User Guide Supplement –
Advanced Software Options

IM/SM3000ADV Issue 4

Multipoint Videographic Recorder

SM3000

ABB

The Company

We are an established world force in the design and manufacture of instrumentation for industrial process control, flow measurement, gas and liquid analysis and environmental applications.

As a part of ABB, a world leader in process automation technology, we offer customers application expertise, service and support worldwide.

We are committed to teamwork, high quality manufacturing, advanced technology and unrivalled service and support.

The quality, accuracy and performance of the Company's products result from over 100 years experience, combined with a continuous program of innovative design and development to incorporate the latest technology.

The UKAS Calibration Laboratory No. 0255 is just one of the ten flow calibration plants operated by the Company and is indicative of our dedication to quality and accuracy.

EN ISO 9001:2000

Cert. No. Q 05907

EN 29001 (ISO 9001)

Lenno, Italy – Cert. No. 9/90A

Stonehouse, U.K.

0255

Electrical Safety

This equipment complies with the requirements of CEI/IEC 61010-1:2001-2 'Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use'. If the equipment is used in a manner NOT specified by the Company, the protection provided by the equipment may be impaired.

Symbols

One or more of the following symbols may appear on the equipment labelling:

	Warning – Refer to the manual for instructions
	Caution – Risk of electric shock
	Protective earth (ground) terminal
	Earth (ground) terminal

	Direct current supply only
	Alternating current supply only
	Both direct and alternating current supply
	The equipment is protected through double insulation

Information in this manual is intended only to assist our customers in the efficient operation of our equipment. Use of this manual for any other purpose is specifically prohibited and its contents are not to be reproduced in full or part without prior approval of the Technical Publications Department.

Health and Safety

To ensure that our products are safe and without risk to health, the following points must be noted:

1. The relevant sections of these instructions must be read carefully before proceeding.
2. Warning labels on containers and packages must be observed.
3. Installation, operation, maintenance and servicing must only be carried out by suitably trained personnel and in accordance with the information given.
4. Normal safety precautions must be taken to avoid the possibility of an accident occurring when operating in conditions of high pressure and/or temperature.
5. Chemicals must be stored away from heat, protected from temperature extremes and powders kept dry. Normal safe handling procedures must be used.
6. When disposing of chemicals ensure that no two chemicals are mixed.

Safety advice concerning the use of the equipment described in this manual or any relevant hazard data sheets (where applicable) may be obtained from the Company address on the back cover, together with servicing and spares information.

Contents

1 Introduction

This supplement details the programming and operation of the math equations and logic editor option on the Multipoint Videographic Chart Recorder.

The instructions contained herein must be read in conjunction with the instrument's User Guide (IM/SM3000 issue 3 or later).

Instruments with the optional math equations and logic editor functionality are identified by the appearance of the respective items in the main Operator menu – see Fig. 1.1.

For information on accessing Configuration mode, refer to Section 4 of the User Guide.

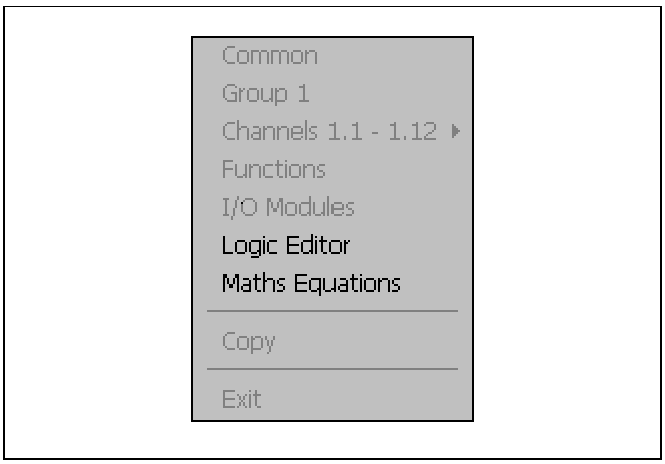


Fig. 1.1 Math and Logic Menu Items

2 Math Configuration

2.1 Math Block Description

Note.

- Up to twelve Math Blocks, configured individually using the 'Math Pad' – see Fig. 2.2, page 6.
- Each Math result has its own Long and Short Tags and Engineering Range
- Up to 18 different preset functions – see Table 2.4, page 5
- Constants up to three decimal places
- Maximum equation length – 40 characters
- Up to three digital signals per equation

Individual recording channel signals, analog and digital sources can be combined in a Math Block to produce a customized recording channel or retransmission source.

Typical examples include adding/subtracting the values of a number of analog sources together to form one recording channel.

More complex blocks can also be implemented that determine relative humidity, mass flow or zirconia oxygen concentration.

Digital signals can be used in Math Blocks to enable/disable the output when certain conditions are true.

2.2 Typical Math Block – Fig. 2.1

Each math block comprises any number of sources, constants, operators and functions, to a maximum length of 40 characters, – see Fig. 2.1, page 3.

Possible operators, sources and functions are listed in Tables 2.1 to 2.4.

2.3 Operators – Table 2.1

Operator	Description	Operator	Description
+	Add	–	Subtract
*	Multiply	/	Divide

Table 2.1 Operators

2.4 Constants

Math blocks may contain any number of constants, each with a limit of three decimal places, up to the maximum of 40 characters for the whole block. The maximum range of each constant is 9999 to – 999.

