FOUNDATION Function Blocks
Agenda

- Standard Blocks
- Block Examples
Applications are modeled using function blocks which may be distributed between field devices.

FF function block application process is consistent with IEC 61804 Process Industry Function block

Function block execution may be synchronized through system management - based on each device having a common sense of time.
Mode and Status, foundation of distributing control

- **BLOCK_ERR** Parameter
- **Target and Actual** attributes of Mode parameter
- **Engineering Unit Value + STATUS** attributes of input and output parameters

**ControlLoop Knowledge Base**
### Mode

Possible modes:

<table>
<thead>
<tr>
<th>Bit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Remote-Output (Rout)</td>
</tr>
<tr>
<td>1</td>
<td>Remote-Cascade (RCas)</td>
</tr>
<tr>
<td>2</td>
<td>Cascade (Cas)</td>
</tr>
<tr>
<td>3</td>
<td>Automatic (Auto)</td>
</tr>
<tr>
<td>4</td>
<td>Manual (Man)</td>
</tr>
<tr>
<td>5</td>
<td>Local Override (LO)</td>
</tr>
<tr>
<td>6</td>
<td>Initialization Manual (IMan)</td>
</tr>
<tr>
<td>7</td>
<td>Out of Service (O/S)</td>
</tr>
</tbody>
</table>

*Section 5.2 for definition of LSB and MSB in B.*
Mode

- TARGET, ACTUAL, PERMITTED
- TARGET is the desired mode.
- ACTUAL is the actual mode.
- PERMITTED are the permitted modes.
- You can not use a non-permitted mode.
- If the resource block is out of service, all blocks go to Out of Service.
- If the Transducer Block is in OOS, the status will be Bad, Out of Service.
BASIC FF FUNCTION BLOCKS

- Discrete Input
- Discrete Output
- Analog input
- Analog Output
- PID, PI, I Controller
- P, PD Controller
- Control Selector
- Manual Loader
- Bias/Gain Station
- Ratio Station
ADVANCED FF FUNCTION BLOCKS

- Pulse Input
- Complex Analog Output
- Complex Discrete Output
- Step Output PID
- Device Control
- Setpoint Ramp Generator
- Splitter
- Input Selector
- Signal Characterizer
- Lead Lag

- Deadtime
- Arithmetic
- Calculate
- Integrator (Totalizer)
- Timer
- Analog Alarm
- Discrete Alarm
- Analog Human Interface
- Discrete Human Interface
Flexible Function Block For Devices that are Complex or have high I/O Count

New Block Subclass - Flexible

- Flexible (MIO) - Part 4
  * Multiple Analog Input - 8 Channels
  * Multiple Analog Output - 8 Channels
  * Multiple Discrete Input - 8 Channels
  * Multiple Discrete Output - 8 Channels

- Flexible (61131) - Part 5
  * Application-specific Blocks
Function Blocks Addressed by FF Interoperability Testing, v4.5

- **AI** – Analog Input
- **AO** – Analog Output
- **PID** – PID Control
- **DI** – Discrete Input
- **DO** – Discrete Output
- **ISEL** – Input Selector
- **ARITH** – Arithmetic
- **SC** – Signal Characterizer
- **INT** – Integrator
- **MAI** – Multiple Analog Input
- **MAO** – Multiple Analog Output
- **MDI** – Multiple Discrete Input
- **MDO** – Multiple Discrete Output
Example - Emerson 3051

- Resource Block
- Analog Input Block (Press)
- Analog Input Block (Temp)
- Transducer Block (Sensor)
- PID
- Input Selector
- Arithmetic
- Signal Characterization
- Diagnostic Block
- LCD Block
- Integrator

Typical Fieldbus Tx
3051S - Standard
3051S - Optional
FF function block capability may be used to address many applications:

- Single loop feedback control
- Feedforward control
- Cascade control
- Interlock based on a discrete input
- Input selection when redundant measurements are available
- Flow integration
- Calculations and signal characterization
Control in the field

Fieldbus

- AI1
- PID1
- AI2
- PID2
- AO1
- PID3
- AO2
- AI4

ControlLoop Knowledge Base
Engineering Monitoring and Control Applications Using Function Blocks
Easy control strategy configuration

CASCADE CONTROL

TT100

TIC100

SP

IN

CAS

FT101

FIC101

FCV101
Easy control strategy configuration

Temperature Transmitter

TT100

IN

OUT

TIC100

IN

OUT

BCKCAL_IN

BCKCAL_OUT

Flow Transmitter

FT101

IN

OUT

CAS_IN

FIC101

IN

OUT

CAS_IN

BCKCAL_IN

FCV101

BCKCAL_OUT

Positioner.

