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Bailey®
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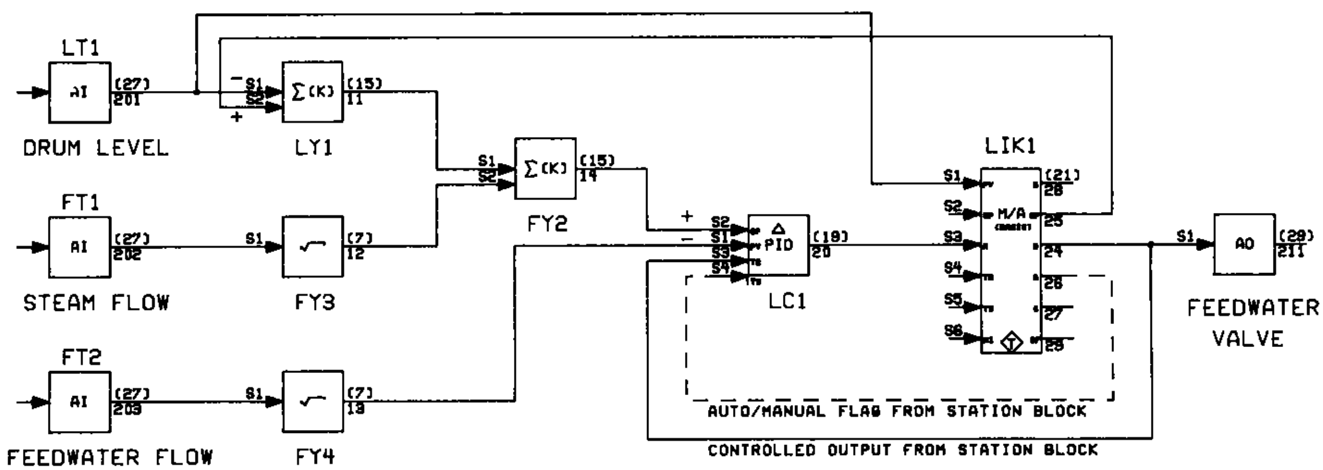
Loop Command Application Notes



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Application Notes

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Bailey Controls
Babcock & Wilcox, a McDermott company

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INTRODUCTION:

This document is intended to show typical configurations which can be used to achieve a number of different control actions in a Bailey Loop Command Controller The configurations shown are intended to serve as guidelines to aid in the configuration process They can be used in conjunction with other configurations or as a starting point for the development of other control loops

The first part of this document contains the various function codes needed to make the following configurations A general description of the function code is included along with the description of its various specifications Also a description or an explanation of the application is included

The second part of the document has twelve control algorithms There is a short description of each application, a process drawing and the Loop Command function block drawing of the configuration

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SYMBOLS:

The selection and interaction of control functions on the active modules is accomplished by configuring "function blocks"

A function block is merely an input or output, or an operation on an input or output These function blocks are generic software control algorithms that can be used to perform specific tasks which require dedicated hardware in other types of systems There are four types of function blocks

1 Executive
2 System Constants
3 Input/Output
4 User Configurable

The Executive blocks contain parameters which affect the overall operation of the module

System constant blocks are analog and digital parameters such a 0, 1, and 100 0, which are used as inputs for other blocks This eliminates the need to configure blocks with commonly used parameters

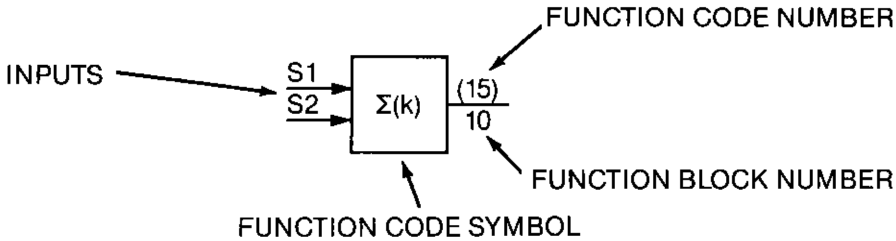
The I/O blocks are fixed block addresses which correspond to a module's field inputs and outputs through termination units and field wiring

User-configurable blocks are not pre-assigned but, instead, may be set up by the user to perform a wide variety of functions to implement control logic Each Loop Command Controller has a pre-defined set of block addresses for selection

The process of defining module operations with function blocks is called configuration To configure a function block, you must define the following parameters

- Block Number
- Function Code
- Specification List

For example, a 2-input summer, Function Code 15, performs a weighted sum of two inputs By choosing the proper gains and inputs this block can perform proportional, bias or difference functions It can also be used as a scaler for a non-zero band signal by referencing the second input to a constant block The operation of this function is described by the equation
Output = <S1> (S3) + <S2> (S4)



SPECIFICATIONS:

S1 is block address of first input
S2 is block address of second input
S3 is gain parameter of input 1
S4 is gain parameter of input 2

(15) is function code number
10 is function block that function code 15 is assigned to
Σ(k) is the symbol representing a summer with gain

DATA RANGES

DATA TYPE	RANGE	RESOLUTION
BOOLEAN	LOGIC 0 OR 1	N/A
INT(1)	0 TO 255	N/A
INT(2)	−32,768 TO +32,767	N/A
REAL(2)	±1 0 E −03 TO ±4 0 E 06	0 1%
REAL(3)	±2 7 E −20 TO ±9 2 E 18	0 0015%

For more detailed information on each of the following function codes and how they are configured, please refer to the Bailey Function Code Application Manual, E93-900-20

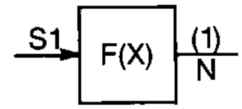
LOOP COMMAND SYSTEM FUNCTION BLOCKS

BLOCK	USE
Logic Constants	
0	Logic 0
1	Logic 1
Analog Constants	
3	−100 0
4	−1 0
5	0 0
6	1 0
7	100 0
8	−9 2 E 18
9	9 2 E 18
10 through 199	User-Configurable Blocks (Analog or Digital)
201	Analog Input 1
202	Analog Input 2
203	Analog Input 3
204	Analog Input 4
211	Analog Output 1
212	Analog Output 2
221	Digital Input 1
222	Digital Input 2
223	Digital Input 3
231	Digital Output 1
232	Digital Output 2
233	Digital Output 3
234	Digital Output 4
240	Executive Block (Function Code 53)

FUNCTION CODE 1

FUNCTION GENERATOR

GENERAL DESCRIPTION



This function is used to approximate a non-linear output to input relationship The input range is divided into five sections and a linear input to output realtionship is set up for each of those five sections This function then computes an output which is related to the input according to those five linear relationships

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Output value of function

SPECIFICATIONS

SPEC NO.	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	0	INT(2)	0 to 255	Block address of input
S2	YES	4 0 E 06	REAL(2)/(3)	FULL	Input coordinate
S3	YES	0 000	REAL(2)/(3)	FULL	Output coordinate for S2
S4	YES	4 0 E 06	REAL(2)/(3)	FULL	Input coordinate
S5	YES	0 000	REAL(2)/(3)	FULL	Output coordinate for S4
S6	YES	4 0 E 06	REAL(2)/(3)	FULL	Input coordinate
S7	YES	0 000	REAL(2)/(3)	FULL	Output coordinate for S6
S8	YES	4 0 E 06	REAL(2)/(3)	FULL	Input coordinate
S9	YES	0 000	REAL(2)/(3)	FULL	Output coordinate for S8
S10	YES	4 0 E 06	REAL(2)/(3)	FULL	Input coordinate
S11	YES	0 000	REAL(2)/(3)	FULL	Output coordinate for S10
S12	YES	4 0 E 06	REAL(2)/(3)	FULL	Input coordinate
S13	YES	0 000	REAL(2)/(3)	FULL	Output coordinate for S12

EXPLANATION

To set up this function, you must first determine what the output should be for a given range of input and draw a graph to show this relationship

The coordinates of the end points of these sections are then used as entries for specification S2 through S13 The even-numbered specifications are the X-axis coordinates and the odd-numbered ones are the Y-axis coordinates This sets up a relationship such that when the X-axis input value is at S2, the output will be the value of S3 as shown in the graph This actually divides the graph into five linear (straight-line) sections, each section having its own particular slope

FUNCTION CODE 1

If the input value is between two X-axis points, the output will be determined by the equation

$$\text{Block Output} = Y_{n-1} + \frac{(Y_n - Y_{n-1})}{(X_n - X_{n-1})} \times [X - X_{n-1}]$$

In this equation X = the present input value

X_n = the X-axis specification point just above the present input value

X_{n-1} = the X-axis specification point just below the present input value

Y_n = the Y-axis value that corresponds to X_n

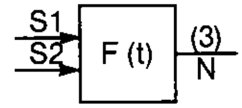
Y_{n-1} = the Y-axis coordinate that corresponds to X_{n-1}

The $[(Y_n - Y_{n-1})/(X_n - X_{n-1})]$ term is the slope of that particular graph segment (how much the output changes per input change)

The $[X_n - X_{n-1}]$ term is the amount that the input is above the next lower specification point

FUNCTION CODE 3

LEAD/LAG



GENERAL DESCRIPTION

In a block using this Function Code the output equals the product of some time function and the input value By using either S3 or S4 individually, either a lead or lag function is available This function can also be used as a lead/lag filter

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Output value with lead/lag function applied

SPECIFICATIONS

SPEC. NO.	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	5	INT(2)	0 to 255	Block address of input
S2	NO	0	INT(2)	0 to 255	Block address of Track Switch Signal 0 = track 1 = release
S3	YES	0 000	REAL(2)/(3)	FULL	Time constant T1 (lead) sec
S4	YES	0 000	REAL(2)/(3)	FULL	Time constant T2 (lag) sec

EXPLANATION

This function code causes the output of the function block to lead or lag changes in the input signal The operation is described by the equation

$$Y = Y_L + \frac{(S3)\ (<S1> - <S1_L>)}{(S4) + dt} + \frac{dt\,(<S1> - Y_L)}{(S4) + dt}$$

where $<S1>$ = Present Input Value
$<S1_L>$ = Value of the Input on the Previous Cycle
$(S3)$ = Value of time constant T1 (lead) in seconds
$(S4)$ = Value of time constant T2 (lag) in seconds
Y = Present Output Value
Y_L = Value of the Output on the Previous Cycle
dt = Module Cycle Time (seconds)

The S2 term enables or disables this function If S2 is a logic 0, then the output will track the input, in other words, the output will be the same as the input at any given time If S2 is set to a logic 1 level, the lead or lag function will be implemented

FUNCTION CODE 3

Lag Function

If only a lag function is desired, S3 is left at its initial value (0) and a number is entered for S4 The equation then becomes

$$Y = Y_L + \frac{dt\,(<S1> - Y_L)}{(S4) + dt}$$

S4 is the time constant term and is defined as the time that it takes for the output of this function to reach 63 2% of the input value The output will not reach approximately 99% of the input value until the end of five time constants In this application, it will be five times S4 before the output to nearly equal the input in a certain number of seconds (t), the following equation can be used

$$(S4) = \frac{t}{5}$$

In this equation

(S4) = the time contant term for Function Code 3

t = the number of seconds for the output to reach 99% of the input value

5 = the number of time constants required for the output to reach about 99% of the input value

For example, if it is required for the output to reach the input level in 30 seconds, the S4 term needed would be

$$S4 = \frac{t}{5} = \frac{30}{5} = 6$$

Lead Function

If only a lead function is desired, S4 is left at its initial value of 0 and a number is entered for S3 The equation then becomes

$$Y = Y_L + \frac{(S3)(<S1> - <S1_L>) + dt(<S1> - Y_L)}{dt}$$

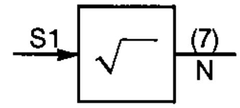
where

$<S1>$ = Present Input Value
$<S1_L>$ = Value of the Input on the Previous Cycle
(S3) = Value of time constant T1 (lead) in seconds
(S4) = Value of time constant T2 (lag) in seconds
Y = Present Output Value
Y_L = Value of the Output on the Previous Cycle
dt = Module Cycle Time (seconds)

The output is set to the value that the input will be in S1 seconds if it continues to change at the same rate as it did during the last cycle The lead function is essentially equal to the derivative function except that the Function Code 3 block output will eventually be the same as the input if the input remains constant long enough, while the output if a derivative function is zero when the input is not changing

FUNCTION CODE 7

SQUARE ROOT



GENERAL DESCRIPTION

This function computes the square root of the input signal in engineering units The output equals a factor (K) times the square root of the input The equation is

$$Y = S2\sqrt{<S1>}$$

where $<S1>$ = Input value
S2 = Gain value (K) in engineering units
Y = Output value
Y = 0 if $<S1> \leq 0$

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Output value equals square root of input value multiplied by a scale factor

SPECIFICATIONS

SPEC. NO.	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	6	INT(2)	0 to 255	Block address of input
S2	YES	1 000	REAL (2) /(3)	FULL	Gain value K in E U

APPLICATIONS

The Gain (K) can be any number used to scale an input signal to a meaningful or easy to work with output signal Figure 7-1 shows an example of how Function Code 7 can be used In this example, a flow rate of 0 to 50,000 lb/hr is being measured by a different pressure transducer whose output range is 0 to 200″ H_2O The flow is a function of the square root of the differential pressure multiplied by some constant (K) The equation for this is

$$\text{Flow} = K\sqrt{\text{diff press}}$$

Since it is known that the flow is 50,000 lb/hr at a transmitter output indicating 200″ H_2O differential pressure, the required constant (K) can be calculated as follows

$$50{,}000 \text{ lb/hr} = K\sqrt{200}$$
$$50{,}000 \text{ lb/hr} = K\,(14\,142)$$
$$\frac{50{,}000}{14\,142} = K$$
$$K = 3535\,534$$

This value for K would be entered for S2 to implement this function

FUNCTION CODE 7

Many inputs are calibrated on a 0 to 100 scale To ensure that outputs are also expressed in a linear 0 to 100 scale, a gain of 10 is commonly used

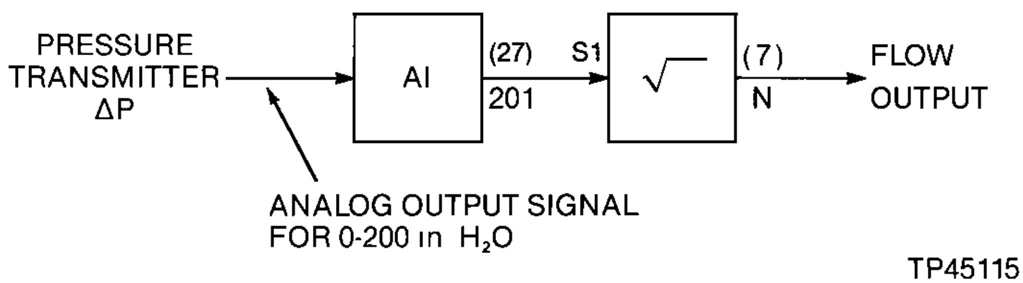


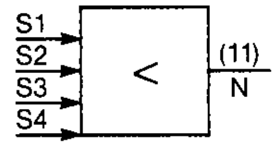
FIGURE 7-1 — Converting a Pressure Signal to a Flow Rate Using Function Code 7

FUNCTION CODE 11

LOW SELECT

GENERAL DESCRIPTION

This function selects and outputs the input with the lowest algebraic value



OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Output value equals the lowest of the four inputs

SPECIFICATIONS

SPEC NO.	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	9	INT(2)	0 to 255	Block address of 1st input
S2	NO	9	INT(2)	0 to 255	Block address of 2nd input
S3	NO	9	INT(2)	0 to 255	Block address of 3rd input
S4	NO	9	INT(2)	0 to 255	Block address of 4th input

APPLICATIONS

As well as selecting the lowest input value (common application) Function Code 11 can be used to memorize the lowest value over a period of time

To memorize the lowest value over a period of time, use Function Code 11 in conjunction with Function Code 9 This is shown in Figure 11-1 Create a loop with the output of Function Code 11 as an input to the Function Code 9 block and the output of Function Code 9 as an input to the Function Code 11 block By selecting the output of the block executing Function Code 11 as the value that Function Code 9 tracks, you can feed the output of Function Code 11 back into Function Code 11, thus yielding the same value as the output of Funtion Code 11 for the period of time that it is the input with the smallest algebraic value

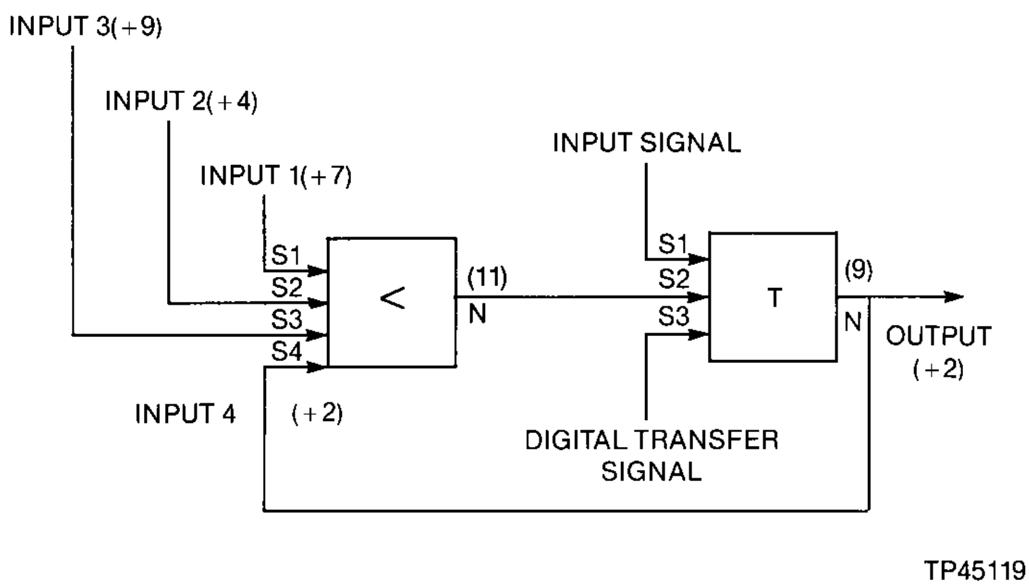
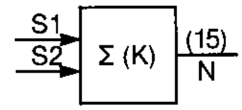


FIGURE 11-1 — Using Function Code 11 to Memorize a Low Value Over a Period of Time

2-INPUT SUMMER



GENERAL DESCRIPTION

This function performs a weighted sum of two inputs By choosing the proper gains and inputs this block can perform proportional, bias or difference functions
It can also be used as a scaler for a non-zero based signal by referencing the second input to a constant block
The operation of this function is described by the equation

$$\text{Output} = \langle S1 \rangle (S3) + \langle S2 \rangle (S4)$$

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Output value is the weighted algebraic sum of the two input signals

SPECIFICATIONS

SPEC NO	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	5	INT(2)	0 to 255	Block address of 1st input
S2	NO	5	INT(2)	0 to 255	Block address of 2nd input
S3	YES	1 000	REAL(2)/(3)	FULL	Gain parameter of input 1
S4	YES	1 000	REAL(2)/(3)	FULL	Gain parameter of input 2

APPLICATIONS

In addition to performing proportional, bias or difference functions, this code can also be used for scaling By referencing the second input to one of the constant blocks or to a Manual Set Constant block (Function Code 2), a non-zero based signal can be scaled