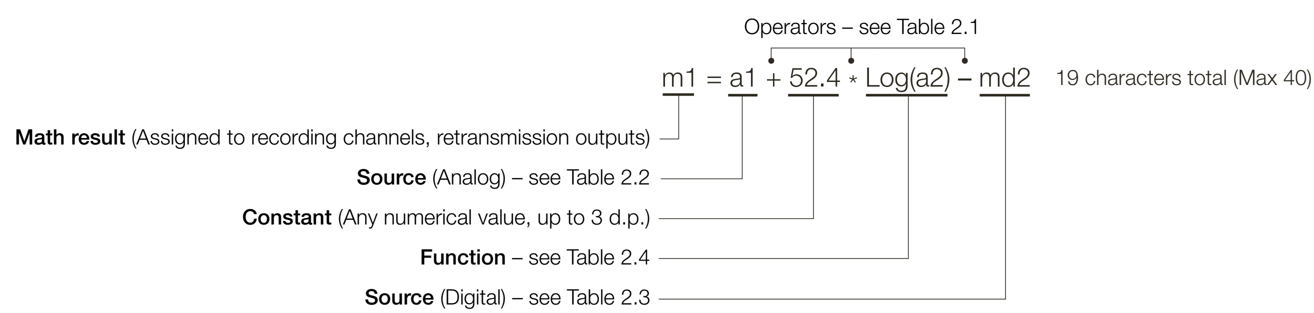


Fig. 2.1 Typical Math Block

Note.

- Operators are evaluated from left to right therefore the above equation is evaluated as:
  [(a1 + 52.4)* Log(a2)] – md2 and NOT as a1 + (52.4* Log(a2)) – md2.
- Functions cannot be nested within other functions. To enter an equation requiring nested functions it is necessary to use another math block, e.g. to evaluate the equation:
  $\frac{a1 + a2}{52.4 - a3}$ proceed as follows:
  - Enter math block 1 as m1 = a1 + a2/m2
  - Enter math block 2 as m2 = 52.4 – a3
- Digital signals (md1 to md3) are evaluated as 0 (inactive) and 1 (active), thus in the following example:

  m1 = a1 + a2*md1

  the sum of (a1+ a2) is set to zero if the digital input md1 is also zero.

2.5 Analog Sources – Table 2.2

Sources can be either analog or digital.

Analog sources are identified within a math block by the preset mnemonic shown in Table 2.2.

Source Name		Mnemonic	Description
Analog input values	Analog I/P A1 to Analog I/P F6	a1 to f6	From Analog input module.
Comms Analog input values	Comms AIN 1 to Comms AIN 24	ci1 to ci24	Received via the Modbus/Modbus TCP serial communications link – see Appendix B in the User Guide (IM/SM3000).
Maximum Statistics Input Value See **Note** at top right	Stats 1.1A max to Stats 6.12B max	sh11a to sh612b	Value since the totalizer on a given channel last wrapped or reset. Available only on analog channels and only if the relevant totalizer is enabled.
Minimum Statistics Input Value See **Note** at top right	Stats 1.1A min to Stats 6.12B min	sl11a to sl612b	Value since the totalizer on a given channel last wrapped or reset. Available only on analog channels and only if the relevant totalizer is enabled.
Average Statistics Input Value See **Note** at top right	Stats 1.1A avg to Stats 6.12B avg	sa11a to sa612b	Value since the totalizer on a given channel last wrapped or reset. Available only on analog channels and only if the relevant totalizer is enabled.
Math Blocks	Math Block 1 to Math Block 12	m1 to m12	Current value of the math result. Enabled math blocks only.

Table 2.2 Analog Sources

Note. Mnemonics for statistics (maximum, minimum and average) values are interpreted as follows:

s	statistics
h l a	(high) maximum value (low) minimum value average value
1…6	group
1…12	channel
a b	totalizer A totalizer B

s h 3 12 b maximum value of input to totalizer 3.12B

2.6 Digital Sources – Table 2.3

Up to three digital signals, identified within the Math Pad as md1, md2 and md3, can be used within each math block. These signals must be assigned to a digital source from Table 2.3 prior to selection within the math pad.

Source Name	Mnemonic	Description
Any internal or external digital signal available in the instrument	md1 md2 md3	See Appendix A in the User Guide (IM/SM3000).
Math Block 1 Failure to Math Block 12 Failure		Active when math block result falls outside the ±10% fault detection level
Logic Equation 1 to Logic Equation 12		Logic equation results.

Table 2.3 Digital Sources

2.7 Functions – Table 2.4

All functions begin with an uppercase character to distinguish them from sources.

