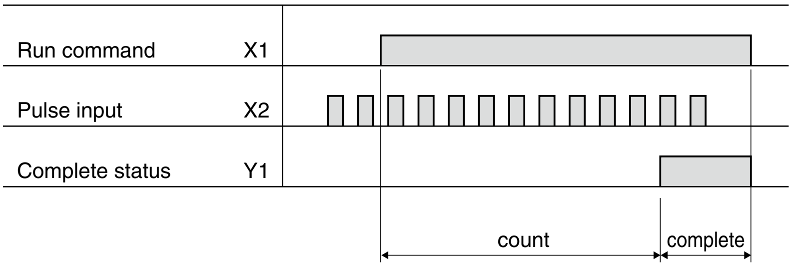
Counter block counts external pulse inputs at Pulse input SW (S2) until the count reaches a preset value and Complete status output (Y1) is turned on. Counting is reset and off when Run SW (S1) is turned off.

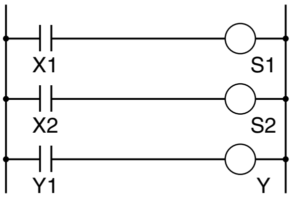


- Shut off external signal inputs to the S2 to interrupt counting.
- Pulse input cycle must be longer than one computation cycle.

6.4.3 APPLICATION EXAMPLES

■ PULSE COUNTER

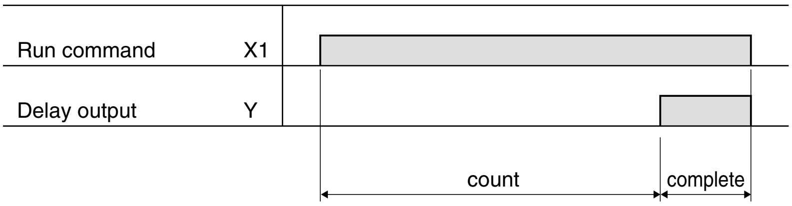


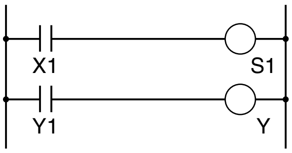


INPUT	X1	Run command
OUTPUT	S1	Count SW
INPUT	X2	Pulse input
OUTPUT	S2	Pulse input SW
INPUT	Y1	Complete status
OUTPUT	Y	Complete SW

■ ON DELAY TIMER

Output is turned on in a certain time period after the run command is turned on.

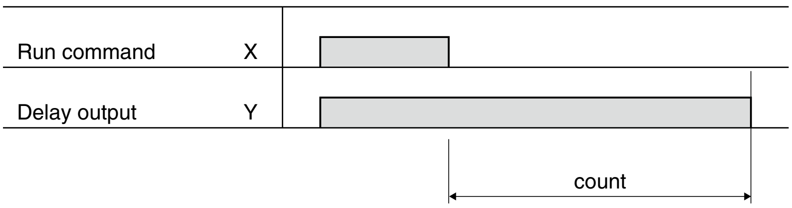


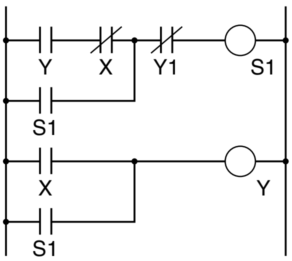


INPUT	X1	Run command
OUTPUT	S1	Count SW
INPUT	Y1	Reset SW
OUTPUT	Y	Delay output

■ OFF DELAY TIMER

Output is turned off in a certain time period after the run command is turned off.

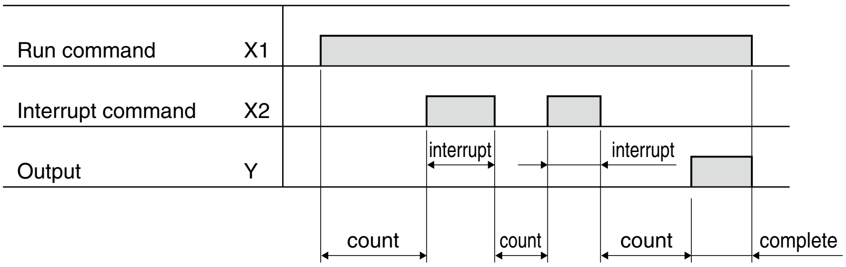


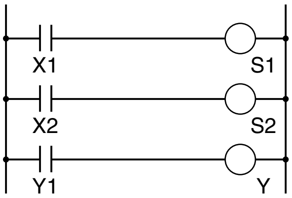


INPUT	Y	Delay output
AND NOT	X	Run command
OR	S1	Timer’s run SW
AND NOT	Y1	Timer complete output
OUTPUT	S1	Timer’s run SW
INPUT	X	Run command
OR	S1	Timer’s run SW
OUTPUT	Y	Delay output