Control Loop Knowledge Base
Easy control strategy configuration
Single Loop PID Control Configuration

![Control Loop Knowledge Base](image)
Control Loop Configuration

Transducer Scale: 10 to 210 in H2O
OUT Scale: 0 to 15 ft

PV Scale: 0 to 15 ft
OUT Scale: 0 to 100 % (Default)
Kp=1, Tr=10 min
Direct Acting

PV Scale: 0 to 100 % (Default)
Transducer Scale: 0 to 180 0 rpm
Fail Safe Value=0

TAG: LT108
TAG: LIC108
TAG: SC108
Analog Input Block

DP Measurement

- TRANSDUCER
- TRANSUDER SCALE
  - 100 % = 100
  - 25 %
  - 0 % = 0
- FUNCTION
  - Direct
  - Indirect
  - Square root
- FILTER
- OUTPUT SCALE
  - 100 % = 100
  - 0 % = 0
- Alarms
  - LOW/LOW-LOW
  - HIGH/HIGH-HIGH
- OUT
- 50 in H₂O
- STATUS
  - Good
- Sensor
- Type
- Trim
- Characterization
- Diagnostics

Control Loop Knowledge Base
Calibration in Fieldbus

- **Calibration** - **checking against a standard source** - is done in the Transducer Block.

- **Wet leg compensation** - **Elevation and Suppression** - should be done at the Analog Input Block.
TRANSDUCER BLOCKS PROVIDE DEVICE SPECIFIC INFORMATION
Impact of sample rate

- **Transducer Updates (free running)**

- **AI Updates (Depends on Macrocycle)**

- **Macro Cycle**

- **Transducer Block**

- **Analog Input Block**

Control Loop Knowledge Base
Transducer Block Filtering

- Use the Transducer Block Filter to compensate for differences between transducer and Analog Input execution rates

![Diagram showing Transducer Block Filtering](image)
Example: Single Loop

Feed Tank
Single Loop - Fieldbus

Control Loop Knowledge Base
Example: Interlock Based on Status of Blocking Valve
Interlock Example: Use of Discrete Input From Upstream On-Off Valve
Example: Selection of Redundant Measurement
Automatic Input Selection for Redundant Measurements
Example: Cascade Control

- Reactor 1
- Coolant Discharge
- TC 201
- TT 201
- TT 202
- TC 202
- RSP
Cascades Loop - Fieldbus
Arithmetic Block May be used to address a Variety of Calculations

- Flow Compensation – Linear
- Flow Compensation – Squareroot
- Flow Compensation – Approximate
- BTU Flow
- Multiply and Divide
- Average of inputs
- Sum of inputs
- Fourth order polynomial
- Simple HTG compensate level
Example: Calculation and Integration of Mass Flow
Example: Arithmetic and Integrator Function Blocks
Fieldbus enables Multi-sensor Applications

Distillation
Multi-sensor Applications (Cont)

Chemical Reactors

- Process In
- Cooling Fluid In
- Cooling Fluid Out
- Process Out
Example: Multiple Analog Input Block Supports a Maximum of 8 Inputs From a Fieldbus Device
NOTE
S
BRIGHT
ENGINEERING
1  UNLESS
OTHERWISE
NOTED ALL INSTR.
ON THIS DRAWING
CARRY AN AREA
DESIGNATION OF
878, THAT IS FI-1 IS
878FI-1.
GOOD
MANUFACTURING
IP
102
FIELD
LOCATIO
N
FIC
102
FRC
103
16
1
LIC
101
4
AI
103
19
20
21
22
23
24
25
26
INTERLOC
KS
LIME FEEDERS
WILL
TRIP OFF IF
GREEN
LIQUOR FLOW IS
LOW
From
Recover
y
Area
Green
Liquor
Storag
e
Re-
Burned
Lime
Purchase
d
Lime
Heat
er
Coole
Slaker
#1
To Slaker
#2
Condutivi
ty
CV-10
1
2
4
6
12
13
14
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25
26