Function	Description
Trigonometric Functions: – see Section 2.9.1, page 10	
Sin(x)	The sine of x (x specified in radians, Rad = π/180°)
Cos(x)	The cosine of x (x specified in radians, Rad = π/180°)
Tan(x)	The tangent of x (x specified in radians, Rad = π/180°)
Statistical Functions: – see Section 2.9.2, page 10	
Avg(x, n, t)	The average of variable x, over n samples at a sample rate of t seconds. n=1 to 9999 samples, t=1 to 9999 seconds. The average resets after n samples.
Rav(x, n, t)	The rolling average of variable x, over n samples at a sample rate of t seconds. The oldest sample in each Rav calculation is lost and the new result is calculated by taking into account the current sample. N=1 to 9999 samples, T=1 to 9999 seconds.
Sd(x, n, t)	Standard Deviation of variable x, over n samples at a sample rate of t seconds. N = 1 to 200 samples; t = 1 to 9999 seconds.
Logarithmic Functions: – see Section 2.9.3, page 10	
Log(x)	Log base 10 of x. For Antilog, see X^a (x, a)
Ln(x)	Natural log of x
Exp(x)	e to the power x
Special Functions: – see Section 2.9.4, page 10	
RH(x, y)	Relative humidity calculation using wet(x) & dry(y) bulb readings
F0(x, y, z)	Optimization of sterilization times using F0 calculation and measured temperature(x), target temperature(y) and Z factor(z)
Abs(x)	The absolute value of variable x
Switch Functions: – see Section 2.9.6, page 14	
Hs(x, y, z)	Returns the variable with the greatest magnitude
Ms(x, y, z)	Returns the variable whose magnitude is between the upper & lower limits of the three variables
Ls(x, y, z)	Returns the variable with the smallest magnitude
Mux(x, y, s)	Selects x if s is false, otherwise y
Power Functions:	
X^a (x, a)	Raises the variable x to the power a
Sqr(x)	Returns the square root of variable x

Table 2.4 Functions

2.8 Creating Math Blocks – Figs. 2.2 and 2.3

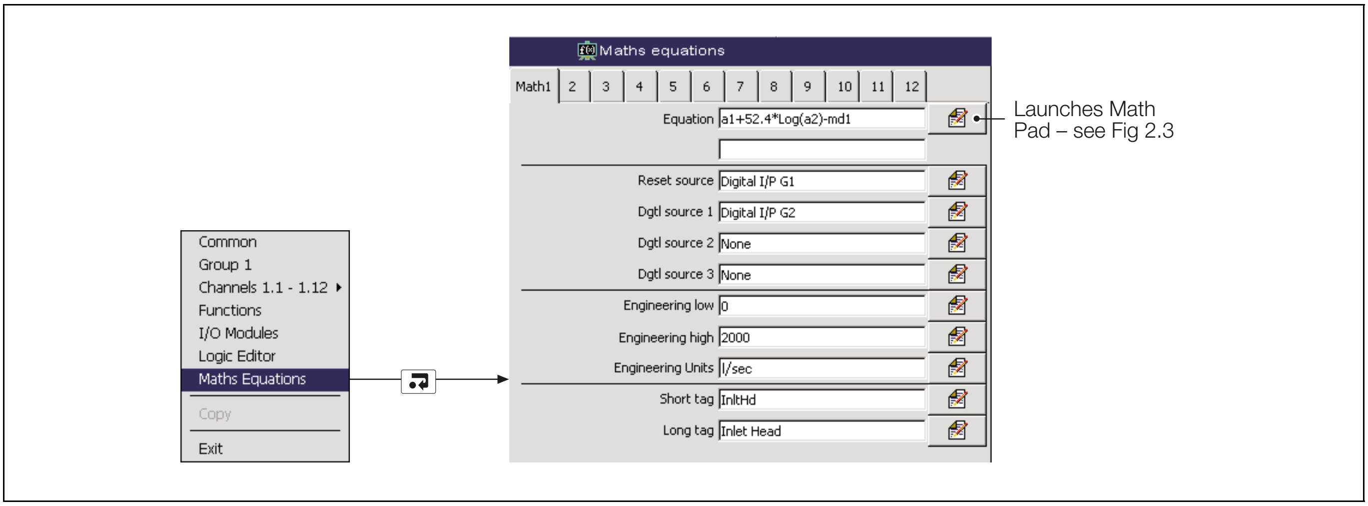


Fig. 2.2 Launching the Math Block Editor (Math Pad)

Note. For further information on accessing the Configuration level, refer to Section 4 of the User Guide (IM/SM3000).