In the example shown in Figure 15-1 it is desired to scale an input with a range of 200 to 500 E U to give an output of 10 to 110 E U The S3 constant can be calculated using the equation

$$S3 = \frac{\text{Output Span}}{\langle S1 \rangle \text{Span}}$$

$$= \frac{110\text{-}10}{500 - 200} = 0\ 333$$

Fixed block 4 is entered for S2 to give it a constant value of -1 0 S2 could be set to any fixed value by using Function Code 2 but this approach requires more memory than using a fixed block Since S2 and S4 are both constants in this example, they can be considered as a unit The value for the product of <S2> and S4 is determined from the equation

<S2>(S4) = Output min – [<S1 min>(S3 min)]

In this example then

<S2>(S4) = 10 – [(200)(0 3333)] = –56 667

<S2> and S4 could be set to any allowable values that will give the product of –56 667 In our example, <S2> is set to –1 000 so S4 would be set to 56 667

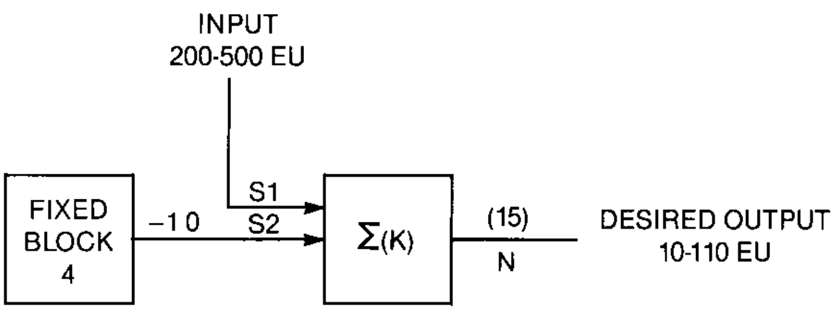


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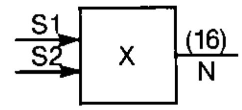
FIGURE 15-1 — Using Function Code 15 as a Scaler

FUNCTION CODE 16

MULTIPLY



GENERAL DESCRIPTION

This function performs a multiplication of <S1> by <S2> with the result multiplied by a constant S3

OUTPUT (EU) = (S3) × (<S1> × <S2>)

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Output value is the weighted product of the two input signals

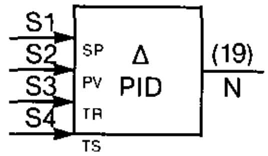
SPECIFICATIONS

SPEC. NO	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM	RANGE MAXIMUM	DESCRIPTION
S1	NO	6	INT(2)	0	255	Block address of 1st input
S2	NO	6	INT(2)	0	255	Block address of 2nd input
S3	YES	1 000	REAL(2)/(3)	FULL		Gain parameter

FUNCTION CODE 19

PID — PV and SP

GENERAL DESCRIPTION



This function provides proportional, integral and derivative action on an error developed from the PV (process variable) and SP (setpoint) inputs The block has four inputs and one output Besides the PV and SP inputs, there are also track reference and track switch input signals If the track switch specification <S4> is a logic 0, the output will follow the track reference signal specification <S3> This provides a means for making smooth control transfers when the output of the PID controller is not being used as the control signal (such as when the loop is in "manual") The parameters for the function block include an overall gain constant (S5), a proportional constant (S6), an integral constant (S7) and derivative gain constant (S8)

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Output is PID signal in percent

SPECIFICATIONS

SPEC. NO	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	5	INT	0 to 255	Block address of process variable input
S2	NO	5	INT	0 to 255	Block address of set point
S3	NO	5	INT	0 to 255	Block address of track reference signal
S4	NO	1	INT	0 to 255	Block address of track switch signal 0 = track 1 = release
S5	YES	1 000	REAL(2)/(3)	FULL	(K) Gain multiplier
S6	YES	1 000	REAL(2)/(3)	FULL	(KP) Proportional contant
S7	YES	0 000	REAL(2)/(3)	FULL	(KI) Integral constant (1/min)
S8	YES	0 000	REAL(2)/(3)	FULL	(KD) Derivative constant (min)
S9	YES	105 000	REAL(2)/(3)	FULL	High output limit
S10	YES	-5 000	REAL(2)/(3)	FULL	Low output limit
S11	YES	0	BOOLEAN	0 or 1	0 = normal 1 = integral only (KI NE 0) set point change
S12	YES	0	BOOLEAN	0 or 1	0 = reverse 1 = direct acting controller

EXPLANATION

This function operates in two modes — direct and reverse The function is put in the direct mode when S12 is a logic 1 and in the reverse mode when S12 is a logic 0 In the direct mode the setpoint <S2> is subtracted from the process variable input <S1> and the output is obtained according to the following equation

DIRECT MODE S12 = 1

$$\text{OUTPUT}(\%) = (\langle S1 \rangle - \langle S2 \rangle) \times [S5 \times (S6 + S7(I) + S8(D))]$$

where

<S1>	=	Value of the Process Variable Input
<S2>	=	Value of Set Point Input
S5	=	Value of Gain (K) multiplier
S6	=	Value of Proportional Constant (KP)
S7	=	Value of Integral Constant (KI) (1/min)
S8	=	Value of Derivative Constant (KD) (min)
S12	=	Controller mode identifier (direct or reverse)

In the reverse mode the process variable input <S1> is subtracted from the setpoint <S2> and the output is obtained according to the following equation

REVERSE MODE S12 = 0

$$\text{OUTPUT}(\%) = (\langle S2 \rangle - \langle S1 \rangle) \times [S5 \times (S6 + S7(I) + S8(D))]$$

The prime purpose of the main multiplier (S5) is to convert the difference signal (S1 − S2 or S2 − S1) from engineering units to a percentage so that the tuning constants (S6, S7, S8) can always be expressed in percentages If the difference signal is in % (0 to 100%) the possible range of the error signal is −100% to 100% The following equation is used to determine the gain multiplier (S5)

$$S5 = \frac{100}{\langle S1_{max} \rangle - \langle S1_{min} \rangle}$$

For example, with the function in the direct mode, if the range of the process variable signal is 0 to 200 cu ft/sec and the setpoint is 100 cu ft/sec, then S5 would be determined as follows

$$S5 = \frac{100}{\langle S1_{max} \rangle - \langle S1_{min} \rangle}$$

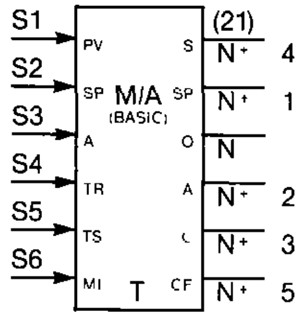
$$S5 = \frac{100}{(200 - 0)}$$

$$S5 = 5$$

FUNCTION CODE 21

M/A STATION (BASIC)

GENERAL DESCRIPTION



All three station functions (Basic, Cascade (Function Code 22), Ratio (Function Code 23)) provide an interface between the Controller module and the following interface devices the Digital Control Station (DCS), the Operator Interface Unit (OIU), the Management Command System (MCS), the Computer Interface Unit (CIU) and the faceplate on the Loop Command Controller

The Basic station generates a set point and provides Manual/Automatic transfers, Control Output adjustment in the Manual Mode, and set point adjustment in the Automatic Mode Specification S2 and S14 select the input the set point will track

Other options include a Control-Output-Override input (S5) and a Manual-Interlock input (S6)

The Control-Output-Overide is used to force the Control Output value to a particular state (e g , when the maintenance of a process safety requires immediate action)

The Manual-Interlock may be used to hold the station in Manual Mode, which allows conditional logic to be used to prevent automatic operations

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Control output (CO) in percent (%)
N + 1	REAL	Set point in engineering units (EU)
N + 2	BOOLEAN	Mode 0 = manual 1 = automatic
N + 3	BOOLEAN	Level 0 = local 1 = computer
N + 4	BOOLEAN	Always 0 for basic station
N + 5	BOOLEAN	Computer backup indicates computer time out 0 = no 1 = yes

SPECIFICATIONS

SPEC. NO	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	5	INT(1)	0 to 255	Block address of process variable input
S2	NO	5	INT(1)	0 to 255	Block address of set point track value
S3	NO	5	INT(1)	0 to 255	Block address of auto signal or input
S4	NO	5	INT(1)	0 to 255	Block address of control output track signal (TR)
S5	NO	0	INT(1)	0 to 255	Block address of track switch (TS) 0 = normal 1 = track
S6	NO	0	INT(1)	0 to 255	Block address of manual interlock 1 = manual
S7	YES	100 000*	REAL(2)	FULL	Process variable high alarm point
S8	YES	0 000*	REAL(2)	FULL	Process variable low alarm point
S9	YES	4 0 E 06*	REAL(2)	FULL	Process variable set point deviation alarm point
S10	NO	100 000	REAL(2)	FULL	Signal span of set point and process variable
S11	NO	0 000	REAL(2)	FULL	Zero value of process variable
S12	NO	0 000	REAL(2)	FULL	Zero value of set point
S13	NO	0	INT(1)	0 to 255	E U identifier (Note for OIU and MCS use only)
S14	YES	0	INT(1)	0 to 255	Set point track option 0 = no 1 = process variable 2 = S2/manual only 3 = S2/manual + auto
S15	NO	0	INT(1)	0 to 255	Computer timeout option 0 = computer auto/manual mode unchanged 1 = computer manual 2 = computer auto 3 = computer cascade/ratio 4 = local auto/manual mode unchanged 5 = local manual 6 = local auto 7 = local cascade/ratio
S16	NO	0	INT(1)	0 to 255	Digital control station address (>15 indicated no station)

* Not Adaptable

EXPLANATION

Specifications

S1 - PV - Block Number whose output is the process variable This input drives the Digital Station PV indicator (in Engineering Units)

S2 - SPT - Block Number whose output the set point is to track, depending on S14 (Track Setpoint)

S3 - COAUTO - Block Number whose output value is the Control Output when the station is in auto mode (usually the output of a PID block)

S4 - COTRCK - Block number whose output is used as the Control Output when the station is tracking (Control Output Override Mode) and also as the initial value for the Control Output on start-up

S5 - COFLG - Block Number whose output value determines whether the Control Output is to be tracked If the output of the block is
0 = No Tracking (normal)
1 = Track output of block specified by S4

S6 - REMLOCK - Block Number whose output value determines whether the station is locked in manual mode
0 = No
1 = Yes

NOTE Specifications S7, S8 and S9 are tunable but not adaptable

S7 - PVH - Engineering Units (EU) value of PV at which a high alarm will be generated (displayed on the faceplate)

S8 - PVL - EU value at which a low alarm will be generated and displayed on the faceplate

S9 - PVDEV - EU value of allowed deviation between PV and SP A high deviation alarm is generated when the PV is greater than the SP and the value of the difference between the two is greater than or equal to this specification A low deviation alarm generated when the PV is less than the SP and the value of the difference between the two is greater than or equal to this specification These two alarm conditions are reported to the OIU and MCS only

S10 - EUSPAN - Value corresponding to EU span for PV and SP

S11 - EUPVZ - Value corresponding to EU zero percent for PV

S12 - EUSPZ - Value corresponding to EU zero percent for SP

S13 - EUID - Engineering units type

NOTE This data is used with OIU and MCS only

S14 - TRCKSP - Value that determined which input the set point will track in Manual mode Selecting 3 causes set point tracking in both Manual and Auto modes
0 = No Tracking
1 = Track PV (S1)
2 = Track SP (S2)
3 = Track S2 always (Auto & Manual)

S15 - COMPDEF - Value that determines the system default mode if the computer times out while the loop is under computer control
0 - computer auto/manual mode unchanged
1 - computer manual
2 - computer auto
3 - computer cascade/ratio (unused in Function Code 21)
4 - local auto/manual mode unchanged
5 - local manual
6 - local auto
7 - local cascade/ratio (unused in Function Code 21)

S16 - DIGSTAAD - Value of the hardware digital station address that the station function block is representing A number greater than 15 indicates no hardware station

STATION OUTPUT EXAMPLE

A user has assigned block number 30 to a standard station The system then assigns the next five block numbers as listed below If the user needs to assign more block numbers after the station block, he must add 6 to the station's block number to obtain the next available block number

BLOCK NO.	STATION OUTPUT
30	CO
31	SP
32	MODE
33	LEVEL
34	STATION MODE
35	COMPUTER BACKUP
36	NEXT AVAILABLE

In this manner, the user may specify each output of a station block by a unique reference number

Control Output Tracking

When the Control Output Track state (S5) is 1, it does not affect the output designation of the block but will override the current Control Output with the value in the block specified by S4 The actual operating state is saved, and will be restored when the track flag input goes to 0

While the station is under Local Manual control, the output is expressed as a percentage from 0 to 100 percent If the input to the station is a calculation function, the input value must be scaled to percent, and the output of the station scaled to the required value, external to the station

When the Manual Interlock state (S6) is 1, the station is tripped to the Manual mode

Set Point Tracking

The set point may be adjusted from the faceplate only if set point tracking is not selected (0 for S14) If one of the tracking options is selected, the set point will be determined by the option chosen

EXAMPLES

S2 - Number of block containing output the set point is to track in Manual mode

S14 - Set Point Track Option
0 - No tracking
1 - Track PV (S1) when station is in manual
2 - Track value in block selected in S2 in Manual mode only
3 - Track Value in block selected in S2 always (Auto and Manual)
No direct control of set point from station

If S14=0 - The set point can be varied using local manual control

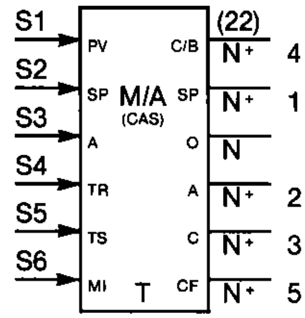
If S14=1 - The set point will track the PV when the station is in Manual This provides bumpless transfer with the station is returned to Automatic mode The set point cannot be varied manually in this mode

If S2=Blk # and S14=2 - The set point will track the value in the block specified in S2 when the station is in Manual Set point may be changed when the station is returned to Automatic mode — bump in the set point value is possible when transferred to manual

If S2=Blk # and S14=3 - The set point will track the value in the block specified in S2 when the station is in either Automatic or Manual mode No direct set point adjustments can be made from the station

FUNCTION CODE 22

M/A STATION (CASCADE)



GENERAL DESCRIPTION

The Cascade station provides all of the basic functions plus an additional mode that allows the set point to be controlled by another function block When the station is in Cascade mode, the value found in the block specified by S2 will be the set point In the Basic (non-cascade) mode, the set point signal is equal to the value set by the operator

Other options include a Control-Output-Override input (S5) and a Manual-Interlock input (S6)

The Control-Output-Override is used to force the Control Output value to a particular state (e g , when the maintenance of process safety requires immediate action)

The Manual-Interlock may be used to hold the station in Manual Mode, which allows conditional logic to be used to prevent automatic operations

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Control output (CO) in percent (%)
N + 1	REAL	Set point in engineering units (EU)
N + 2	BOOLEAN	Mode 0 = manual 1 = automatic
N + 3	BOOLEAN	Level 0 = local 1 = computer
N + 4	BOOLEAN	Station Mode 0 = Basic, 1 = Cascade
N + 5	BOOLEAN	Computer backup indicates computer time out 0 = no 1 = yes

FUNCTION CODE 22

SPECIFICATIONS

SPEC. NO	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	5	INT(1)	0 to 255	Block address of process variable
S2	NO	5	INT(1)	0 to 255	Block address of set point track value
S3	NO	5	INT(1)	0 to 255	Block address of auto signal or input
S4	NO	5	INT(1)	0 to 255	Block address of control output track signal (TR)
S5	NO	0	INT(1)	0 to 255	Block address of track switch (TS) 0 = normal 1 = track
S6	NO	0	INT(1)	0 to 255	Block address of manual interlock 1 = manual
S7	YES*	100 000	REAL(2)	FULL	Process variable high alarm point
S8	YES*	0 000	REAL(2)	FULL	Process variable low alarm point
S9	YES*	4 0 E 06	REAL(2)	FULL	Process variable set point deviation alarm point
S10	NO	100 000	REAL(2)	FULL	Signal span of set point and process variable
S11	NO	0 000	REAL(2)	FULL	Zero value of process variable
S12	NO	0 000	REAL(2)	FULL	Zero value of set point
S13	NO	0	INT(1)	0 to 255	E U identifier (Note for OIU and MCS use only)
S14	YES	0	INT(1)	0 to 255	Set point track option 0 = no 1 = process variable 2 = S2/manual only 3 = S2/manual + auto
S15	NO	0	INT(1)	0 to 255	Computer timeout option 0 = computer auto/manual mode unchanged 1 = computer manual 2 = computer auto 3 = computer cascade/ratio 4 = local auto/manual mode unchanged 5 = local manual 6 = local auto 7 = local cascade/ratio
S16	NO	0	INT(1)	0 to 255	Digital control station address (>15 indicated no station)

* Not Adaptable

EXPLANATION

Specifications

S1 - PV - Block Number whose output is the process variable (Engineering Units) This input drives the Digital Station PV indicator

S2 - CASCADE - Block address of Cascade input The output of this block is the set point when the station is in Cascade mode

S3 - COAUTO - Block Number whose output value is the Control Output when the station is in auto mode (usually the output of a PID block)

S4 - COTRCK - Block Number whose output is used as the Control Output when the station is tracking (Control Output Override Mode) and also as the initial value for the Control Output on start-up

S5 - COFLG - Block Number whose output value determines whether the Control Output is to be tracked

0 = No
1 = Yes

S6 - REMLOCK - Block Number whose output value determines whether the station is locked in manual mode
0 = No
1 = Yes

NOTE Specifications S7, S8 and S9 are tunable but not adaptable

S7 - PVH - Engineering Units (EU) value of PV at which a high alarm will be generated (displayed on the faceplate and/or OIU or MCS)

S8 - PVL - EU value of PV at which a low alarm will be generated

S9 - PVDEV - EU value of allowed deviation between PV and SP A high deviation alarm is generated when the PV is greater than the SP and the value of the difference between the two is greater than or equal to this specification A low deviation alarm generated when the PV is less than the SP and the value of the difference between the two is greater than or equal to this specification These two alarm conditions are reported to the OIU and MCS only

S10 - EUSPAN - Value corresponding to EU span for PV and SP

S11 - EUPVZ - Value corresponding to EU zero percent for PV

S12 - EUSPZ - Value corresponding to EU zero percent for SP

S13 - EUIDENT - Engineering units type

NOTE This data is used with OIU and MCS only

S14 - TRCKSP - Value that determines which input the set point will track in Manual mode Selecting 3 causes set point tracking in both Manual and Auto modes
0 = No Tracking
1 = Track PV (S1)
2 = Track CASCADE (S2)
3 = Track S2 always (Auto & Manual)

S15 - COMPDEF - Value that determines the system default mode if the computer times out while the loop is under computer control
0 - computer (auto/manual mode unchanged)
1 - computer manual
2 - computer auto
3 - computer cascade
4 - local (auto/manual mode unchanged)
5 - local manual
6 - local auto
7 - local cascade