Control Applications May Be Distributed

Fieldbus Segment #2

LT101  FT102  IP102  SC111  AT103  AT106  AT107B  AT107A

Green Liq Flowcv  Lime Grn Ratio  Caust. Efficiency Control

Causticizing Process

Cond.Meas. Select
Indicator

AI
LT111

LI
111

LT
111

Re-Burned Lime
Analog Input Function Block

- OUT (Mode in Man)
- OUT (Mode in Auto)
- PV
- FIELD_VAL

63% of Change

PV_FTIME

Time (Sec)
Indicator Configuration
Analog Output Function Block

- OUT (Mode in Cas)
- OUT (Mode in Auto)
- OUT (Mode in Man)
- SP

Time (Sec) 1 Second 1 Second

SP_RATE_UP

SP_RATE_DOWN
Manual Loader Function Block

- IN
- FILTER
- ALARM HI / LO
- OUTPUT OUT_HI_LIM OUT_LO_LIM
- OUT
- TRK_IN_D
- TRK_VAL
- BCKCAL_IN
- PV_FTIME
Hand Indicator Controller Configuration
Single Loop PID Control

- AI
- PID
- AO
- LT108
- LIC108
- SC108

Control Loop Knowledge Base
Control loop Configuration

**AI**

- **TAG:** LT108
- **OUT Scale:** 0 to 15 ft
- **Transducer Scale:** 10 to 210 in H2O
- **PV Scale:** 0 to 15 ft

**PID**

- **CAS_IN**
- **BCKCAL_IN**
- **FF_VAL**
- **TRK_VAL**
- **TRK_IN_D**
- **BCKCAL_OUT**

**AO**

- **TAG:** SC108
- **OUT Scale:** 0 to 100 % (Default)
- **PV Scale:** 0 to 100 % (Default)
- **Transducer Scale:** 0 to 180 0 rpm
- **Fail Safe Value:** 0

**Control Loop Knowledge Base**

**PV Scale:** 0 to 15 ft

**OUT Scale:** 0 to 15 ft

**Kp=1, Tr=10min Direct Acting**
Single Loop PID Control Configuration
Override Control

Control Loop Knowledge Base
Control Selector Block

- **BCKCAL_IN**
- **SEL_1**
- **SELECTOR SEL_TYPE**
  - high, medium or low
- **OUTPUT OUT_HI_LIM OUT_LO_LIM**
- **OUT**
- **SELECTOR SEL_TYPE**
- **BCKCAL_OUT1**
- **BCKCAL_OUT1**
- **BCKCAL_OUT1**
Override Control Configuration
Cascade Control, Split Range Control

AI → PID (TT105) → PID (TIC105) → PID (TIC104) → SPLT (FY104) → AO (IP104A, IP104B)

TT104 → AI (TT104) → TIC104 → FY104

COOLER HEATER

TIC104

Control Loop Knowledge Base
Split Range Output (FY104)

Valve Position (% of Span)

TIC104 Output (% of Span)

Cooling (IP104B)

Heating (IP104A)
Splitter Block

- **CAS_IN**
- **HI/LO LIMIT**
- **SP RATE LIMIT**
- **BCKCAL_OUT**
- **OUT_1**
- **OUT_2**
- **BCKCAL_IN_1**
- **BCKCAL_IN_2**
- **SHED MODE**
- **CALCULATE OUTPUT**
- **TABLE**
- **BALANCE OUTPUT**
- **BALANCE OUTPUT**
- **MODE**

Control Loop Knowledge Base
Splitter Block

OUT_1

OUT_2

OUT ARRAY
0 100 0 100
IN ARRAY
0 100 0 100

OUT ARRAY
100 0 0 100
IN ARRAY
0 40 35 100

OUT ARRAY
0 100 0 100
IN ARRAY
0 40 35 100

LOCK_VAL “holds”