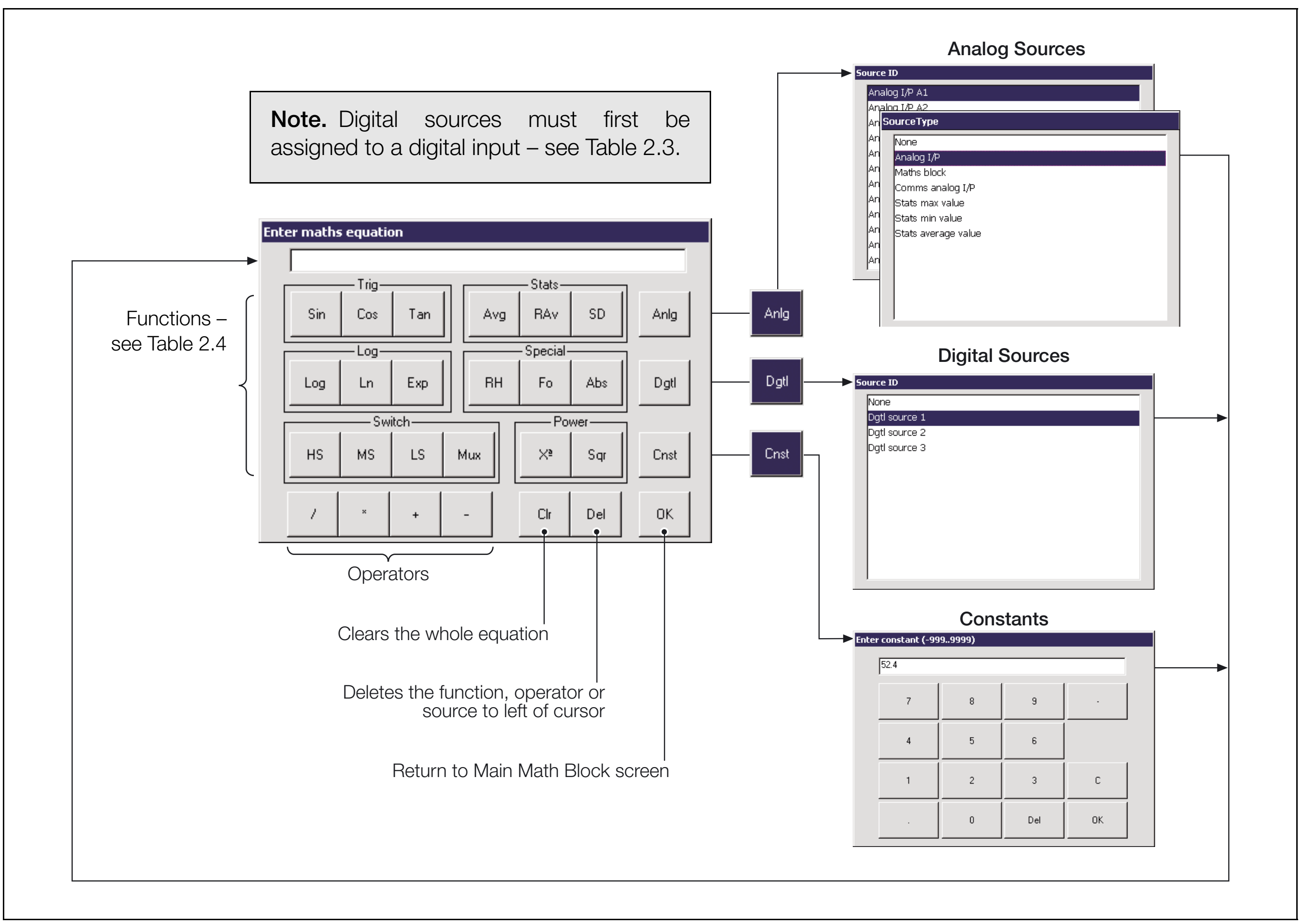
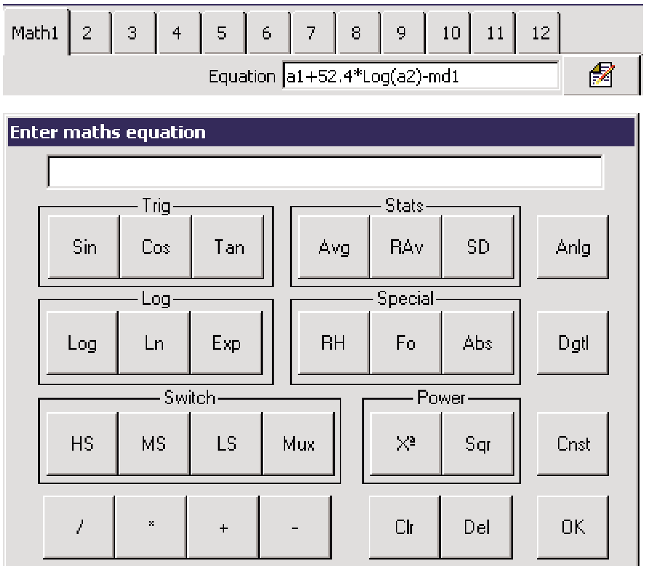


Fig. 2.3 Math Pad



Select the Math Block to configure – M1 to M12.

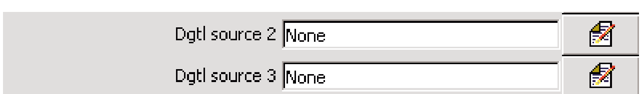
Set the equation using the math pad – see Fig. 2.4, page 5.

Note. Digital sources must first be assigned to a valid digital signal – see below.

Set the digital source (e.g. alarm signal, real-time event) used to reset the equation.

Select the digital signal (e.g. alarm signal, real-time event) used as Digital Source 1 (md1) within the math block.

Note. When used in a Math Block, an active digital signal has a numerical value of 1 and an inactive digital signal has a value of 0.



Select the digital sources (e.g. alarm signal, real-time event) used as Digital Source 2 and 3 (md2 and md3) within the equation.