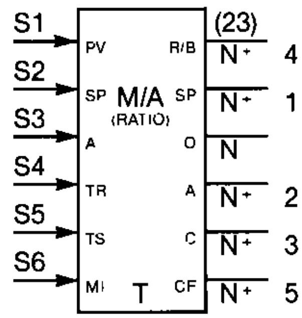
S16 - DIGSTAAD - Value of the hardware digital station address that the station function block is representing A number greater than 15 indicates no Hardware Station

FUNCTION CODE 23

M/A STATION (RATIO)

GENERAL DESCRIPTION

The Ratio station provides Manual/Automatic transfers, Control Output adjustment in the Manual mode, and set point adjustment in the Automatic mode It differs from the Basic and Cascade stations in its method of set point generation A ratio adjustment is provided to control the measured variable in a ratio (R) to a second uncontrolled (wild) variable (S2) A Ratio/Basic switch provides the ability to operate as a set point station in the Basic position Specifications S2 and S14 select the input the set point will track in the Manual Basic mode In the Basic (non-ratio) mode, the set point signal is equal to the value set by the operator



NOTE The maximum ratio is 10, the minimum practical ratio is 0 05

Other options include a Control-Output-Override input (S5) and a Manual-Interlock input (S6)

The Control-Output-Override is used to force the Control Output value to a particular state (e g , when the maintenance of process safety requires immediate action)

The Manual-Interlock may be used to hold the station in Manual Mode, which allows conditional logic to be used to prevent automatic operations

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Control output (CO) in percent (%)
N + 1	REAL	Set point in engineering units (EU)
N + 2	BOOLEAN	Mode 0 = manual 1 = automatic
N + 3	BOOLEAN	Level 0 = local 1 = computer
N + 4	BOOLEAN	Station Mode 0 = Basic, 1 = Ratio
N + 5	BOOLEAN	Computer backup indicates computer time out 0 = no 1 = yes

SPECIFICATIONS

SPEC. NO.	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	5	INT(1)	0 to 255	Block address of process variable
S2	NO	5	INT(1)	0 to 255	Block address of set point track value
S3	NO	5	INT(1)	0 to 255	Block address of auto signal or input
S4	NO	5	INT(1)	0 to 255	Block address of control output track signal (TR)
S5	NO	0	INT(1)	0 to 255	Block address of track switch (TS) 0 = normal 1 = track
S6	NO	0	INT(1)	0 to 255	Block address of manual interlock 1 = manual
S7	YES*	100 000	REAL(2)	FULL	Process variable high alarm point
S8	YES*	0 000	REAL(2)	FULL	Process variable low alarm point
S9	YES*	4 0 E 06	REAL(2)	FULL	Process variable set point deviation alarm point
S10	NO	100 000	REAL(2)	FULL	Signal span of set point and process variable
S11	NO	0 000	REAL(2)	FULL	Zero value of process variable
S12	NO	0 000	REAL(2)	FULL	Zero value of set point
S13	NO	0	INT(1)	0 to 255	E U identifier (Note for OIU and MCS use only)
S14	YES	0	INT(1)	0 to 255	Set point track option 0 = no 1 = process variable 2 = S2/manual only 3 = S2/manual + auto
S15	NO	0	INT(1)	0 to 255	Computer timeout option 0 = computer auto/manual mode unchanged 1 = computer manual 2 = computer auto 3 = computer cascade/ratio 4 = local auto/manual mode unchanged 5 = local manual 6 = local auto 7 = local cascade/ratio
S16	NO	0	INT(1)	0 to 255	Digital control station address (>15 indicated no station)

* Not Adaptable

EXPLANATION

Specifications

S1 - PV - Block Number whose output is the process variable This input drives the Digital Station PV indicator (in Engineering Units)

S2 - WILD - Block address of uncontrolled input A multiple of the output of this block is the set point when the station is in Ratio mode

S3 - COAUTO - Block Number whose output value is the Control Output when the station is in auto mode (usually the output of a PID block)

S4 - COTRCK - Block Number whose output is used as the Control Output when the station is tracking (Control Output Override Mode) and also as the initial value for the Control Output on start-up

S5 - COFLG - Block Number whose output value determines whether the Control Output is to be tracked
0 = No
1 = Yes

S6 - REMLOCK - Block Number of the Remote Interlock which determines whether the station is locked in manual mode
0 = No
1 = Yes

NOTE Specifications S7, S8 and S9 are tunable but not adaptable

S7 - PVH - Engineering Units (EU) value of PV at which a high alarm will be generated (displayed on the faceplate and/or OIU or MCS)

S8 - PVL - EU value of PV at which a low alarm will be generated

S9 - PVDEV - EU value of allowed deviation between PV and SP A high deviation alarm is generated when the PV is greater than the SP and the value of the difference between the two is greater than or equal to this specification A low deviation alarm generated when the PV is less than the SP and the value of the difference between the two is greater than or equal to this specification These two alarm conditions are reported to the OIU and MCS only

S10 - EUSPAN - Value corresponding to EU span for PV and SP

S11 - EUPVZ - Value corresponding to EU zero percent for PV

S12 - EUSPZ - Value corresponding to EU zero percent for SP

S13 - EUIDENT - Engineering units type

NOTE This data is used with OIU and MCS only

S14 - TRCKSP - Value that determines which input the set point will track in Manual mode Selecting 3 causes set point tracking in both Manual and Auto modes
0 = No Tracking
1 = Track PV (S1)
2 = Track WILD (S2)
3 = Track S2 always (Auto & Manual)

S15 - COMPDEF - Value that determines the system default mode if the computer times out while the loop is under computer control
0 - computer (auto/manual mode unchanged)
1 - computer manual
2 - computer auto
3 - computer ratio
4 - local (auto/manual mode unchanged)
5 - local manual
6 - local auto
7 - local ratio

S16 - DIGSTAAD - Value of the hardware digital station address that the station function block is representing A number greater than 15 indicates no Hardware Station

FUNCTION CODE 24

ADAPT

GENERAL DESCRIPTION

This function allows the adaptation of any tunable parameter in the system (Tunable parameters may be modified during execution) It is used to compensate for known dynamic loop gains in control schemes All gains and time constants are tunable parameters, therefore, using this function, you can set gains and time constants to fit current process operating states

The function block output value has no significance The specification is modified only during execution, and the original parameter that is stored in NVRAM is not modified Thus, the revised specification is not accessible via any of the operator interface devices unless the ADAPT input is read (Block inputs are read by reading the output of the block preceding the block of interest)

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N		See description

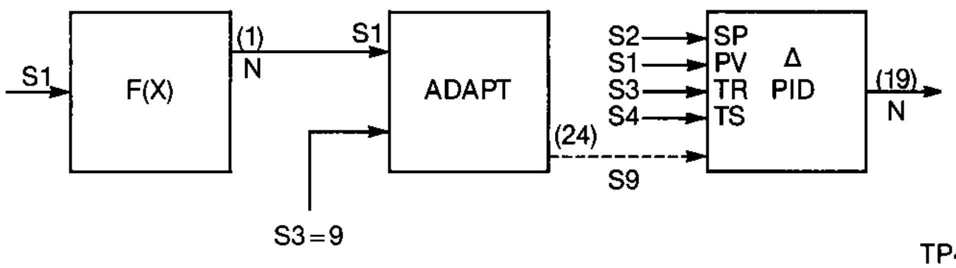
SPECIFICATIONS

SPEC. NO.	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	0	INT(1)	0 to 255	Block address of input
S2	NO	0	INT(1)	0 to 255	Address of Block containing spec to be adapted
S3	NO	0	INT(1)	0 to 255	Spec number of spec to be adapted

APPLICATIONS

Figures 24-1 and 24-2 show the input to an ADAPT block as the result of a function defined by Function Code 1 If the function varies with time, the adapted parameter also varies with time The same is true for functions of pressure, temperature, tank level, etc This arrangement makes variable control of tunable parameters possible, allowing the user to compensate for gains inherent in a process

In Figure 24-1, the High output limit (S9) of a Function Code 19 block varies as a function of x as defined in a Function Code 1 block



TP45132

FIGURE 24-1 — Creation of a Sliding Limiter or Index With Function Code 24

In 24-2 an ADAPT block adapts the proportional constant (S6) of a Function Code 19 block to the value received from a Function Code 1 block, allowing the user to modify gain with changes in a specified parameter, x

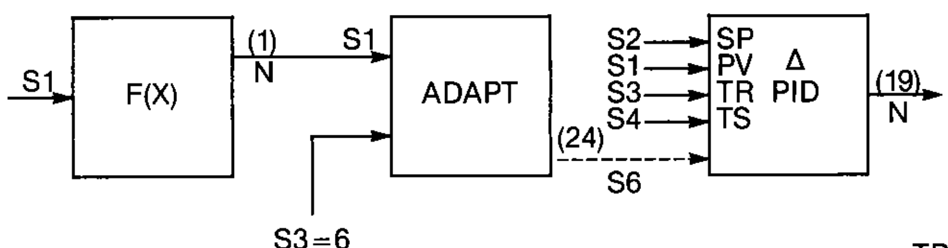


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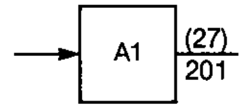
FIGURE 24-2 — Function Code 24 Used to Achieve Variable Controller Gain

ANALOG INPUT



GENERAL DESCRIPTION

The ANALOG INPUT Function Code is used to acquire analog inputs from the termination unit for the Loop Command This function acts ONLY on Loop Command fixed inputs Analog input 1 will always be found in block 201, analog input 2 in block 202, etc To obtain this function, specify a fixed analog input block number (201-204) Zero and span values, expressed in engineering units, are defined by the specifications If a span in 0 0, the input is defined as unused Fixed blocks can be modified with the Configuration and Tuning Module (CTM), Configuration and Tuning Terminal (CTT), the Operator interface units (OIU) or the Management Command System (MCS)

A Point Quality flag is generated based on the analog signal To test the quality of the signal, include a Function Code 31 (TEST QUALITY) block in your configuration The quality of the point cannot be used as an input to any other type of block The analog output value can be used as an input to any analog processing block

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
201	REAL	CLC fixed input AI #1 and Quality
202	REAL	CLC fixed input AI #2 and Quality
203	REAL	CLC fixed input AI #3 and Quality
204	REAL	CLC fixed input AI #4 and Quality

SPECIFICATIONS

SPEC. NO.	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM	RANGE MAXIMUM	DESCRIPTION
S1	NO	0 000	REAL(2)	FULL		Signal zero in E U
S2	NO	0 000	REAL(2)	FULL		Signal span in E U

FUNCTION CODE 27

EXPLANATION

Figure 27-1 shows the use of a Function Code 31 block to test the quality of the output from the Function Code 27 block

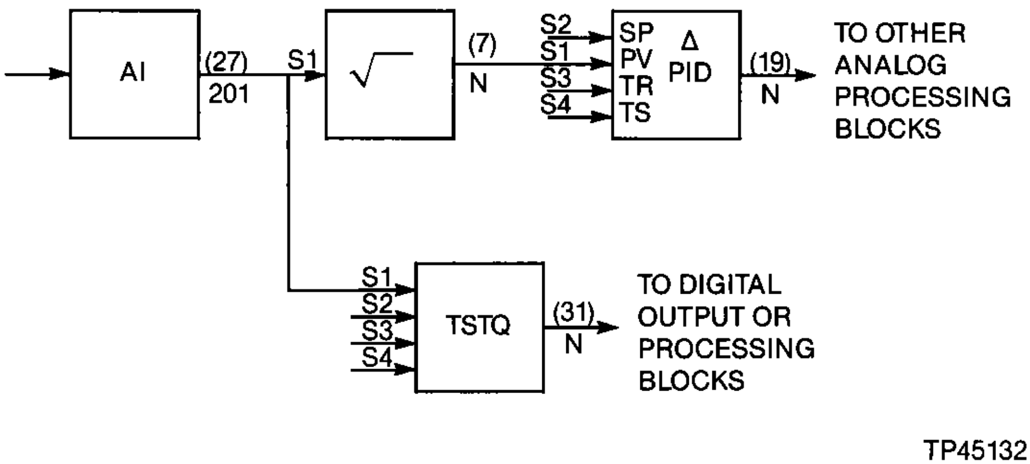


FIGURE 27-1 — Configuration Required to Test Point Quality

ANALOG EXCEPTION REPORT

GENERAL DESCRIPTION

The ANALOG EXCEPTION REPORT Function Code causes the input value to be sent on the plant loop if the time limit and/or significant change is exceeded This function also generates an alarm if the high or low limit values are exceeded

This function does not perform any conversion of input S3 and S4 (zero and span of input) are used internally for limits, and significant change is used for reporting to other Process Control Units or Operator Interface Devices The engineering units parameters are used only for reporting to these higher level devices

A Boolean point quality flag is generated based on the analog signal To test the quality of the signal, you must include a Function Code 31 (TEST QUALITY) block in your configuration You can also propagate quality if the input is from Function Code 137 (BASIC REAL OUTPUT) The quality of the point cannot be used as an input to any other type of block

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Analog Output Value and Quality Quality 0 = good, 1 = bad

SPECIFICATIONS

SPEC. NO.	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	0	INT(2)	0 to 255	Block address of input
S2	NO	0 000	INT(2)	0 to 255	Engineering unit identifier
S3	NO	0 000	REAL(2)/(3)	FULL	Zero of S1 input in E U
S4	NO	100	REAL(2)/(3)	FULL	Span of S1 input in E U
S5	YES	100	REAL(2)/(3)	FULL	High alarm point limit value
S6	YES	0 000	REAL(2)/(3)	FULL	Low alarm point limit value
S7	NO	1 000	REAL(2)/(3)	FULL	Significant change (% of span)

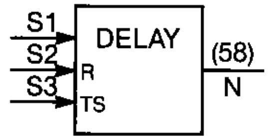
All alarm limits are tunable, but not adaptable

FUNCTION CODE 58

TIME DELAY (ANALOG)

GENERAL DESCRIPTION

The TIME DELAY Function Code provides a pure delay on an analog signal This function can be used to create fixed to variable time delays, or to model systems to represent dynamic time delays



OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Time delayed function of input

SPECIFICATIONS

SPEC. NO.	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	0	INT(2)	0 to 255	Block address of input (X)
S2	NO	6	INT(2)	0 to 255	Block address of rate input (R, in units/sec)
S3	NO	1	INT(2)	0 to 255	Block address of track switch signal 0 = track 1 = release
S4	NO	0 000	REAL(2)/(3)	FULL	Length of queue (L, in units)
S5	NO	1 000	INT(1)	0 to 255	Number of intervals (N)

EXPLANATION

Specifications

S1 <X> - Block address of input

S2 <R> - Block address of rate input in units per second

S3 <T> - Block address of track switch signal
<S3> = 0, track input, <S3> = 1, release
When <S3> = 0, it initializes all N elements of the memory to the input value

Then $M_1 = M_2 = \quad M_N =$ <S1>, and elapsed time since the last sample = 0
There is no time delay

If <S3> = 1, then

$$\text{Time delay} = \frac{S4}{\langle S2 \rangle}$$

$$\text{Timing interval (TI)} = \frac{\text{Time Delay}}{S5}$$

Elapsed Time = ET + t

where	ET	=	time since last sample in seconds
	t	=	time since last algorithm execution in seconds
	TI	=	internal input sample in seconds
	M_i	=	Memory locations where input values are stored during time delay

If ET $\geq$ TI
then, $M_i = M_{i+1}$, for i = 0 to N.
M_N = output value, and M_1 = <S1>
Elapsed time = ET − TI

S4 L - Length of the queue in units, The queue is the number of units over which the time delay is to be effective.

S5 N - Number of Intervals — Number of times from one to 190, that the input is to be sampled. N is determined by dividing the time delay (TD) by the desired sampling frequency. See the Fixed Time Delay example.

APPLICATIONS

Fixed Time Delay

For a fixed time delay, the rate input, <S2>, is constant. The time delay between output and input varies only with S4. It is directly proportional to S4. Assume you wish to simulate the time delay for flow through a pipe. Assume a required time delay of two minutes with input sampling desired every five seconds. Select the default value of 1.0 (found in Fixed Block 6) for S2 since rate is constant for fixed delays.

<S2>	=	Rate in units per second = 1.0
S4	=	Length of the queue in units
S5	=	Number of intervals
Time Delay	=	2 minutes = 120 seconds
TD	=	120 seconds

$$TD = \frac{S4}{<S2>}$$

$$120 = \frac{S4}{1.0}$$

S4 = 120 units = Length of queue

For input sampling every five seconds

$$N = \frac{TD}{5\ sec}$$

$$= \frac{120\ sec}{5\ sec}$$

= 24 intervals

Variable Time Delay

Variable time delays may be dynamically adjusted by changing the value of S2 Using a Function Code 9 block, as illustrated in Figure 58-2, the user can switch between two fixed input rates In the fixed time delay example, when <S2> = 1 0, the time delay, S4/<S2> = 120 seconds If <S2> is changed to 2 0, then the time delay becomes 60 seconds, and the timing interval, TD/N = 2 5 seconds Changing the rate input <S2> while holding all other parameters constant changes the timing interval Faster rates produce more frequent input sampling, and slower rates produce less frequent input sampling for the same number of intervals

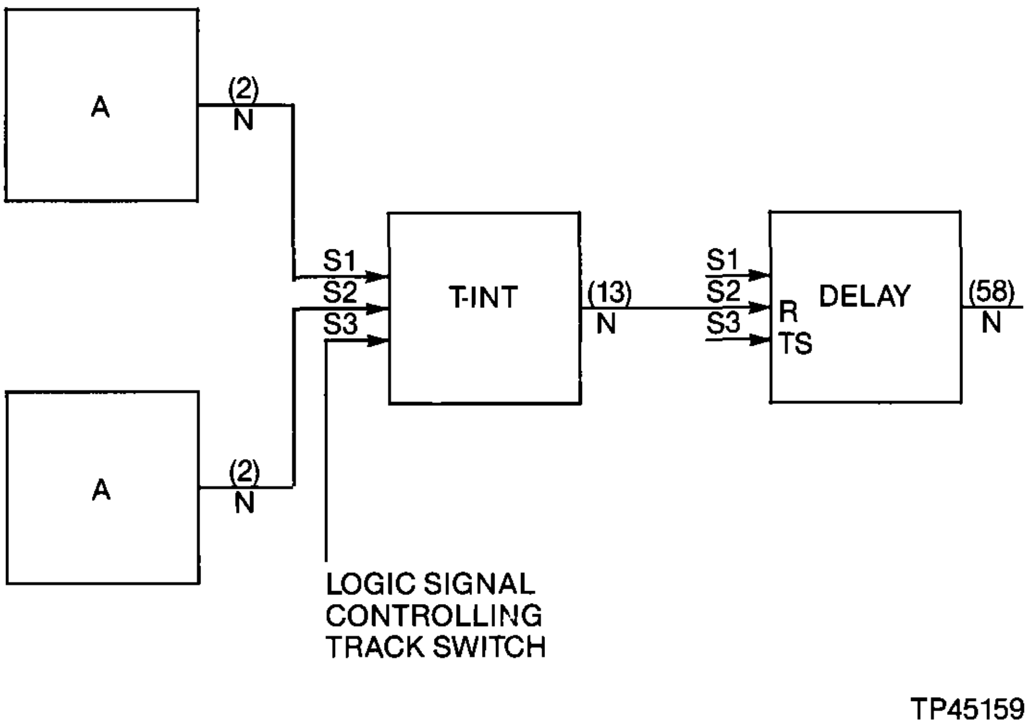
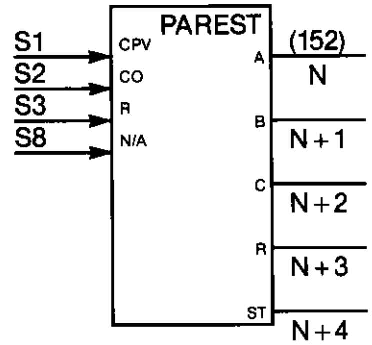