LOCK_VAL “is zero”
Cascade Control, Split Range
Control Configuration
Ratio and Cascade
Lime/Green Liquor Vs Causticizing Efficiency

Causticizing Efficiency

Lime/GL Ratio
Lead Lag Function Block

DYNAMIC COMPENSATION

GAIN

BALANCE OUTPUT

MODE

MANUAL VALUE

IN

FOLLOW

LAG_TIME

LEAD_TIME

OUT

AUTO

MANUAL

Control Loop Knowledge Base
**Lead Lag Function Block**

- **OUT (FOLLOW On), Auto**
  - DeltOut
  - \( GAIN = \frac{\text{DeltOut}}{\text{DeltIn}} \)

- **OUT (FOLLOW Off), Auto**
  - 63% of Change
  - LAG_TIME

- **IN**
  - DeltIn

- **Time (Sec)**

---

**ControlLoop Knowledge Base**
Ratio and Cascade Configuration

Control Loop Knowledge Base
Throughput Coordination

From Recovery Area

Green Liquor Storage

Control Loop Knowledge Base
Throughput Coordination Configuration
Control For Motors

![Control Diagram]

DI → DEVC → DO

AI → AALM

FT102 → FAL102

SC 111

FAL 102

FT 102

26

25

FAL102

Run Contact

Stop

OUTPUT

Control Loop Knowledge Base
Control For Motors Configuration
Example - Control Execution

Product

Steam

TIC100.OUT

SP

TT100

IN

CAS

IN

FIC101

FCV101

FT101
Scheduling By System Management – see Communication

Total Current = \( I_{q1} + I_{q2} + I_{q3} + \ldots \ldots I_{qn} \)
Data sequence

TT

AI PID

355 lb/s
Good, Cascade

FT

FCV

TIC100.OUT

356 lb/s
Good, Cascade

Cyclic

Block Execution

Control Loop Knowledge Base
Steam

FT101

357lb/s

FIC101

55%

FCV101

Product

Control Loop Knowledge Base
Data sequence

TT
- TIC100.OUT
  - PID
  - AI
  - 355 lb/s
  - Good, Cascade

FT
- FIC101.OUT
  - PID
  - AI
  - 55 %
  - Good, Cascade

FCV
- macro-cycle

Cyclic

Acyclic

Block Execution
Data sequence

- **TT**
  - TIC100.OUT → 355 lb/s
  - Good, Cascade
  - FIC101.OUT → 55%
  - Good, Cascade

- **FT**
  - TIC100.OUT → 356 lb/s
  - Good, Cascade
  - FIC101.OUT → 56%
  - Good, Cascade

- **FCV**
  - Macro-cycle

**Cyclic**

**Acyclic**

**Block Execution**

Control Loop Knowledge Base
Data sequence

**TT**
- AI PID → 355 lb/s Good, Cascade

**FT**
- AI PID → 355 lb/s Good, Cascade

**FCV**
- AO macro-cycle → 55 % Good, Cascade

**Control Loop Knowledge Base**

- Cyclic
- Acyclic
- Block Execution
An installation with Fieldbus: Control in the Controller

1 - Transmitter
2 - Valve
3 - Cable
4 - Fieldbus Power Supply
5 - H1 Card
6 - Backplane
7 - Controller
8 - Controller Power Supply

Control Loop Knowledge Base
An installation with Fieldbus: Control in the Field

1 - Transmitter
2 - Valve
3 - Cable
4 - Fieldbus Power Supply
## Reliability Analysis

<table>
<thead>
<tr>
<th>Control in the DCS</th>
<th>Control in the Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Transmitter</td>
<td>1. Transmitter</td>
</tr>
<tr>
<td>2. Valve</td>
<td>2. Valve</td>
</tr>
<tr>
<td>3. Cable</td>
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<tr>
<td>7. Controller</td>
<td></td>
</tr>
<tr>
<td>8. Controller Power Supply</td>
<td></td>
</tr>
</tbody>
</table>