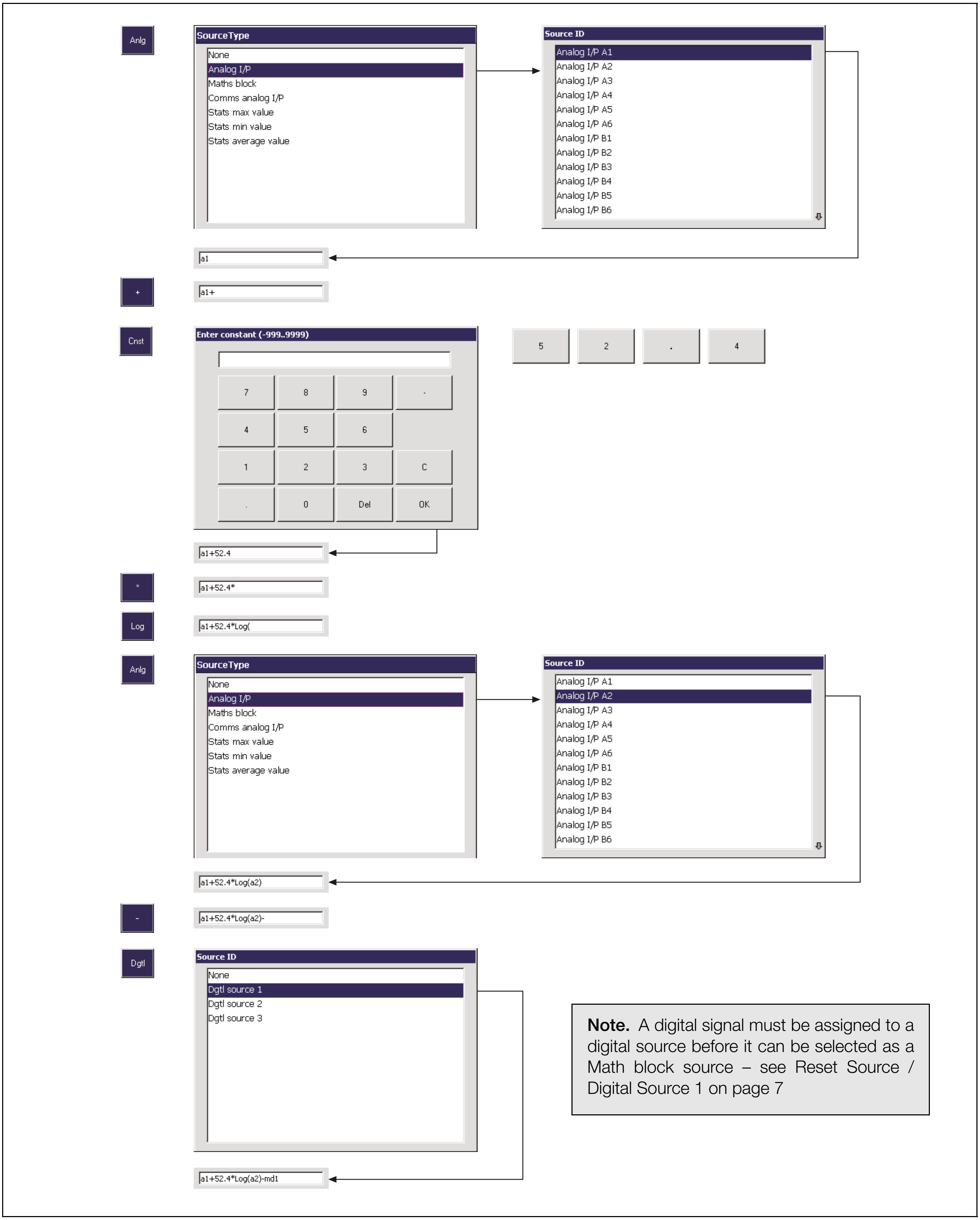
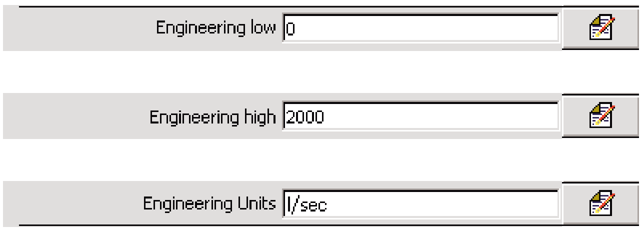


Fig. 2.4 Worked Example



Specify the display range and units of the engineering value corresponding to the electrical high and low values, within the limits defined below:

Example – Maximum and minimum calculated values function.

$a1 + a2$, where $a1 \equiv 0$ to 150 l/s, $a2 \equiv -50$ to 100 l/s, Engineering High = 250.0, Engineering Low = –50.0.

Note. For the best resolution enter engineering ranges to the maximum permissible number of decimal places.

Enter the tag name to be displayed on channel indicators and used to identify the channel in archive files. (8 characters max.).

Note. Tags with a high percentage of capital letters and wide characters such as 'W' or 'M' may appear truncated in some Operator Views. In such cases, use lower case letters or fewer characters.

Enter the tag name to be displayed in the process view and used in the archive files (20 characters max.).

2.9 Standard Functions

The following examples, using preset functions available on the Math Pad, are included for easier reference.

2.9.1 Trigonometric Functions

Three trigonometric functions, Sin(x), Cos(x) and Tan(x) return the Sine, Cosine and tangent of the variable x.

> **Note.** The variable x must be specified in Radians, where 1° = π/180 Radians.
>
> For example, to find the Sine of 90°, first convert degrees to radians:
>
> 90° = (90 x π) / 180 = π/2 ≈ 1.571Radians
>
> The equation is entered as Sin(1.571)

2.9.2 Statistical Functions – Table 2.5 and Fig. 2.5

Statistical functions can be used to calculate the average, rolling average and standard deviation of an analog variable.