FIGURE 58-2 — Function Code 58 Used for Variable Time Delay

MODEL PARAMETER ESTIMATOR

GENERAL DESCRIPTION



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The Model Parameter Estimator function block uses a recursive least-squares algorithm to identify a mathematical model of a process This function block calculates the parameters for a linear, first-order dynamic model with deadtime of the specific form

$$Y(t) = a * y(t-1) + b * u(t-k) + c$$

This function continuously monitors the value of the controlled process variable and the control output The value of the model parameters is calculated whenever the process behavior deviates significantly from the established parameters The Model Parameter Estimator outputs the value of the calculated process model parameters, the statistical residual between the actual data and the calculated model and an indication of the paramters estimate quality

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Model Parameter A
N + 1	REAL	Model Parameter B
N + 2	REAL	Model Parameter C
N + 3	REAL	Residual
N + 4	BOOLEAN	Quality of Model Parameter Estimates (0 = Good, 1 = Bad)

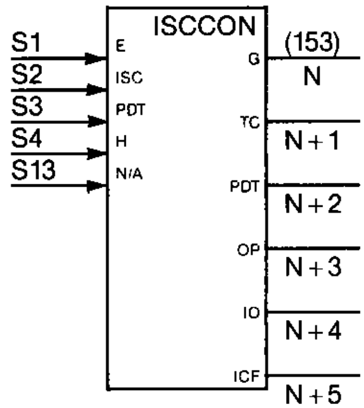
SPECIFICATIONS

SPEC. NO.	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	5	INT(2)	0 to 255	Block address of controlled process variable
S2	NO	5	INT(2)	0 to 255	Block address of control output
S3	NO	0	INT(2)	0 to 255	Block address of Reset Trigger (Resets on 0 to 1 transition)
S4	YES	0 25	REAL(3)	0 25 to 9 2E18	Sample Time (seconds)
S5	YES	1 0	REAL(3)	0 25 to 9 2E18	Process Deadtime (seconds)
S6	YES	0 0	REAL(3)	0 0 to 9 2E18	Expected noise level in process variable (peak-to-peak)
S7	YES	0 0	REAL(3)	FULL	Spare real parameter
S8	NO	0	INT(2)	0 to 9998	Spare boolean input

FUNCTION CODE 153

ISC PARAMETER CONVERTER

GENERAL DESCRIPTION



The ISC Parameter Converter function block calculates optimal tuning parameters for the associated Inferential Smith Controller (ISC) using the outputs of the Model Parameter Estimator The tuning values are the process gain, process deadtime and process lag time These outputs describe process dynamics at one operating point

Through a direct link with the ISC, the tuning parameters may be directly adapted, however, they will only be adapted when

1 The appropriate adapt option is selected in S9

and

2 The quality output of the associated Model Parameter Estimator (FC 152) is good (zero)

The ISC Parameter Converter also supervises an automated initialization routine for establishing initial estimated for the associated ISC and Model Parameter Estimator After completion of initialization, the Converter tunes

- the ISC deadtime, gain and lag time
- the ISC tuning time constant
- the Minimum and Maximum Process Gain for the Converter (FC 153)
- the Minimum and Maximum Process Lag Time for the Converter
- the Sample Time and Expected Noise Level for the Model Parameter Estimator (FC 152)

The ISC Parameter Converter also updates the estimated process deadtime for the associated ISC and Model Parameter Estimator whenever input S3 is connected to a function block other than number 5, and the initialization trigger equals zero If the above is not true, the ISC Parameter Converter updates the Model Parameter Estimator with the value being used by the ISC

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Estimated Process Gain
N + 1	REAL	Estimated Process Time Constant
N + 2	REAL	Adjusted Process Deadtime
N + 3	REAL	Estimated Process Operating Point
N + 4	REAL	Initialization Output 0 = initialization complete/not in progress 1 = initialization failed 2 = initialization in progress
N + 5	BOOLEAN	Initialization complete flag pulsed to one after completion of automated intialization routine, then to zero after five cycles

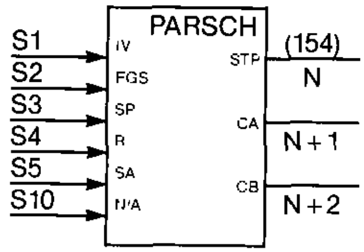
SPECIFICATIONS

SPEC. NO.	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	5	INT(2)	0 to 9998	Block address of associated Model Parameter Estimator
S2	NO	5	INT(2)	0 to 9998	Block address of associated ISC
S3	NO	5	INT(2)	0 to 9998	Block address for deadtime
S4	NO	0	INT(2)	0 to 9998	Block address of hold signal
S5	YES	-9 2E18	REAL(3)	FULL	Minimum allowable value for process gain
S6	YES	9 2E18	REAL(3)	FULL	Maximum allowable value for process gain
S7	YES	0 0	REAL(3)	0 0 to 9 2E18	Minimum allowable value for process lag time
S8	YES	9 2E18	REAL(3)	0 0 to 9 2E18	Maximum allowable value for process lag time
S9	NO	0	INT(2)	0 to 3	Adapt Option 0 = no adapt 1 = adapt process gain only 2 = adapt lag time only 3 = adapt both process gain and lag time
S10	YES	0	INT(1)	0 to 1	Initialization trigger (on 0 to 1 transition)
S11	YES	5 0	REAL(3)	FULL	Maximum control output change for initialization
S12	YES	0 0	REAL(3)	FULL	Spare real parameter
S13	NO	0	INT(2)	0 to 9998	Spare boolean input

FUNCTION CODE 154

ADAPTIVE PARAMETER SCHEDULER

GENERAL DESCRIPTION



The Adaptive Parameter Scheduler function allows process characteristics such as a measured or calculated index variable to be used to adjust the tuning parameters for the associated Inferential Smith Controller (ISC) (FC 160) This feature optimizes controller performance for predictable changes in process operation and prevents periods of potentially unacceptable control while the ISC is being retuned by the Model Parameter Estimator via the ISC Parameter Converter

The Adaptive Parameter Scheduler can be used to automatically establish the relationship between an ISC tuning parameter and a measured or calculated index variable using linear regression The Adaptive Parameter Scheduler uses this relationship to automatically adjust the specified ISC tuning parameter based on the value of the specified index variable

Alternatively, this function can be used to automatically determine the correction bias required for a pre-established gain schedule This permits a nonlinear relationship to be established between the ISC tuning parameter and the index variable, with automatic correction of the relationship for design inaccuracies and/or changes in process behavior

OUTPUTS

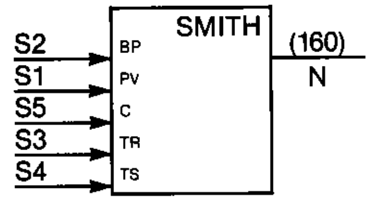
BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Scheduled Tuning Parameter
N + 1	REAL	Coefficient A of Correction Equation
N + 2	REAL	Coefficient B of Correction Equation

SPECIFICATIONS

SPEC. NO	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	5	INT(2)	0 to 9998	Block address of index variable
S2	NO	5	INT(2)	0 to 9998	Block address of fixed gain schedule
S3	NO	5	INT(2)	0 to 9998	Block address of scheduled parameter
S4	NO	0	INT(2)	0 to 9998	Block address of reset trigger
S5	NO	5	INT(2)	0 to 9998	Block address of spec to be adapted
S6	NO	0	INT(1)	0 to 255	Spec to be adapted
S7	NO	0 0	REAL(3)	FULL	Minimum index value
S8	NO	0 0	REAL(3)	FULL	Maximum index value
S9	NO	0	INT(2)	0 to 9998	Block address of Hold/Update Coefficient Flag 0 = Update A, B 1 = Hold Update of A, B
S10	NO	5	INT(2)	0 to 9998	Spare real input

FUNCTION CODE 160

SMITH PREDICTOR



GENERAL DESCRIPTION

The SMITH PREDICTOR Function Code provides predictive process control on an error signal developed for the process variable and set point inputs measured against an internal model of the process It is used for processes that are difficult to control with a PID controller because of long process dead times The output is limited by operator specified high and low limits, and the block can be forced to follow an external value

OUTPUTS

BLOCK NUMBER	DATA TYPE	DESCRIPTION
N	REAL	Predictive control value

SPECIFICATIONS

SPEC. NO	TUNE	DEFAULT VALUE	DATA TYPE	RANGE MINIMUM MAXIMUM	DESCRIPTION
S1	NO	0	INT	0 to 255	Block address of process variable
S2	NO	0	INT	0 to 255	Block address of set point
S3	NO	5	INT	0 to 255	Block address of track reference value
S4	NO	0	INT	0 to 255	Block address of track reference flag 0 = track 1 = release
S5	NO	5	INT	0 to 255	Block address of external reference value (cascade)
S6	NO	0	BOOLEAN	0 or 1	Use external reference flag 0 = Normal 1 = use
S7	YES	1 000	REAL(3)	FULL	Process gain
S8	YES	0 000	REAL(3)	0 0 to 9 2 E 18	Process dead time (seconds)
S9	YES	0 000	REAL(3)	0 0 to 9 2 E 18	Process lag time constant (seconds)
S10	YES	0 000	REAL(3)	FULL	Process tuning time constant
S11	YES	100 000	REAL(3)	FULL	Output high limit
S12	YES	0 000	REAL(3)	FULL	Output low limit

FUNCTION CODE 160

EXPLANATION

A SMITH PREDICTOR is used to control processes that have long time delays For example, assume a control system is to maintain a certain property at the end of a 1000 foot paper machine by adjusting its inlet composition There will be a delay between a control action being taken and the result of that action being measured at the end of the machine because the system has no way of waiting through the deadtime to determine the effect the control action had on the process This causes problems for PID controllers, since they have no way of waiting 20 seconds, or four minutes, or whatever the delay may be, to see if the control action they took was correct Sluggish tuning is required on this type of process

The functionality of the inferential SMITH PREDICTOR block is shown in the block diagram of Figure 160-1 The block compares the process value (PV) to the model value (MV) from the internal model The controller responds to set point changes and differences between the PV and MV The filter time constant allows the user to adjust the speed of response, the smaller the time constant, the quicker the time response

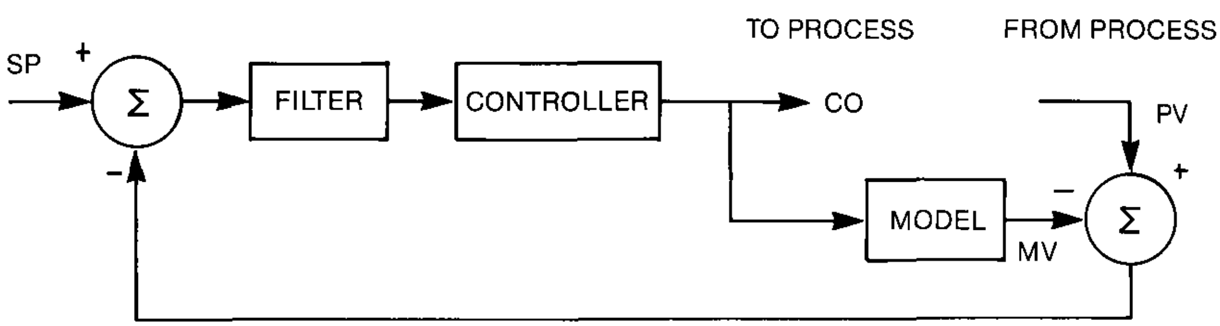


FIGURE 160-1 — Functionality of the SMITH PREDICTOR Function Block

In order to determine the specifications for the model, a simple step response test can be performed Figure 160-2 illustrates the procedure for finding the model parameters

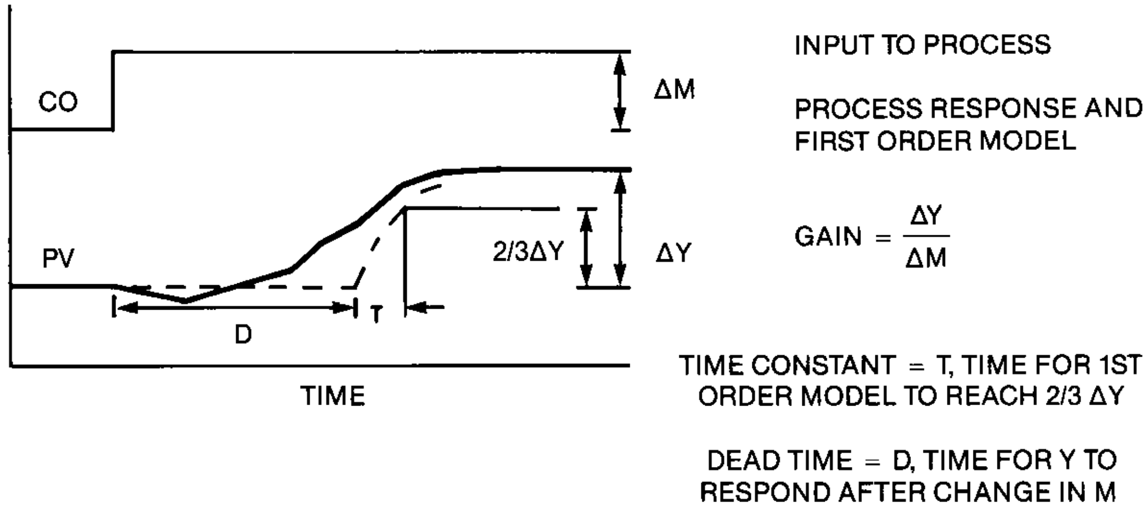


FIGURE 160-2 — Determining Model Parameters From a Step Input

Several step responses should be obtained from the process If the model parameters are consistent, the filter time constant may be made small A very fast response would be obtained by setting the filter constant equal to one third of the model time constant If the model is uncertain, the filter time constant should by set equal to the uncertainty in the deadtime An alternate method of tuning is to set the filter time constant to the deadtime plus the model time constant Perform set point changes and successively reduce the filter time constant until a desirable response is obtained

SPECIFICATIONS

S1 - PV - Block address of process variable

S2 - SP - Block address of set point

S3 - TRACK - Block address of track reference value The set point will track the value in this block when the track switch signal is a 0

S4 - SWITCH - Block address of track switch signal The set point will track <S5> when this input is a 0
0 = Track
1 = Release

S5 - REFER - Block address of an external reference value This is a Cascade input with no connections to the SMITH PREDICTOR block This value can be used to force the output to a safe value in case of equipment failure If it is not in use then S5 should reference the same block as S2

FUNCTION CODE 160

S6 - RFLAG - Block address of the external reference flag If this input is a 1, then the set point will track the external reference value
0 = Release
1 = Track reference value

S7 - GAIN - Process model gain This is used with S9 to create an ideal process model This value is defined for the ideal process with no dead time

S8 - DEADT - Process dead time This value identifies the actual dead time in the real process In most cases with will be a fixed value In other cases it may change with the process When this occurs, it may be necessary to modify S8 with an ADAPT block to reflect actual changes in the dead time

S9 - LAGT - Process model lag time This is used with S7 to create an ideal process model It is defined for the ideal process with no dead time

S10 - TUNET - The tuning time constant is used to take into account the performance characteristics of different processes A good starting value is about 1 3 times the process dead time

S11 - HIGH - High output limit This will normally be 105 0

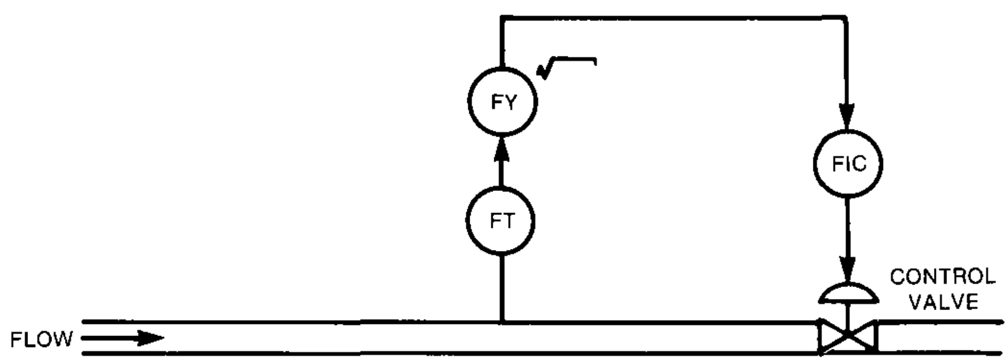
S12 - LOW - Low output limit This will normally be −5 0

BASIC CONTROL LOOP

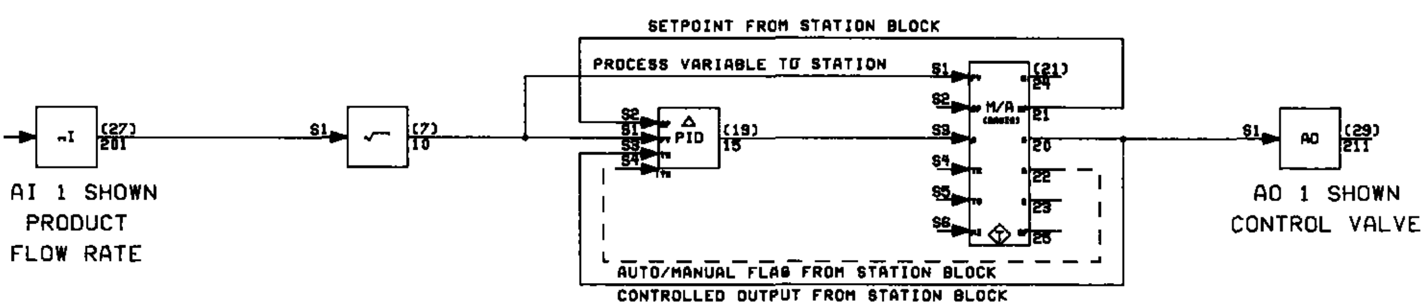
The following example uses a Basic Station combined with a PID controller to form a typical control loop The application shown requires a regulated flow, where the flow is measured using a differential pressure transmitter and regulated using a control valve

To implement the control on the Loop Command Controller, the differential pressure signal is brought in through one of the Analog Inputs and connected to a square root function to calculate the Process Variable flow rate (in engineering units) This PV and the setpoint signal from the station (which is driven by a CLC under operator control) are connected to the PID controller and the output of the PID is the Auto input to the station The Control Output signal from the station is connected to an Analog Output to drive the valve When the station is in the Auto Mode the operator can adjust the setpoint and PID will have control of the CO signal If the station is put into Manual Mode the operator can control the CO signal directly In this mode the PID is forced to track the CO signal as a track reference The M/A status flag is connected to the track switch of the PID to initiate this action This will cause the PID to track the CO signal when in Manual Mode and the transfer to Auto will therefore be bumpless