■ TIME ACCUMULATOR

Time counting is interrupted while the interrupt command X2 is on.

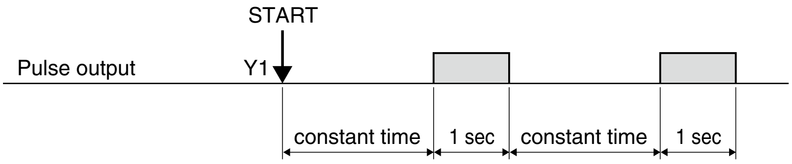


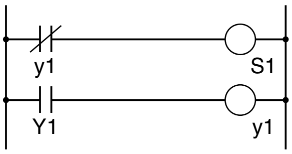


INPUT	X1	Run command
OUTPUT	S1	Timer run SW
INPUT	X2	Interrupt command
OUTPUT	S2	Timer interrupt SW
INPUT	Y1	Timer complete output
OUTPUT	Y	Output

■ CLOCK PULSE TIMER

Pulse output is provided in constant time intervals.





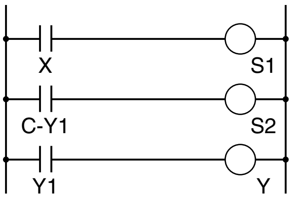
INPUT NOT	y1	Internal SW
OUTPUT	S1	Timer's run SW
INPUT	Y1	Timer complete output*
OUTPUT	y1	Internal SW

* The row is required to set the timer's reset time to 1 second while the computation cycle is 0.5 second.
Timer's minimum count time, 1 second, cannot be synchronized with a reset time set to 0.5 second.
The timer function block must be assigned to a smaller group number than that for the sequential control block.

■ TIMER IN 0.1 MINUTE OR 0.1 HOUR UNIT

Special timer in 0.1 minute or 0.1 hour unit. (Standard timer is available in 1 second or 1 minute unit.)
Counter function block is used to count clock pulses introduced in the above example.

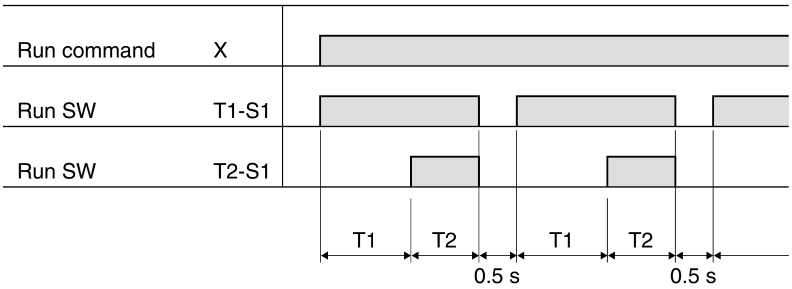
CLOCK	SET TIME	RESET TIME
0.1 minute (6 seconds)	5 seconds	1 second
0.1 hour (360 seconds)	359 seconds	1 second

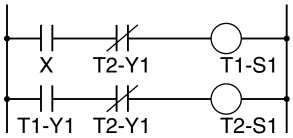


INPUT	Y	Run command
OUTPUT	S1	Counter's run SW
INPUT	C-Y1	Clock pulse (See above)
OUTPUT	S2	Counter's pulse input SW
INPUT	Y1	Count complete output
OUTPUT	Y	Output

■ DOUBLE TIMERS

Two timers are used to count OFF and ON time respectively, to repeat ON and OFF in turn.





INPUT	X	Run command
AND NOT	T2-Y1	T2 complete output
OUTPUT	T1-S1	T1 run SW
INPUT	T1-Y1	T1 complete output
AND NOT	T2-Y1	T2 complete output
OUTPUT	T2-S1	T2 run SW