Instantaneous Samples		RAv()Rolling Average		Avg() Average		SD() Standard Deviation	
No.	Value	Value	Samples	Value	Samples	Value	Samples
1	40	**40.0**	1	–	–	–	–
2	80	**60.0**	1 to 2	–	–	–	–
3	70	**63.3**	1 to 3	–	–	–	–
4	50	**60.0**	1 to 4	–	–	–	–
5	60	**60.0**	1 to 5	**60**	1 to 5	**12.9**	1 to 5
6	30	**58.0**	2 to 6				
7	40	**50.0**	3 to 7				
8	100	**56.0**	4 to 8				
9	120	**70.0**	5 to 9				
10	110	**80.0**	6 to 10	**80**	6 to 10	**37.4**	**31.0**
11	100	**94.0**	7 to 11				

Table 2.5 Sample Statistical Calculations

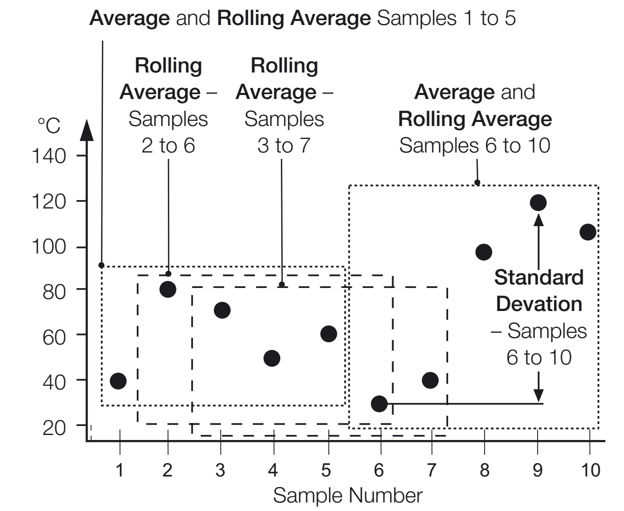


Fig. 2.5 Samples Included

2.9.3 Logarithmic Functions

The logarithmic functions Log(x), Ln(x) and e^x can be used to scale process inputs.

Example – the output of vacuum gauges follow a logarithmic curve and this must be linearized, therefore the antilog of the input must be derived:

Linear Vacuum = k.10(Vacuum Gauge Output)

2.9.4 Relative Humidity – Fig. 2.6

Relative humidity is calculated using the following formula:

$$RH = 100 \times \frac{VPSw - AP \times (Td - Tw)}{VPSd}$$

Where:

VPSw = Saturation Vapour Pressure at Wet Bulb Temperature

VPSd = Saturation Vapour Pressure at Dry Bulb Temperature

Td = Dry Bulb Temperature

Tc = Wet Bulb Temperature

P = Total Atmospheric Pressure (1000 mbar)

A = Psychometric Constant (6.66 x 10–4)

RH = % of Relative Humidity

A relative humidity calculation requires two inputs, one from a wet bulb sensor and one from a dry bulb sensor. Both of these inputs are incorporated into the equation as analog.

RH tables are based on the use of an aspirated psychrometer having an air velocity of at least 11.5 feet per second or 3.5 meters per second across the bulb sensors.

Inputs used for wet and dry bulb measurement must be in the ranges 0 to 100°C or 32 to 212°F. The result must be set to 0 to 100.0% RH.