BASIC CONTROL LOOP



LOOP COMMAND FUNCTION BLOCKS



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Solid lines on the Loop Command Function Block drawings indicate analog signals and dashed lines indicate boolean signals

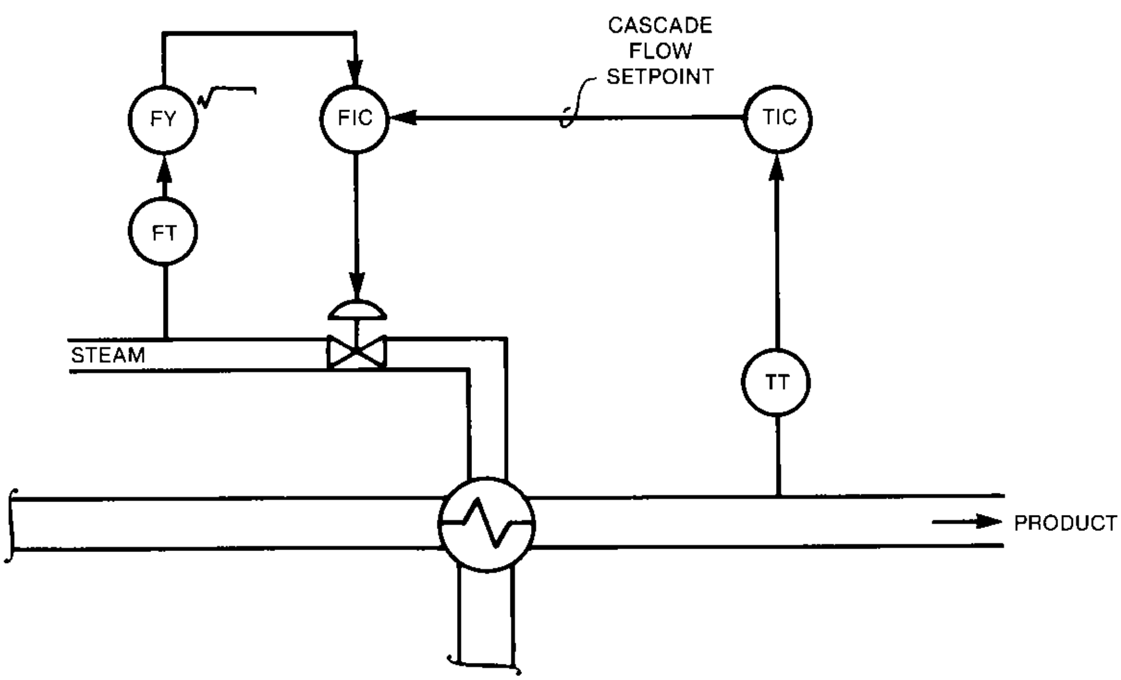
CASCADE CONTROL LOOP

A Cascade control structure is shown next In this structure the output of the primary controller is used as a setpoint to the secondary controller Each controller has its own measurement value but only the secondary controller has a control output signal The secondary controller in this structure may be operated separately from the primary or put into cascade operation where its setpoint is determined by the primary controller

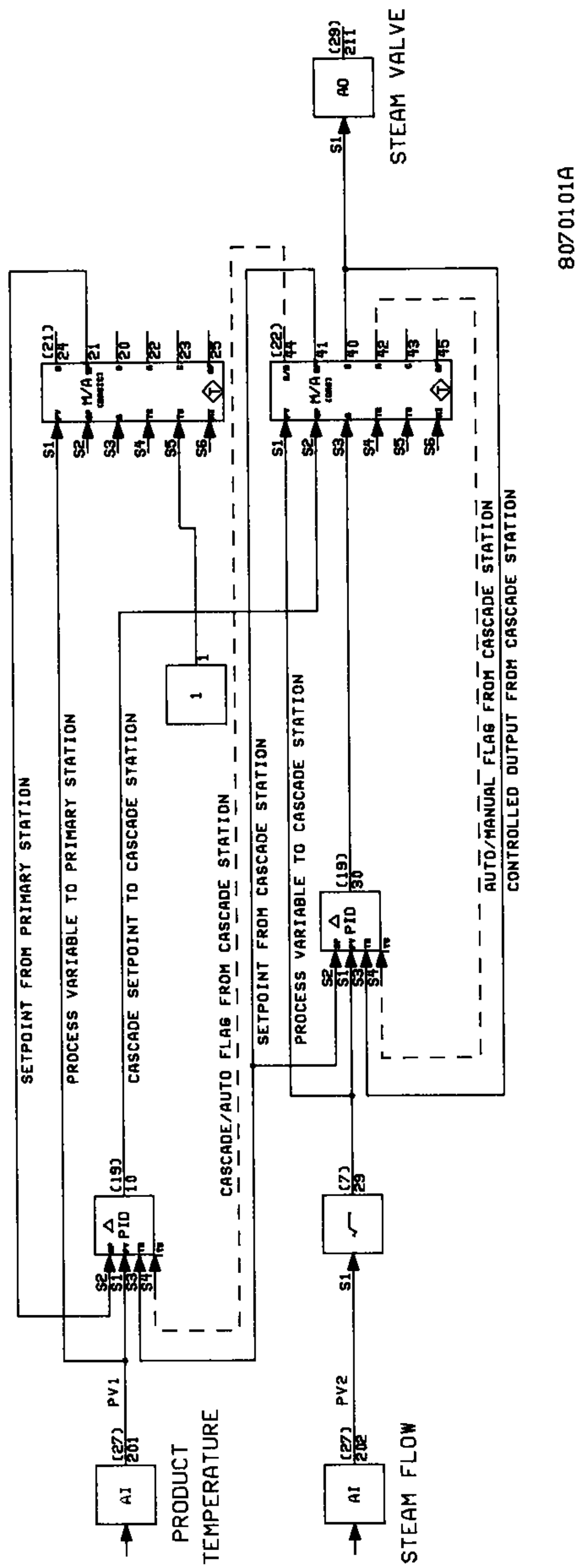
The Loop Command Controller implementation uses two Analog Inputs for the two measurements, two PID controllers, a Basic station for the primary loop for display of and adjustment of the primary process variable and setpoint and a Cascade station for mode selection, display and manual adjustment of the secondary process variable and setpoint Display and manual adjustment of the analog output signal is also provided Note that the secondary station may be operated in Manual, Auto or Cascade Mode In Cascade Mode the secondary controller will be in automatic To prevent windup at the primary controller, the cascade state flag is used to force the primary controller to track the setpoint of the secondary loop until the secondary is put under Cascade control Tracking by the secondary controller is the same as the standard feedback loop in Manual Mode

Reset windup can occur in any system, but most commonly in batch control systems where controllers may be monitoring control variables but not performing any control action during the current step The controller will receive the signal, take action to correct the error, see no result, and take action to correct the error again As long as the controller receives no results from its control action, it will continue to try to correct the error When the controller is later called into service on some other step of the process, it will be wound up so far beyond the value of the controlled variable that it will not be able to control it

CASCADE CONTROL LOOP



LOOP COMMAND FUNCTION BLOCKS

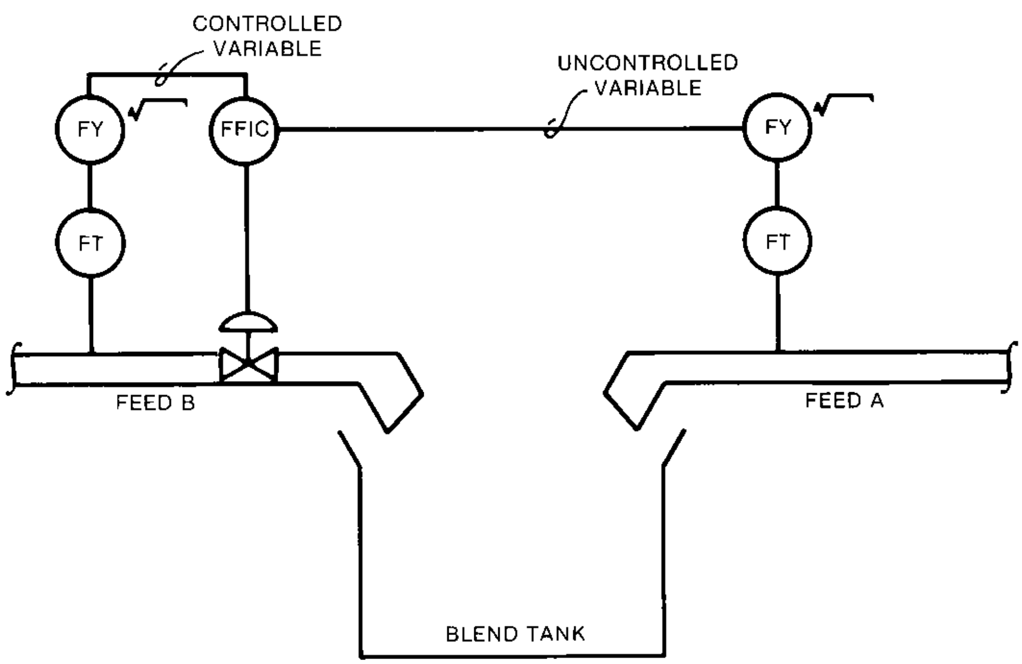


RATIO CONTROL LOOP

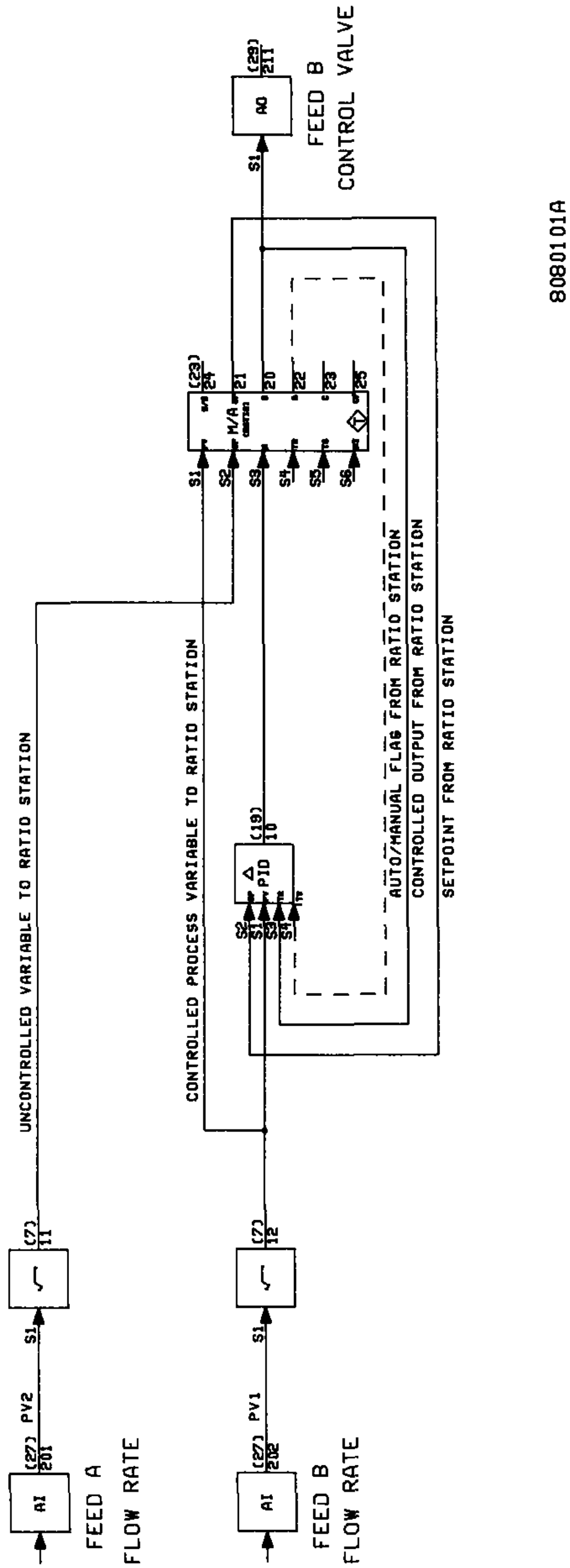
In a Ratio Control structure the objective is to control the ratio of two variables The most common application of ratio control is in mixing operations In general a valve is used to control one process variable and the other variable is left uncontrolled or "wild" The operator selects the desired ratio and the setpoint if the controlled variable needed to maintain the ratio is determined from the ratio multiplied by the "wild" variable

The control structure for the Loop Command Controller uses two analog inputs for PV_1 and PV_2, and the PID function, a Ratio Station and an Analog output for the control output The station may be operated in Manual Mode, where the control output is directly controlled, Auto Mode where the operator may set the setpoint or in Ratio Mode where the operator selects the ratio value and the station calculates the setpoint as the ratio times the PV_2 value The tracking structure for Manual Mode is the same as that used for the basic feedback loop Note that Ratio control could be implemented without a special station using a multiply block but the direct control of the ratio value and the need to display the actual setpoint require that these values be available to the operator interface devices Bumpless transfer of setpoint is achieved by computing the actual ratio whenever the station is not in Ratio Mode

RATIO CONTROL LOOP



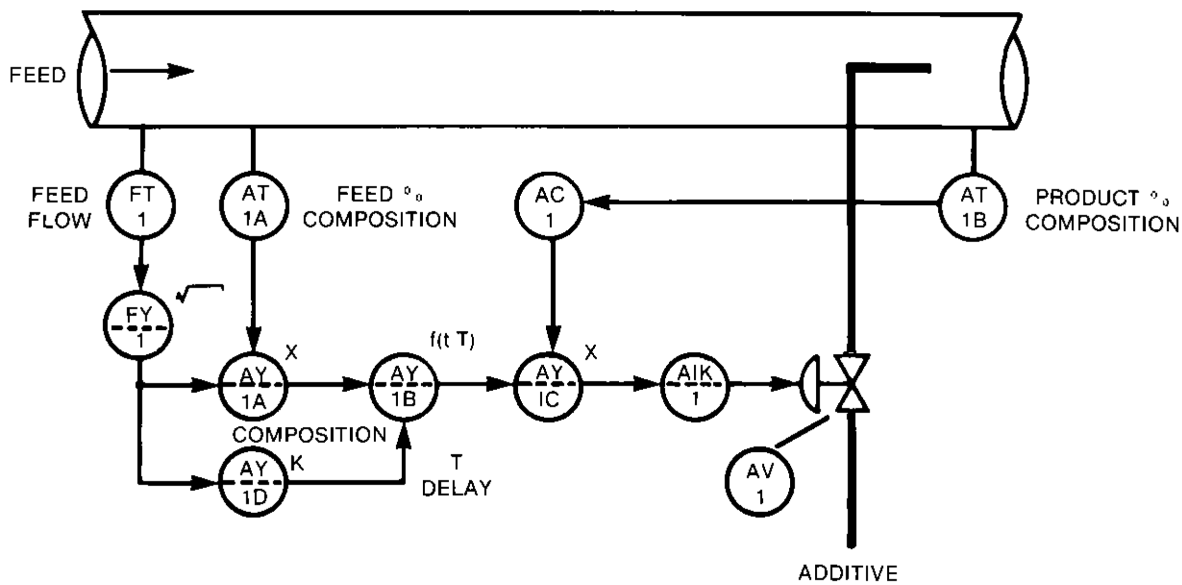
LOOP COMMAND FUNCTION BLOCKS



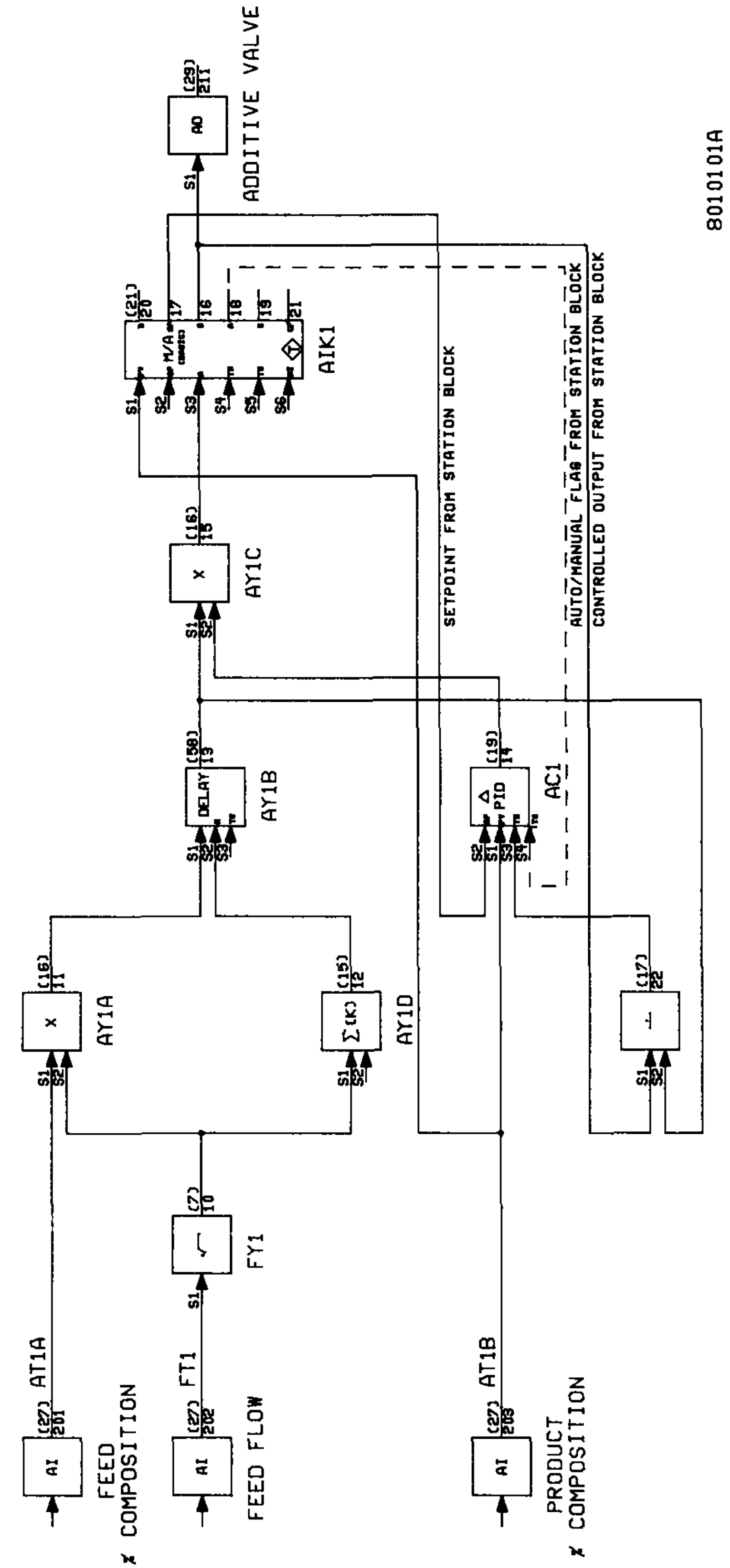
ANALOG TIME DELAY

The Analog Time Delay example involves the inline blending of two streams where the feedforward index is determined a considerable distance upstream of the additive stage, thus resulting in an apriori knowledge of feed composition Assuming plug flow and a fixed pipe dimension, the process transport time as a function of feed flow can be computed A variable analog time delay is therefore used where the upstream mass flow composition is delayed T seconds prior to being used as a feedforward index to the final regulatory loop