MTBF = X  
MTBF = 1.833X
Use the Compensated DP Flow Calc in the ARTH Block For Much tighter Control

- Increase Accuracy
- Easy Configuration
- Execution time = 20 ms
Measure Tank Level without Capillary Systems by using the ARTH Block

- Increased Accuracy
- Execution time = 20 ms
Use the Input Selector Block to Average or Select Stacked Transmitters

- First Good
- Maximum Value
- Minimum Value
- Average
- Execution time = 20ms
Use the Signal Characterizer to Define up to a 20 Point Input/Output Relationship

- 20 Point Strapping Table
- Execution Time = 20 ms
Use the SGCR to correct for Changing Flow Coefficients

- Increased Accuracy
- Execution time = 20 ms
Use the Integrator Block to Totalize Flows and Ratio Control

- Totalizer
- Range 0-SP or SP-0
- Set Point Pre Trip
- Set Point Trip
- Integrate Two Flows

\[ \text{Flow 1} \times (\text{Mix Ratio}) - \text{Flow 2} = 0 \]

- Maintain Mix Quality
- Execution Time = 20 ms

**Control Loop Knowledge Base**
Use the Integrator Block to Totalize Flows and trip a Discrete Output

- Flow 1 (IN_1)
- Flow 2 (IN_2)
- Rev_Flow1
- Rev_Flow2
- Reset_IN

- FT 100
- FCV 100
- FT 101
- FCV 101

Use Integrator Block output to Fine Tune Loading

Set Point
Trip
Pre Trip
Total

ControlLoop Knowledge Base
Output Splitter
Control Selector

Max
Min
First Good, Middle

S1
S2
S3
BK
O
BK1
BK2
BK3
Advanced Flow compensation Function Block

- Calculates mass flow for different types of gases and liquids based on Pressure and Temperature variations.
Multiple Analog Input Block Supports 8 Inputs
Temperature Monitoring and Data Acquisition

Example:
- 8 independently configurable channels
  - RTDs and Thermocouples
**Value Proposition**

- **Multi-Sensor vs. Sensors Wired Direct:**

  - **T/C Wire** (8 x $1.00/ft) = $8.00/ft
  - **Transmitter Wire** (1 x $0.30/ft) = $0.30/ft
Discrete Input / Output with Logic Capability

FOUNDATION Fieldbus
H1 Segment, 2-wire

Com
Input
Output

SW1
SW2
848L Logic Controller for Fieldbus

- Multiplexer for discrete inputs
  - 8 inputs / 4 outputs
- Field hardened
- Basic Logic Blocks
- Logic Function Blocks

Control room

2 Wires

Foundation Fieldbus H1

24 Wires

Control Loop Knowledge Base
Multiple Analog Input Block Supports 8 Inputs
Fieldbus enables Multi-sensor applications

Fielbus H1 - two wires

Up to 24 wires!

Chemical Reactors
Multi-sensor application

Distillation Columns

M1
M2
M3
M4
M5
M6

Naptha
Crude Oil
Kerosene
Light Gas Oil
Heavy Gas Oil
Butane and Lighter Gas

Fielbus H1 - two wires

Control Loop Knowledge Base
Flexible Function Block

FFB is a “Wrapper” for an Application-specific Algorithm

Application-Specific Algorithm
  e.g., IEC 61131
  Ladder Logic
  Structured Text
  Function Blocks

Inputs

Outputs
Flexible Function Block Capability in HSE Devices

IEC 61131
Flexible Function Block

Typical Applications

Sequence of Events
Coordinated Drives (Roll Handling)

Supervisory Data Acquisition
I/O Subsystem Interface

ControlLoop Knowledge Base
Flexible Function Block

Typical Applications

Batch Sequencing

Burner Management

AI, AO, PID, FFB

HMI

100 Mbit/s Switch

Batch Controller

FFB

Gateway

H1 Networks

Linking Device

ControlNet

DeviceNet

Interbus S

World Fip

Profibus

ControlLoop Knowledge Base
Summary - Fieldbus FOUNDATION Solution

- Both Continuous and Discrete Requirements Are Met By FF Function Block Set Capability