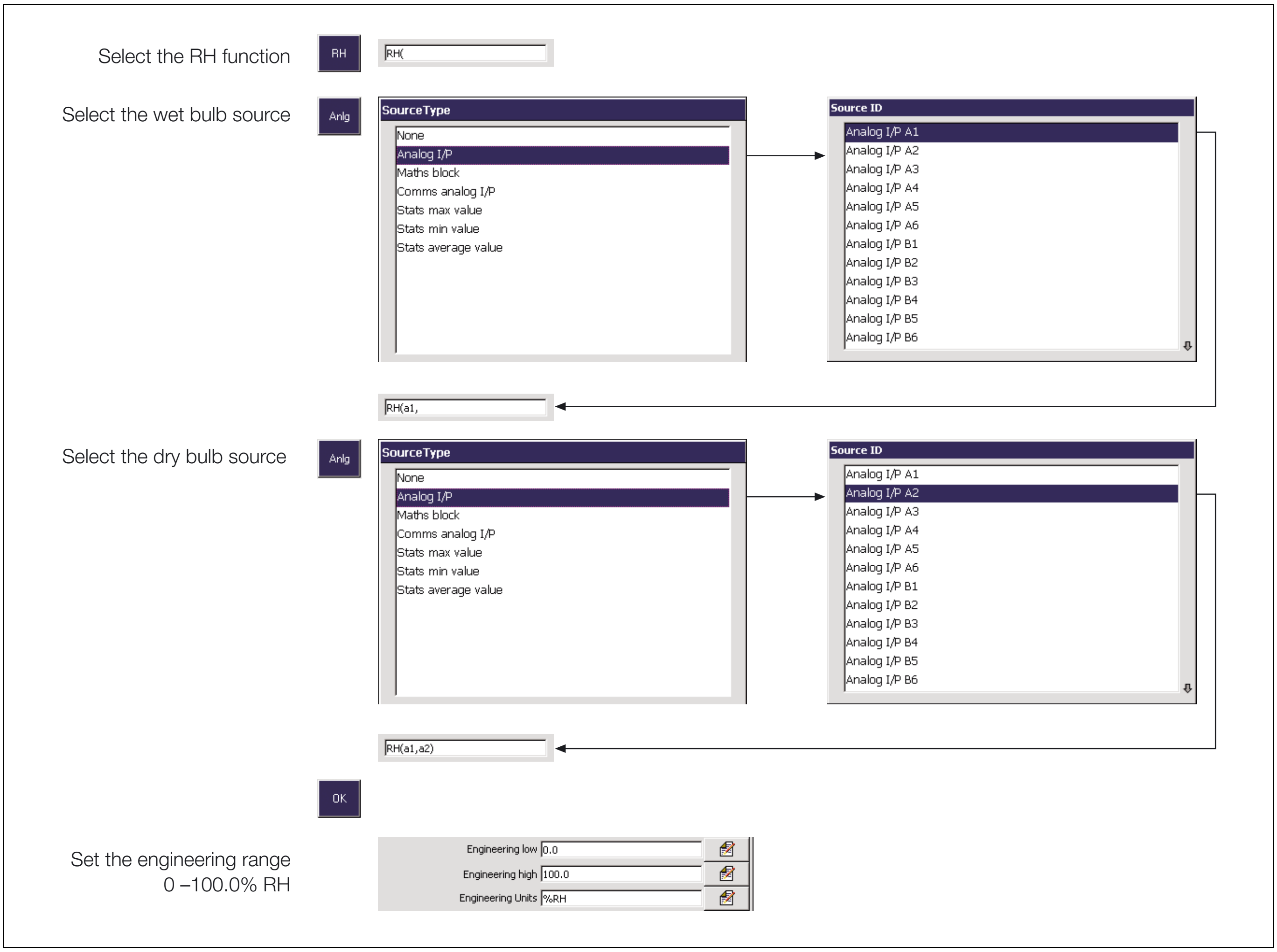


Fig. 2.6 Relative Humidity Calculation

2.9.5 Sterilization Fvalue Calculation – Fig. 2.8

The ability of heat to kill micro-organisms varies with the type of organism and increases exponentially with rising temperature.

Therefore, the time taken in sterilization is reduced if the target temperature is increased and the time spent approaching and receding from the target temperature can be taken into account.

Example – an increase of 10°C from 121.1 to 131.1°C in the steam sterilizing temperature of the *Bacillus stearo-thermophilus* organism increases the death rate by a factor of ten.

The change in sterilization temperature which causes a factor of 10 change in the death rate is unique to each organism and is called the Z value.

Although 121.1°C is universally accepted as a reference for steam sterilization processes, the actual sterilizing temperature varies, depending on the products involved and on each sterilization process.

The Fvalue is calculated using the general formula:

$$F_{val(t)} = F_{val(t-1)} + \frac{\left(10^{\frac{x-y}{z}}\right)}{60}$$

Where

$F_{val(t)}$ = Current Fvalue
$F_{val(t-1)}$ = Fvalue at last sample
x = Actual temperature
y = Target temperature
z = Z-factor (i.e. the temperature interval representing a factor of 10 reduction in killing efficiency)

Example – A typical steam sterilizing cycle – refer to Fig. 2.7 below.

The period AB is the chamber evacuation part of the cycle, when the chamber is alternatively evacuated and purged with steam to remove air. The ramp up to final sterilizing temperature starts at B. The thermal conductivity of the load determines the time taken to achieve point D, but is typically 30% of the total cycle time. It is in the area, C D, and E F, that Fvalues make their contribution to shortening sterilization time, by accumulating credit for the time spent approaching and receding from the sterilizing temperature.

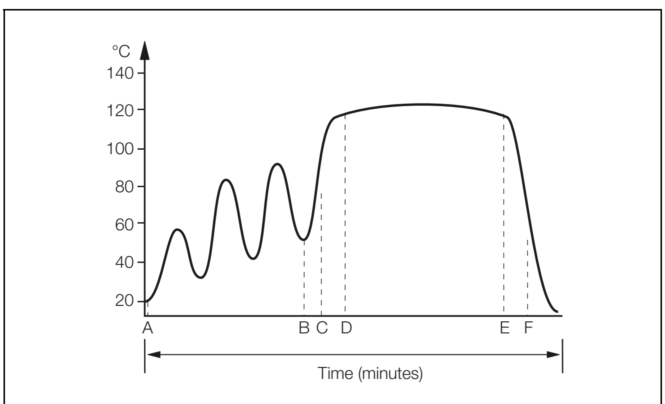


Fig. 2.7 Typical Steam Sterilization Cycle

It is important to note the large change in equivalent sterilizing time which results from a small increase in the sterilizing temperature. Going from 121°C to 122°C, an increase of only 1°C, reduces the time needed to kill an equal number of organisms by a factor of 26%. Likewise, a measurement error which results in the set point being 1°C too low could result in a product not being sterilized properly.

As the Fvalue calculation is essentially a logarithmic function, the effect of measurement errors is significant on the resultant Fvalue.

Table 2.6 shows the resultant error in the Fvalue resulting from various measurement errors with a Z value of 10°C.

Temperature Error (°C)	Fvalue Error (Fo)
0.1	2.3%
–0.1	–2.3%
0.5	12.0%
–0.5	–11.0%
1.0	26.0%

Table 2.6 Fvalue Accuracy

The recorder can measure TC and RTD inputs with an accuracy of better than 0.1%. This results in superior Fvalue calculation accuracy.

To improve the accuracy even further the Scale Adjust facility can be used to adjust the individual channel readings to be correct at the sterilizing temperature.

As Fvalue calculation is an integrating function, the sample rate has a direct effect on the accuracy when the temperature is changing. With a steady state signal the sample rate does not affect accuracy.