ANALOG TIME DELAY — BLENDING EXAMPLE



LOOP COMMAND FUNCTION BLOCKS

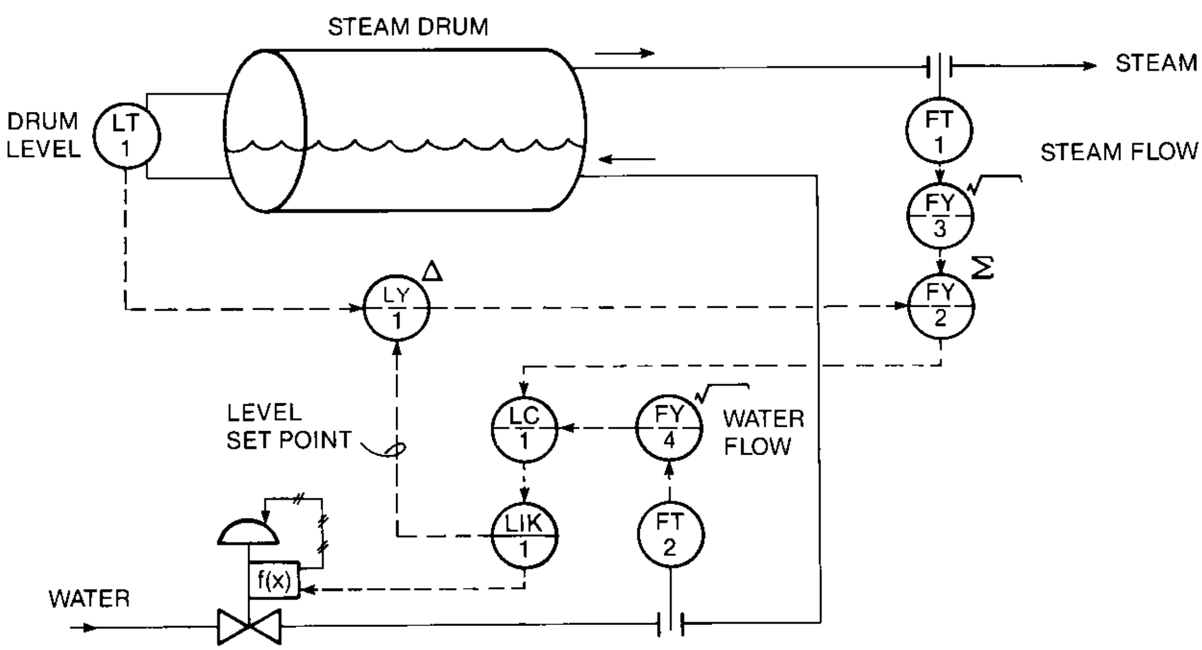


THREE ELEMENT FEEDWATER CONTROL

A Three Element Feedwater Control system is designed to provide a continuous mass balance, since for every pound of steam generated and removed from the boiler, a pound of water must be added to replace it An unbalance in this relationship will result in a change in drum level

For this reason, the steam flow measurement is used as a feedforward load index in determining feedwater demand This feedforward demand is in turn recorrected, based on drum level deviation from set point and used as the cascaded set point for the feedwater controller

THREE ELEMENT FEEDWATER CONTROL



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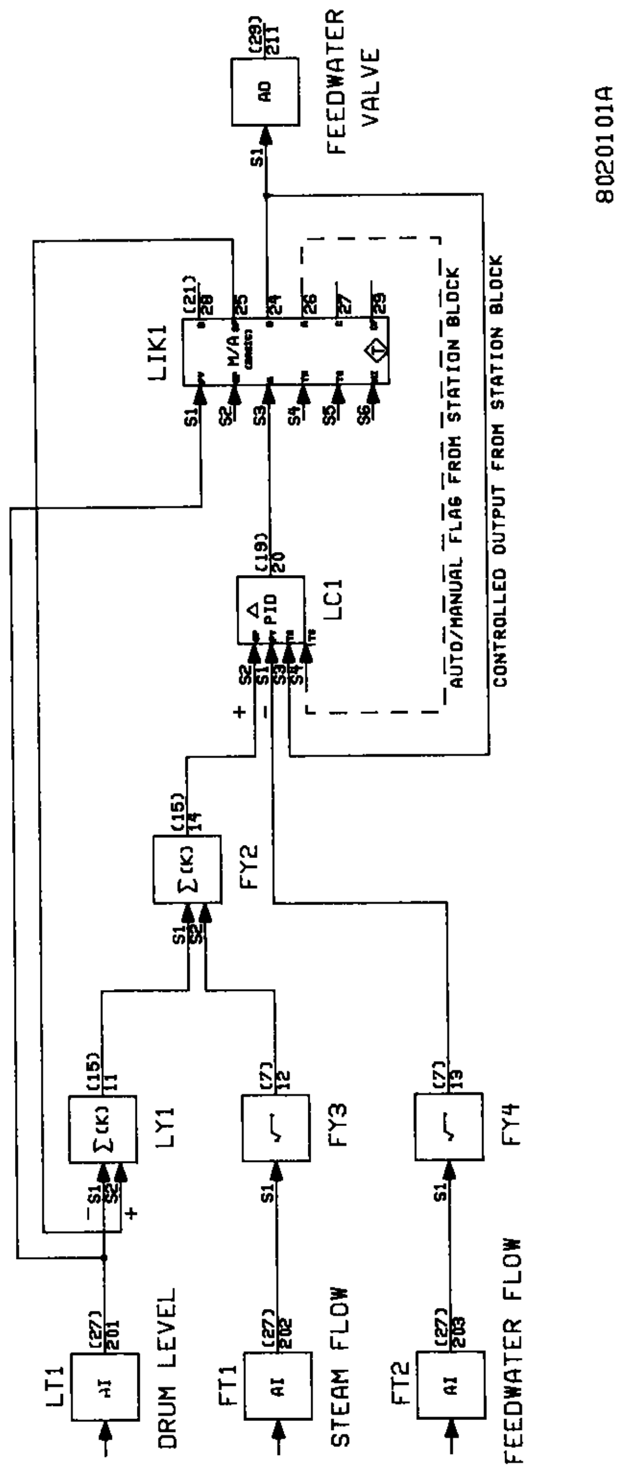
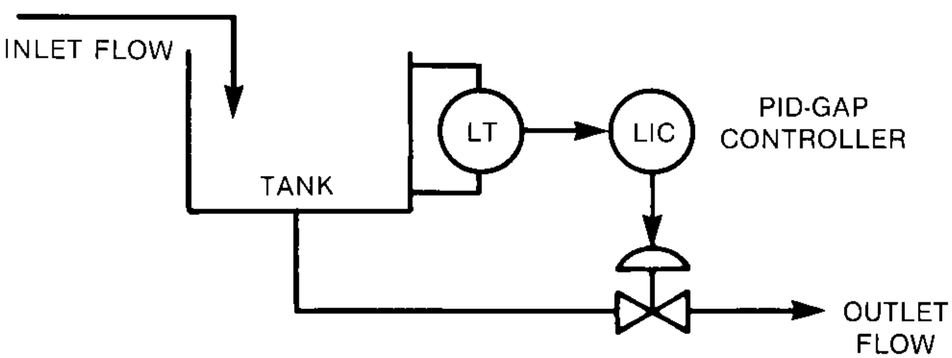
LOOP COMMAND FUNCTION BLOCKS



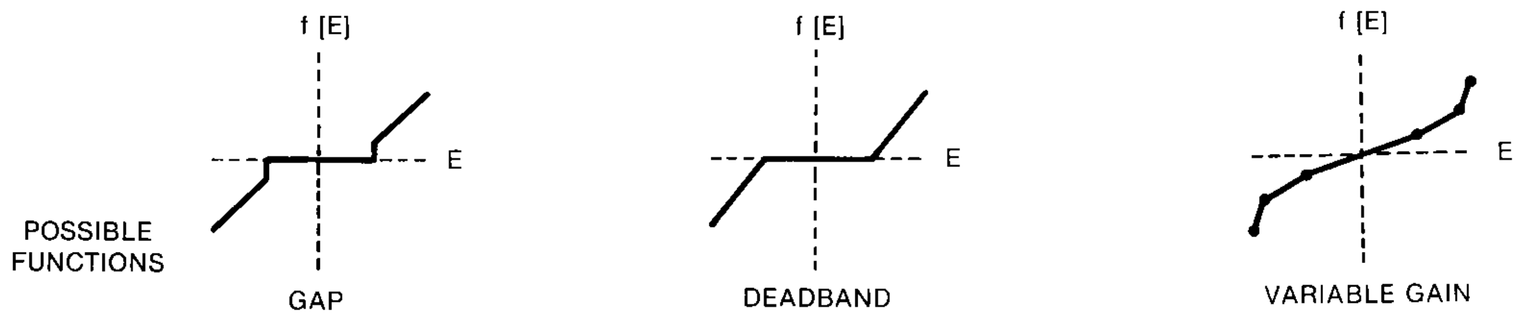
PID — GAP CONTROL
And Generalized Error Characterization

There are a number of applications where linear control response to an error signal is undesirable For example, if the design objective of your tank level control is to stabilize output flow to a downstream process unit then a form of Gap control is desirable Gap control will dampen out the effect of up-stream fluctuations in flow by letting the tank level vary within a prespecified range Large upstream fluctuations will result in control action to maintain tank level at the setpoint

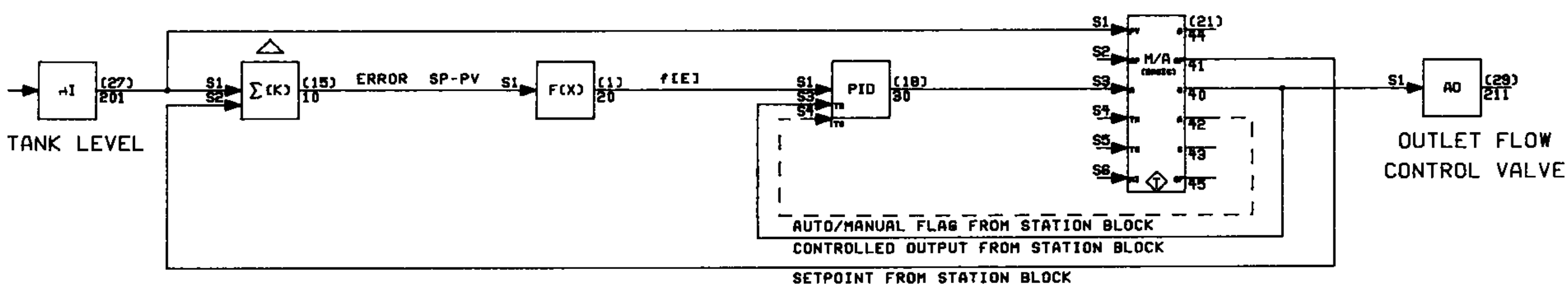
PID — Gap control is implemented on the Loop Command Controller by computing the error between the process variable and the setpoint outside the PID control algorithm The error signal is then shaped by a function generator function code Typical shapes as well as the function block configurations are shown on the following pages



ERROR CHARACTERIZATION USING A FUNCTION GENERATOR ON ERROR



LOOP COMMAND FUNCTION BLOCKS



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FEEDFORWARD CONTROL

Feedforward control is a control technique that calculates an output based on process measurements, the desired setpoint and a model of the process Since it is difficult to get a totally accurate process model, feedforward control is often used with a feedback loop to correct the setpoint to take into account modeling errors and unmeasured process disturbances

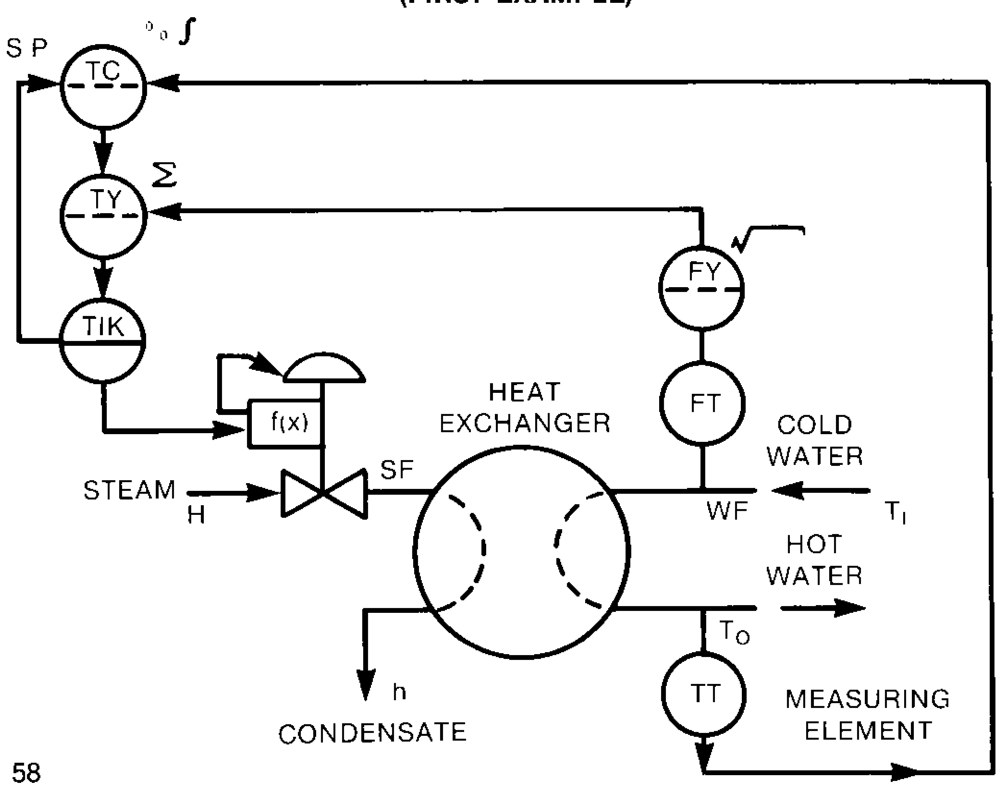
There are many variations of feedforward control but three typical configurations are included, each containing varying levels of model complexity The first two examples are associated with a process heat exchanger The third example is a density control loop associated with an evaporator

The two process heat exchanger control configurations are examples of steady state feedforward control The feedforward process model is designed to compensate for the inherent nonlinearities associated with heat exchangers over their operating range

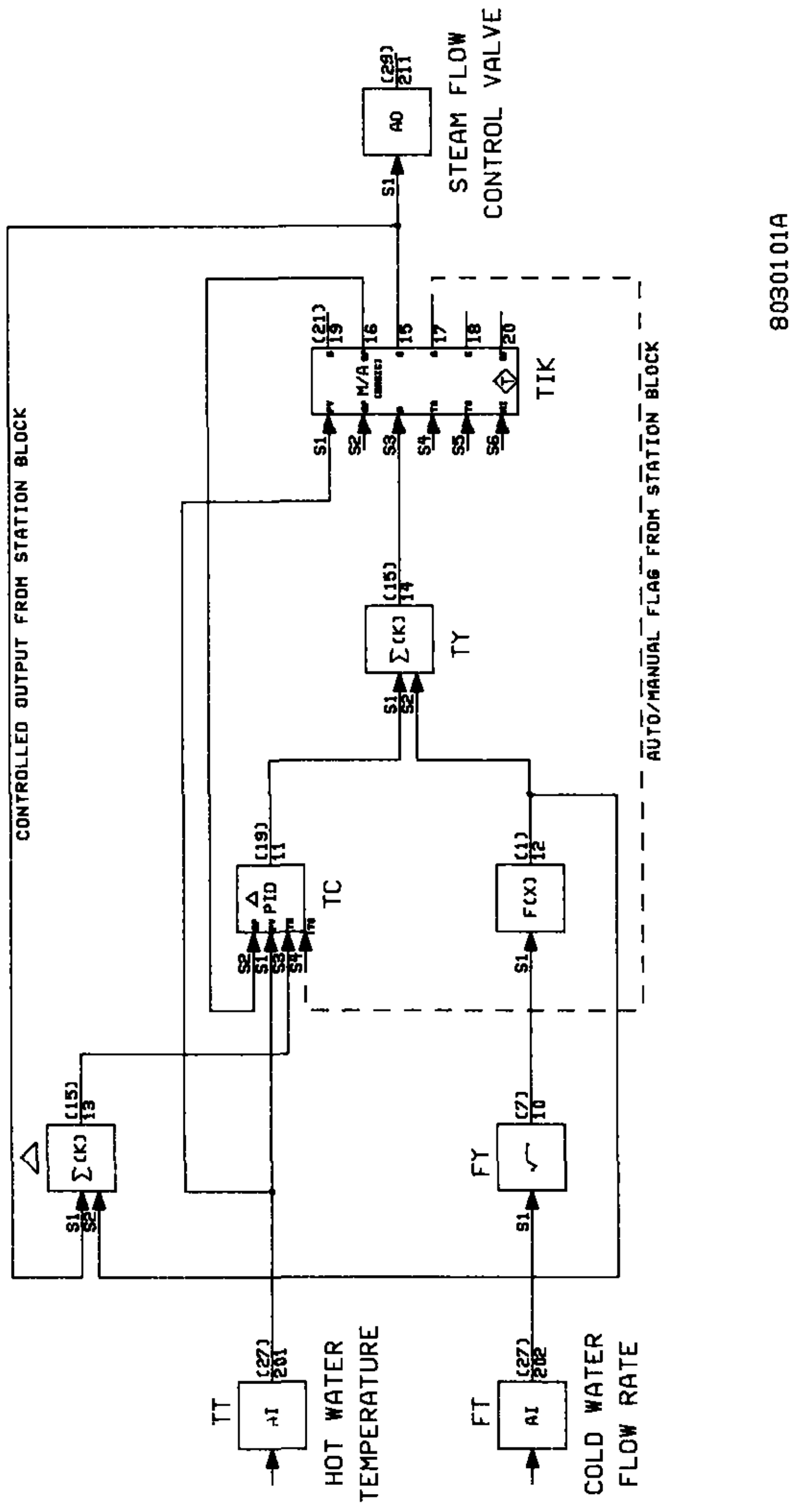
The first process heat exchanger example assumes that steam and cold water temperatures and pressures are relatively constant Under these conditions, water flow can be used to infer steam valve position demand such that the desired exit hot water temperature can be achieved The closed loop temperature controller will bias the steam valve position demand in response to transient disturbances and steady state regulation of water temperature

The Loop Command Controller implementation includes a function generator in the feedforward demand A feedforward program of water flow as steam valve demand will be entered to linearize process characteristics for the feedback controller It has been assumed for this example that gain scheduling of the controller was not required

TEMPERATURE CONTROL OF A PROCESS HEAT EXCHANGER (FIRST EXAMPLE)

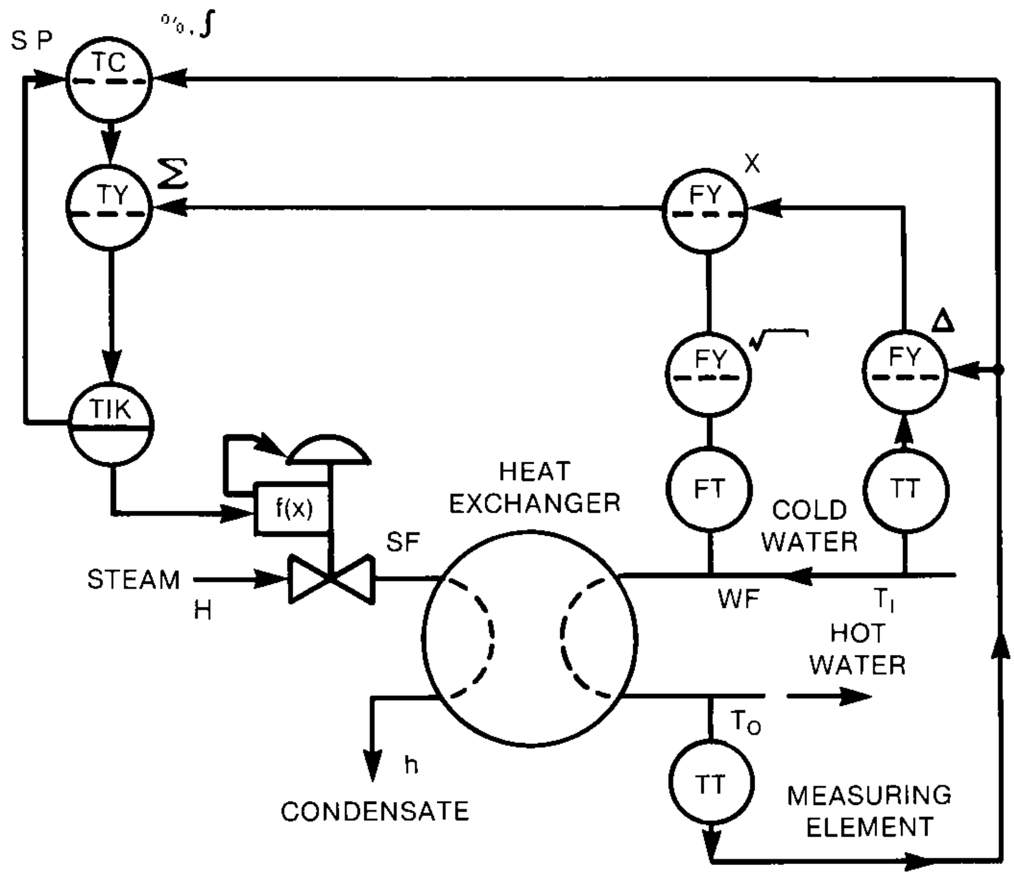


LOOP COMMAND FUNCTION BLOCKS

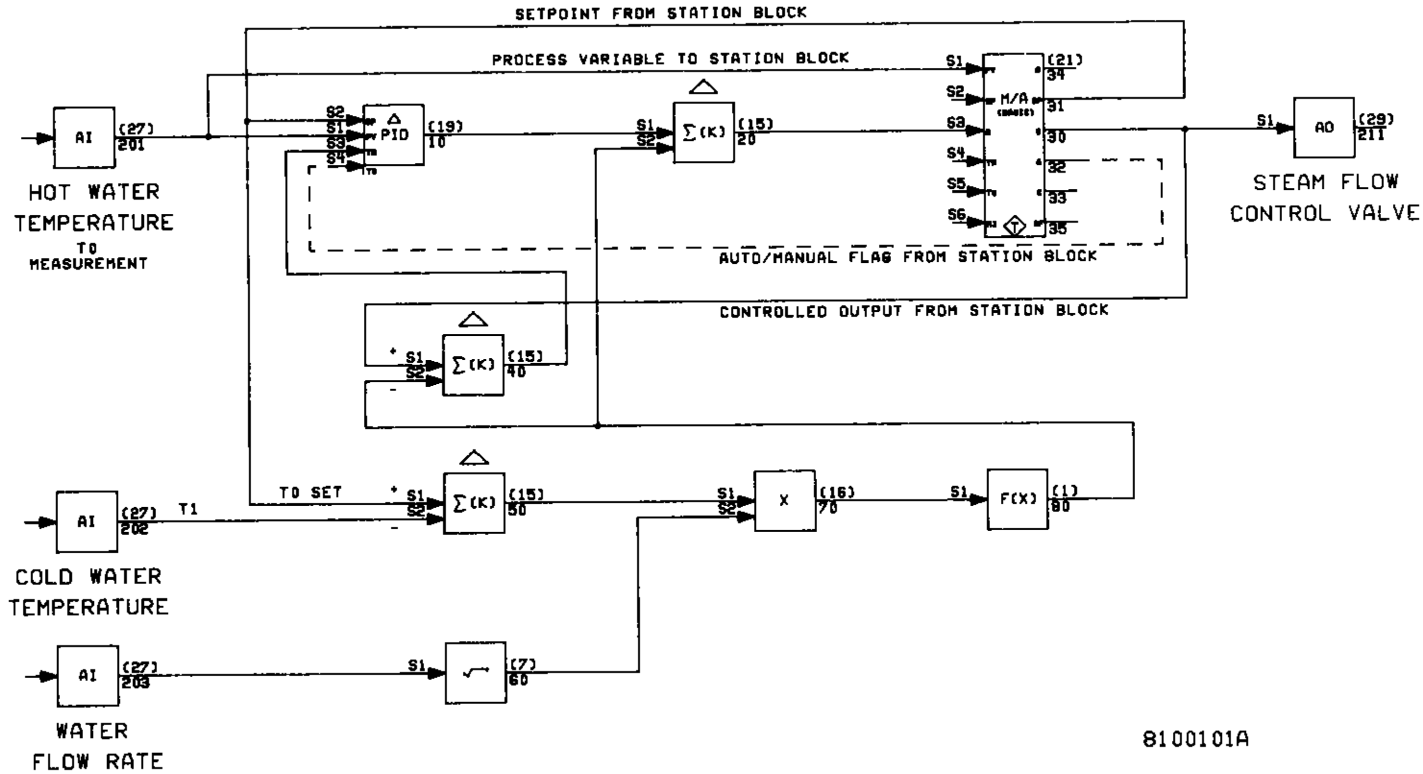


The second process heat exchanger example shows an alternative configuration for the feedforward control loop that accounts for both cold water temperature and desired hot water temperature and flow rate These three parameters are used to estimate energy requirements for the heat exchanger This estimate will be used to infer steam valve position demand using a function generator such that the desired exit hot water temperature can be achieved The closed loop temperature controller will bias the steam valve position demand in response to transient disturbances and steady state regulation of water temperature The steam valve can be controlled manually using the Auto/Manual station Bumpless transfer is incorporated into the track reference signal to the PID controller

TEMPERATURE CONTROL OF A PROCESS HEAT EXCHANGER (SECOND EXAMPLE)



LOOP COMMAND FUNCTION BLOCKS



The third example is the product density control of an evaporator This control utilizes an Inferential Smith Predictor as the primary controller and a dynamic feedforward compensation circuit to decouple the primary controller from changes in product density flowrate The secondary controller consists of a PID algorithm to maintain the steam flow rate at setpoint

The dynamic feedforward control strategy is based on the ratio of the two transfer function models that estimate the change in density caused by a change in product flow rate and steam flow rate For example, if the steam flow to density transfer function can be approximated as

$$Gs = \frac{Ks\,(e)^{-TsS}}{\tau sS + 1}$$

and product flow to density transfer function can be approximated as

$$Gp = \frac{Kp\,(e)^{-TpS}}{\tau sS + 1}$$

then the feedforward transfer function is

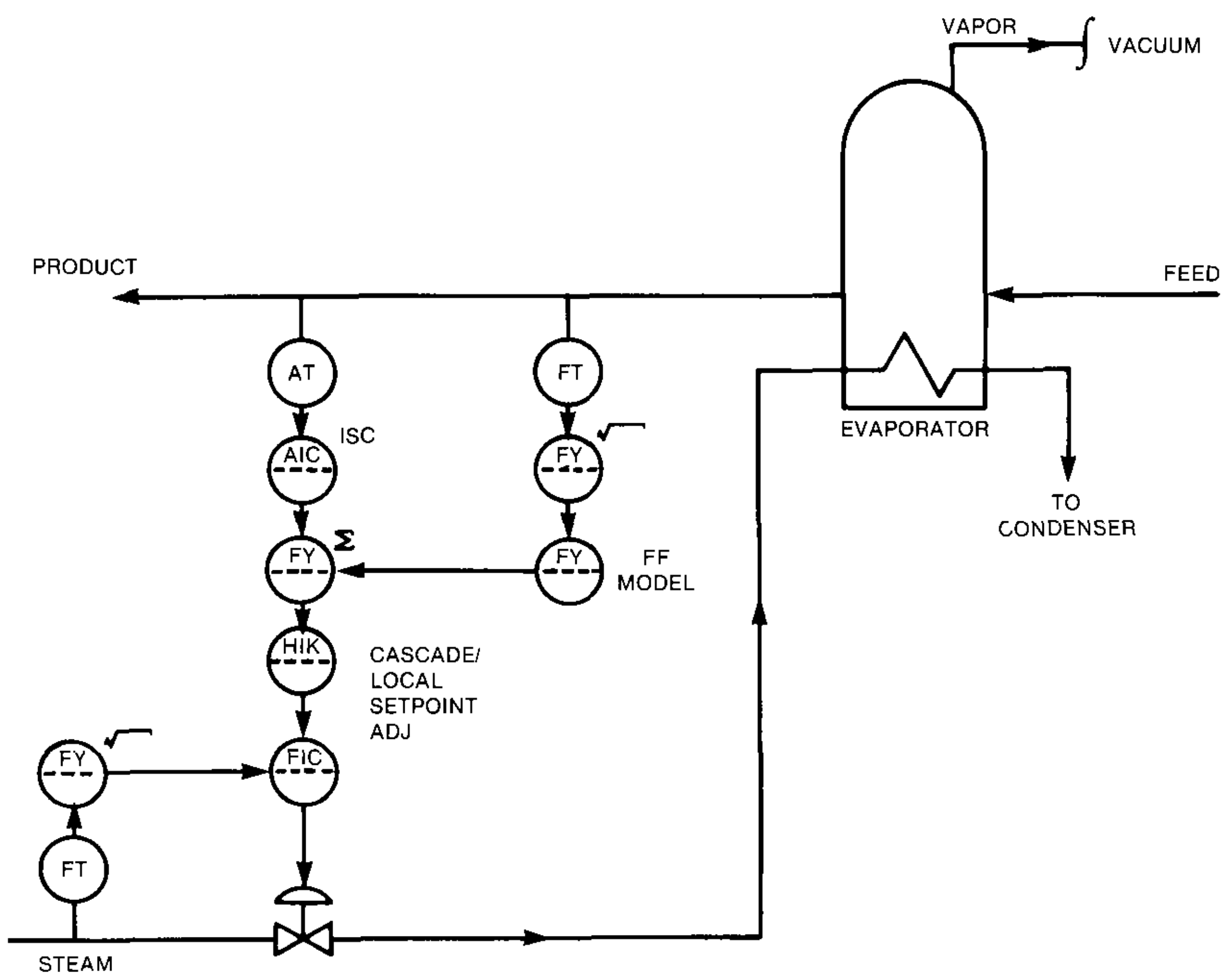
$$Gff = \frac{-Gp}{Gs}$$

$$= \frac{-Kp}{Ks} \bullet \frac{\tau s\ S + 1}{\tau p\ S + 1} \bullet (e)^{-(Tp\ -\ Ts)S}$$

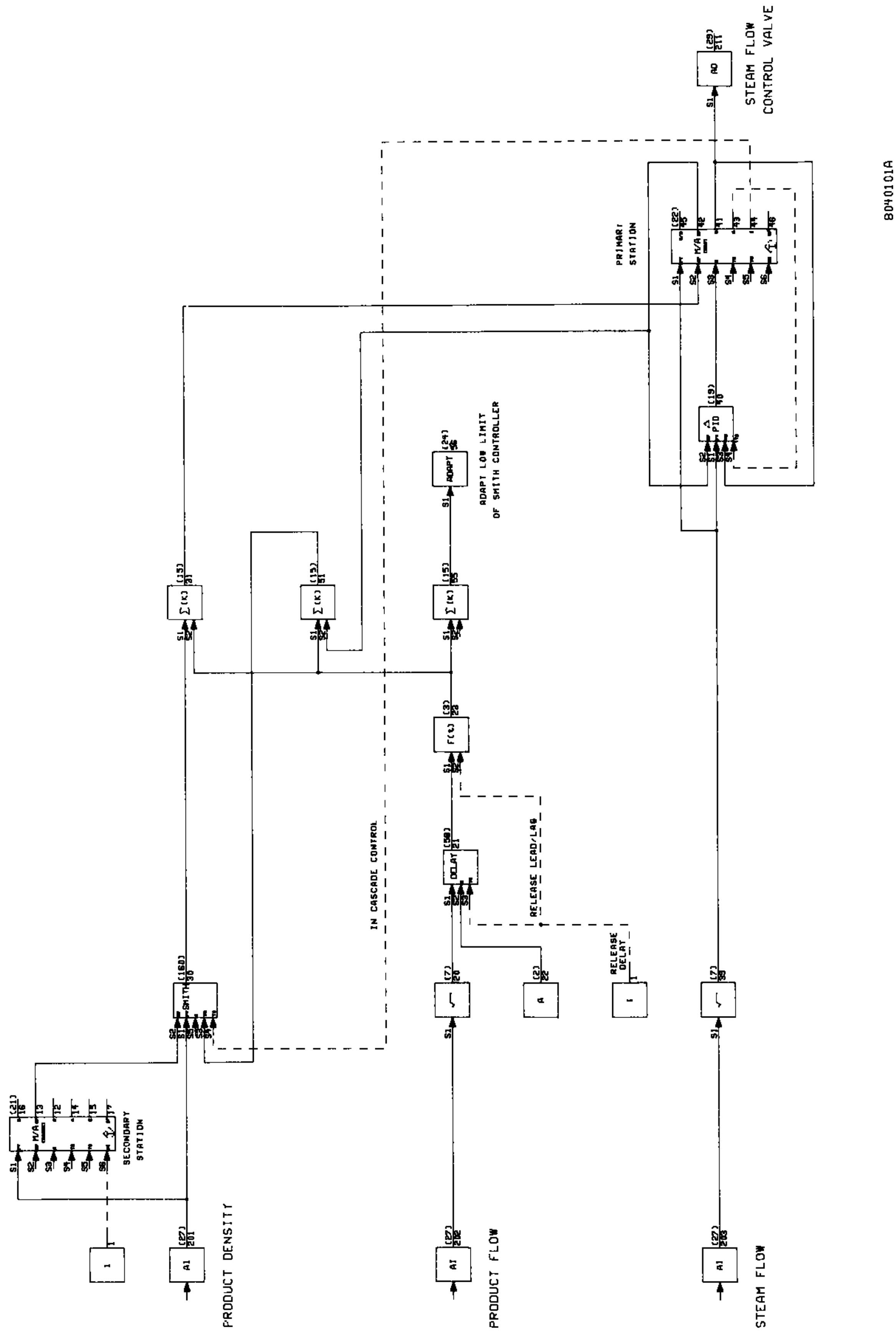
where K = Gain, τ = Time constant, T = Deadtime
The above feedforward model assumes that Tp is greater than Ts

In the Loop Command Controller the primary/secondary faceplate display option is used The secondary faceplate display is used to display product density and its setpoint The primary faceplate is the Cascade/Auto/Manual station

PRODUCT DENSITY CONTROL



LOOP COMMAND FUNCTION BLOCKS



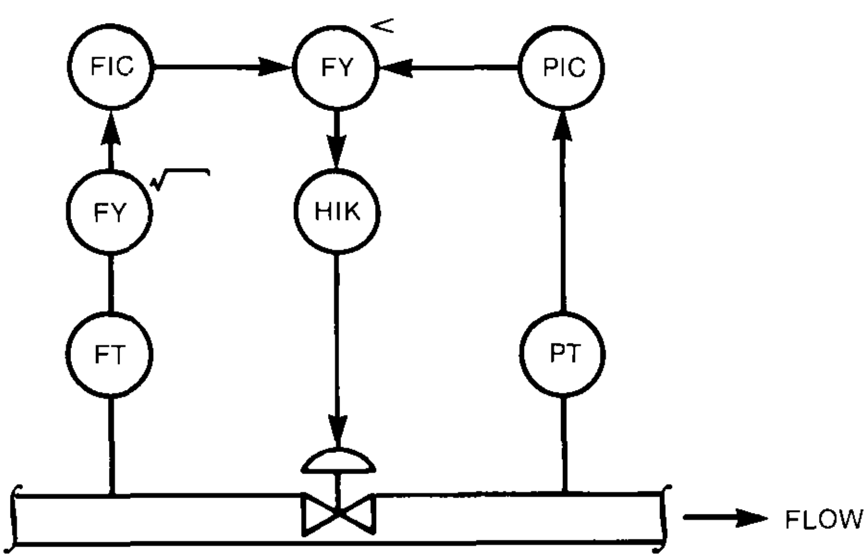
OVERRIDE CONTROL

Override control systems are used where two or more variables must not exceed certain limits for reasons of safety or economy Next is an example of a control system where it is normally desired to control the product flow If the downstream pressure approaches a high limit then to protect the equipment the product flow rate will be reduced to prevent excessive pressure This is done by selecting the lower of the outputs from the flow control loop or the pressure control loop

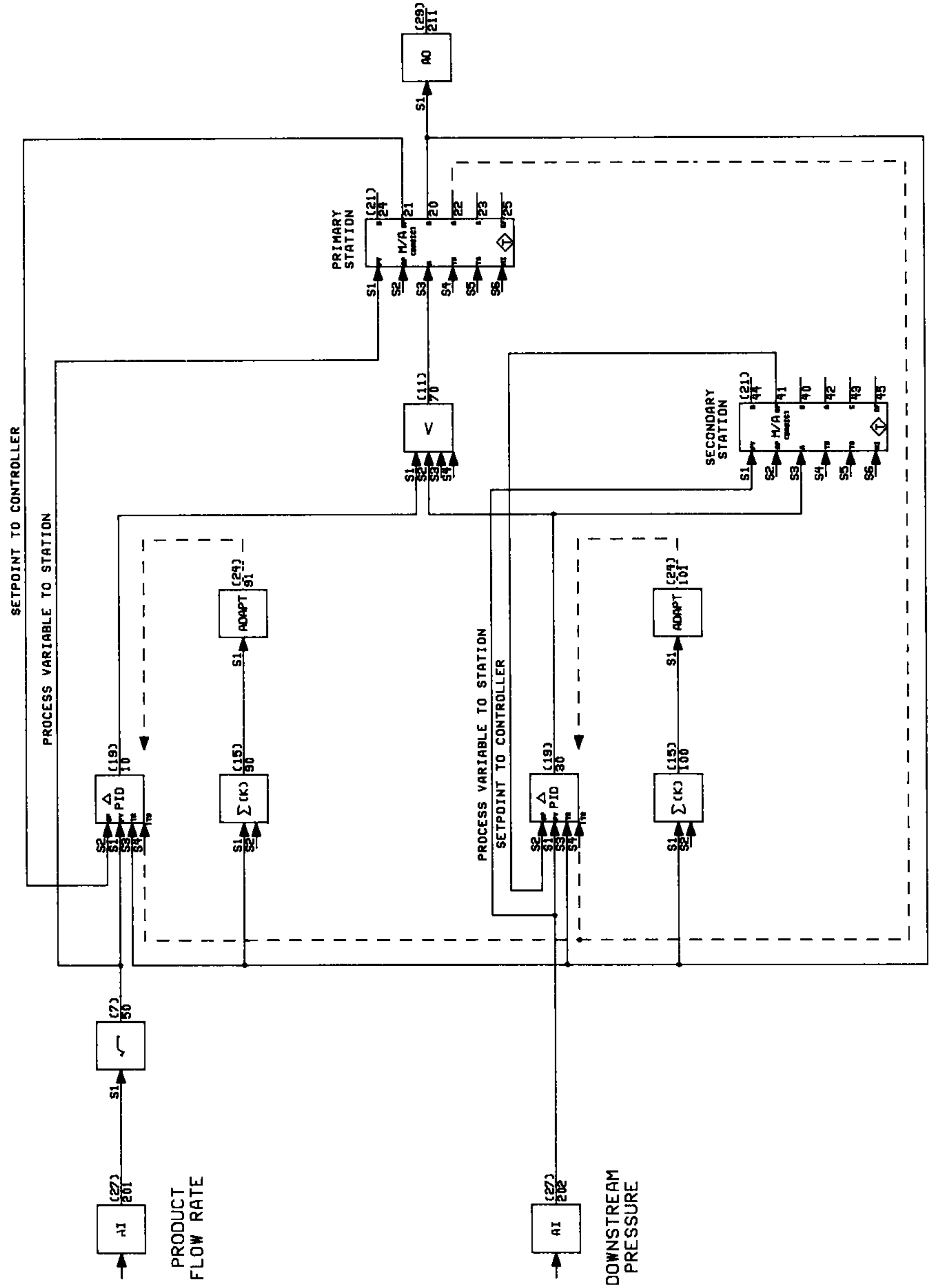
In this example, a standard control loop with a station is used for flow, a standard control loop is used for the pressure limit and a low select to determine the valve position demand To prevent the controller that is not selected from winding up, the output of the low select is used to clamp the high limits of both PID controllers

The flow controller faceplate is also used for manual adjustment of the flow control valve

OVERRIDE CONTROL



LOOP COMMAND FUNCTION BLOCKS



DECOUPLED BLENDING CONTROL

In many control situations process variables are "coupled" in the same sense that a change in a manipulated variable that affects one process variable will also affect the other Decoupling Control systems attempt to reverse the process model to allow the operator to adjust one variable without affecting other variables in the system The process is a blending process and it is desired to control the total flow and the composition by controlling the flow of the two ingredients m_1 and m_2 Since the total flow is given by the sum of the two ingredient flows and the composition is given by the ratio of one ingredient to the total flow, m_1 and m_2 can be solved for in terms of m_f, the desired total flow, and m_x the desired composition

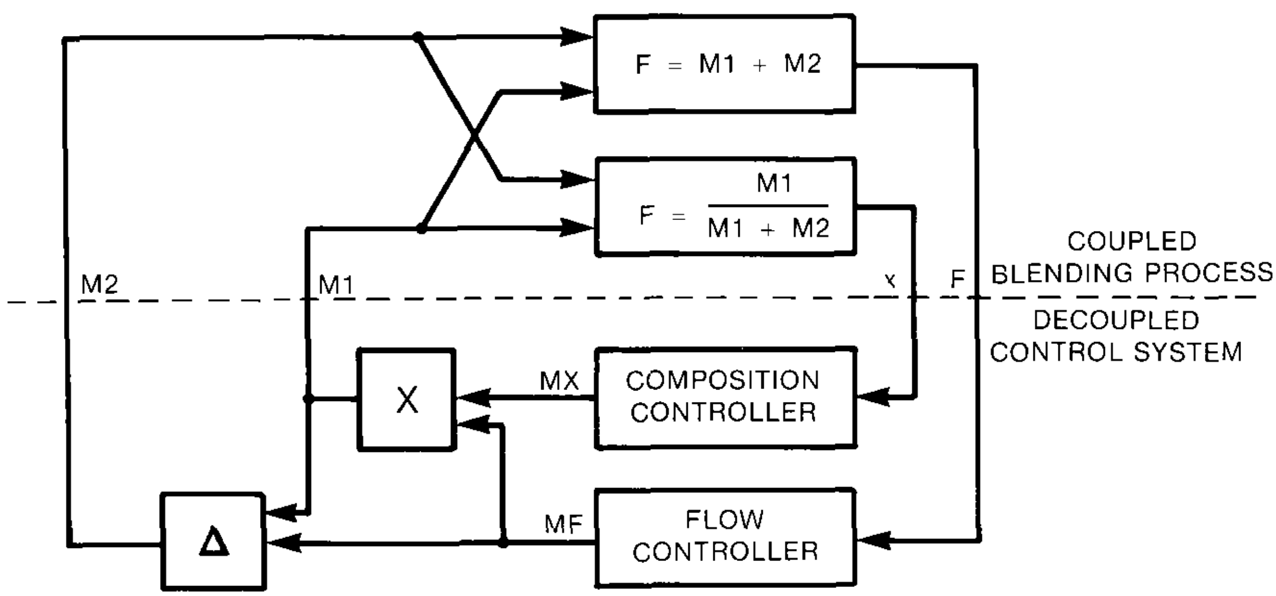
In this example, we have two basic feedback loops, each using a PID and Station, a multiply block to calculate m_1 and a difference block to determine m_2 Note that any model that can be expressed in terms of add, subtract, multiply and divide may be easily implemented in the module

DECOUPLED BLENDING CONTROL

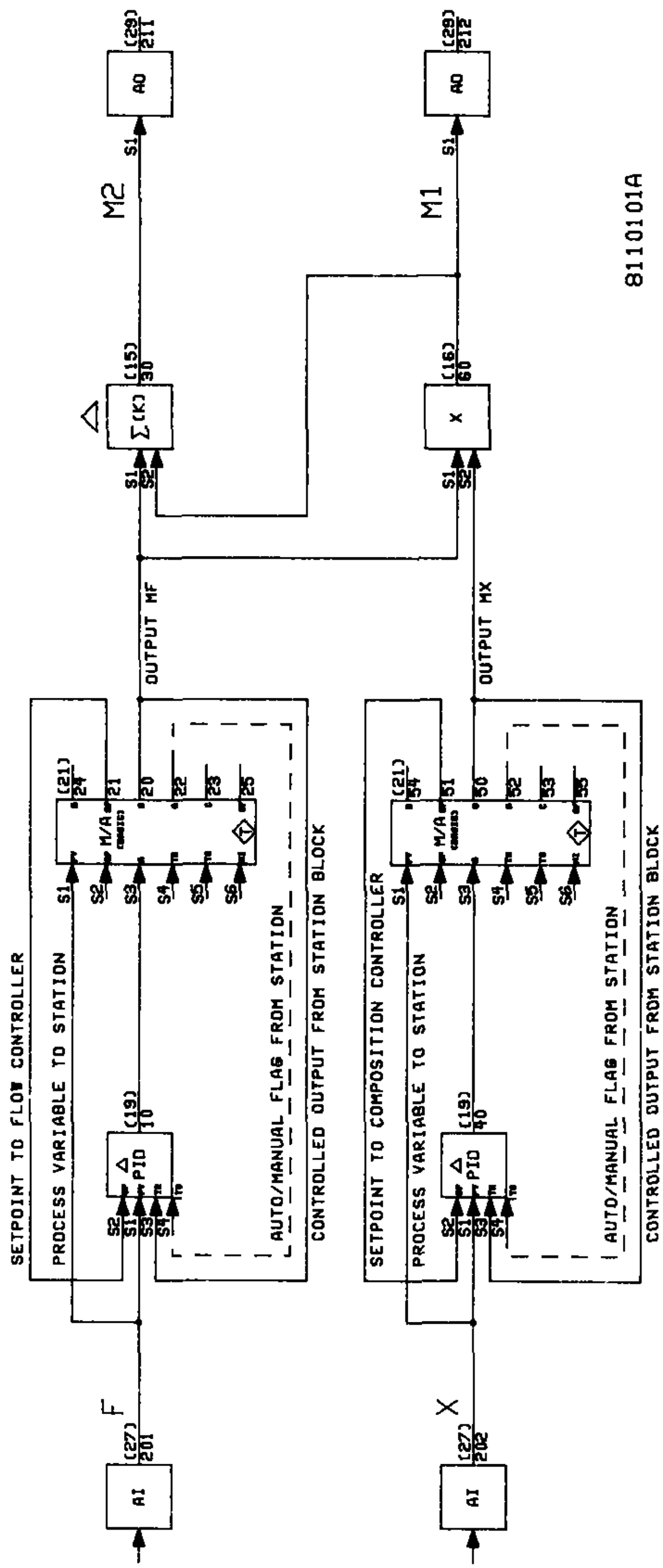
$$M1 = MX \cdot MF$$
$$M2 = MF\,(1 - MX)$$

$\therefore$

$$MF = M1 + M2$$
and
$$MX = \frac{M1}{M1 + M2}$$



LOOP COMMAND FUNCTION BLOCKS



SELF-TUNING CONTROL

Many industrial processes are now required to perform efficiently over a wide range of operating conditions In many cases, these processes and their control systems were initially designed to produce a single product at a single production rate Current economic conditions often require the same process to produce a variety of products at a variety of production rates In many cases, the necessary operating efficiencies require major changes in both the process design and the control strategy

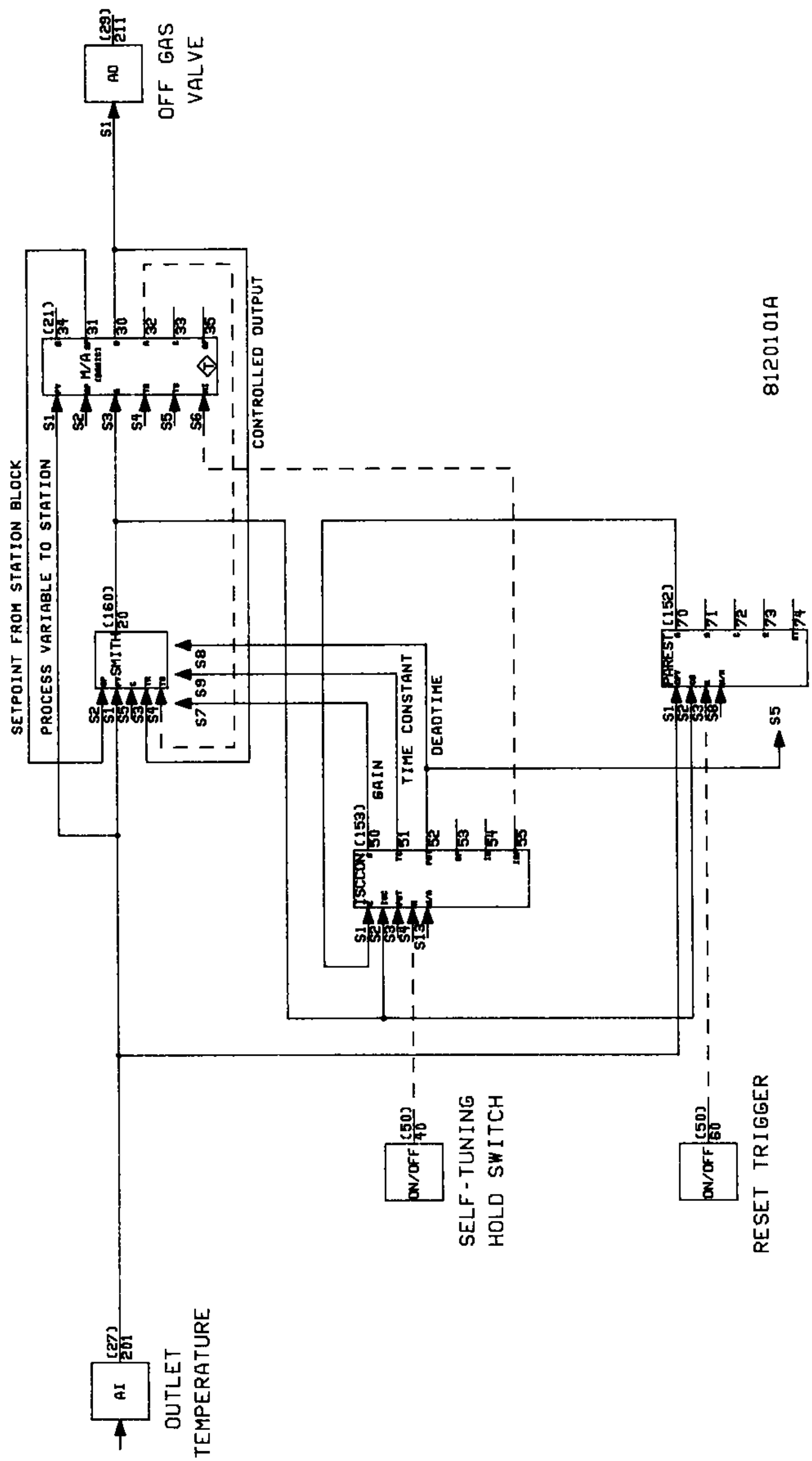
However, one fundamental problem continues to limit process performance Conventional process controllers cannot effectively control the required variables over a broad range of process operating conditions Many techniques address this problem, but only with limited success Bailey Controls provides a unique self-tuning control capability which combines the attributes of many of these techniques, and overcomes the problems associated with each The most effective elements of modern control theory, estimation theory and numerical analysis have been combined with a solid base of process control experience to develop this self-tuning control capability

A group of specialized function blocks have been developed to provide self-tuning for the Inferential Smith Controller (ISC) algorithm available in Bailey microprocessor-based controllers These function blocks can be configured into the control logic to provide superior control for industrial processes which must perform efficiently over a wide range of operating conditions

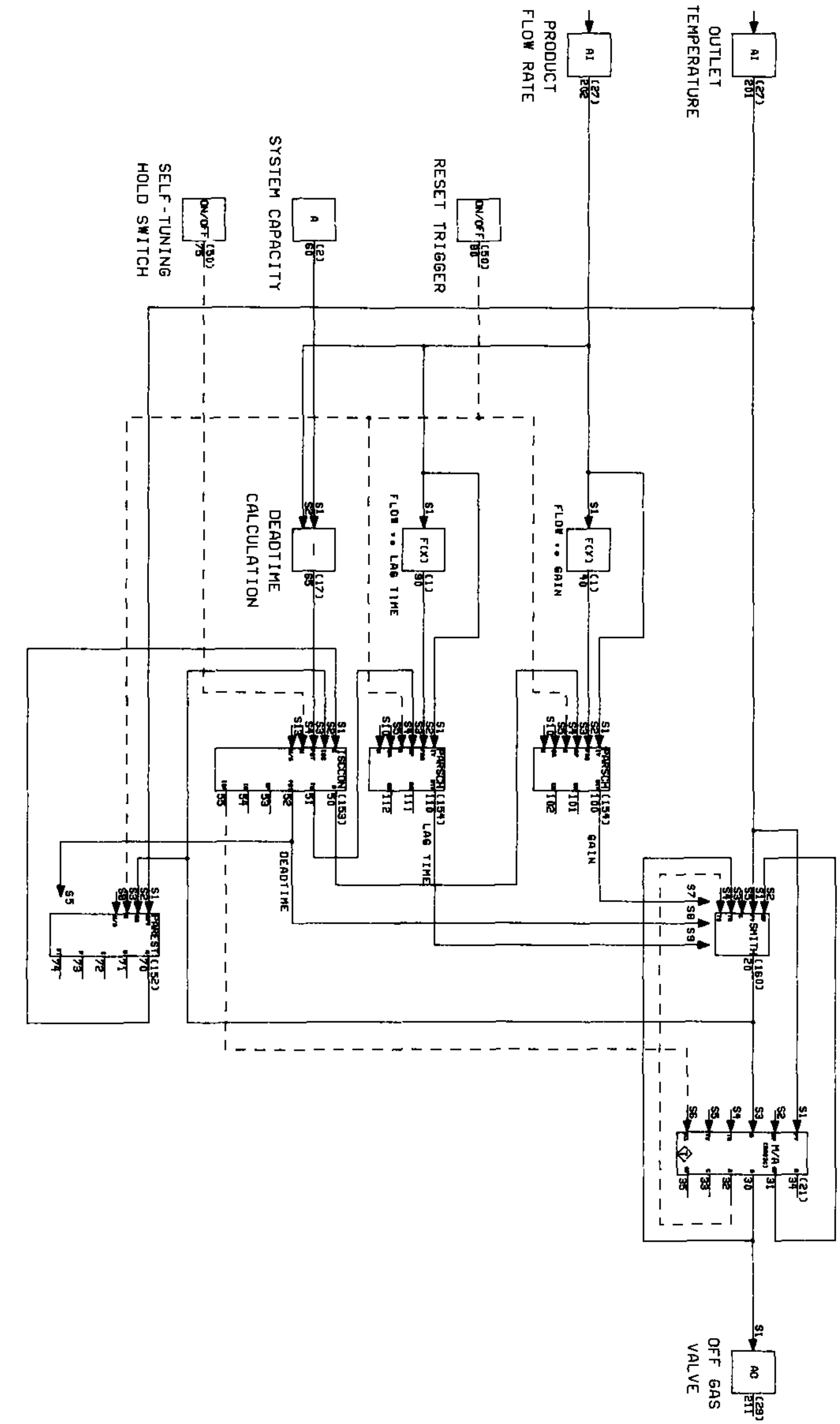
The Model Parameter Estimator monitors the controlled process variable and control output for the ISC, and automatically establishes a first-order dynamic model of these variables The parameters of this dynamic model are automatically translated to the required controller tuning parameters by the ISC Parameter Converter For processes where ISC tuning parameters are related to other process variables, an Adaptive Parameter Scheduler automatically establishes a statistically valid correlation and adjusts the tuning parameters for the ISC based on this correlation

For a detailed explanation of the Bailey Self-Tuning algorithm, please refer to Application Guide AG-0000-953-01

BASIC SELF-TUNING CONFIGURATION



ADVANCED SELF-TUNING CONFIGURATION WITH DEAD TIME SCHEDULING AND ADAPTIVE GAIN/LAG SCHEDULING



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"Using a Building Block Approach
to Implement Advanced Control Technique" — K L King

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"Analog Control Techniques and Tuning" — R K Johnson

APPLICATION GUIDE — AG-E93-900-1
"Three Element Feedwater Control"

APPLICATION GUIDE — AG-E93-900-4
"Analog Time Delay"

APPLICATION GUIDE — AG-0000-953-01
"Self-Tuning Control"

Bailey Controls 29801 Euclid Avenue, Wickliffe, OH 44092 USA

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