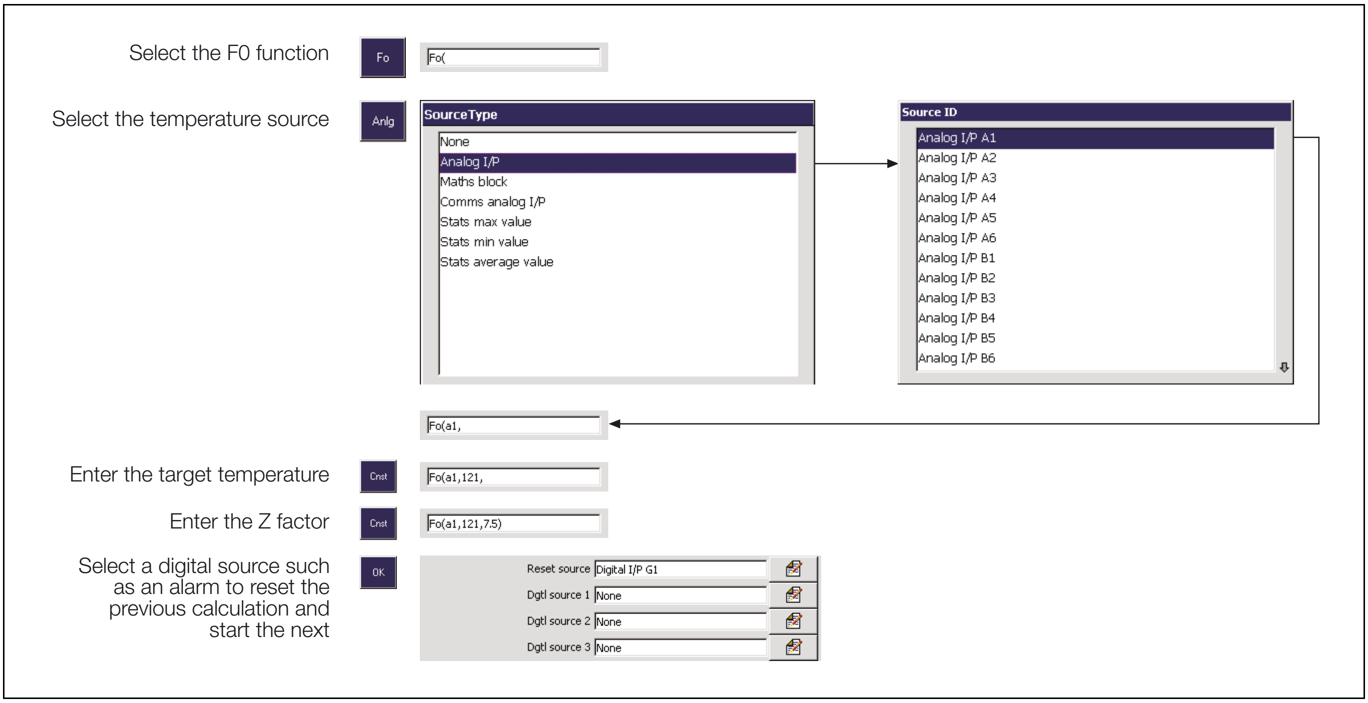


Fig. 2.8 Sterilization Fvalue Calculation

2.9.6 Switch Functions – Figs. 2.9 and 2.10

The switch functions, HS (High Select), MS (Median Select) and LS (Low Select) are used to select between the highest, median and lowest of three analog values.

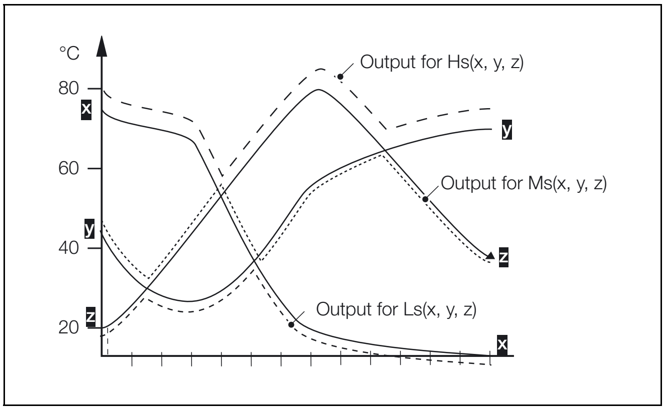


Fig. 2.9 High, Median and Low Select

The switch function Mux (Multiplexer) is used to switch between 2 analog values when a third value becomes true – see Fig. 2.10

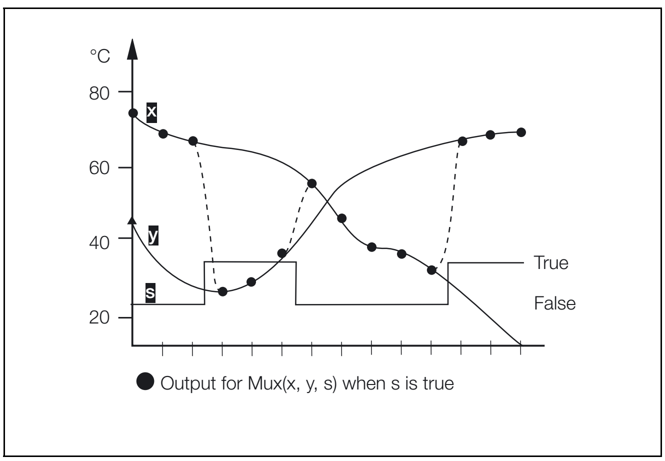


Fig. 2.10 Multiplexer Operation

2.9.7 Absolute Value Function – Fig. 2.11

The Absolute Value Function converts any negative value to it's positive equivalent – see Fig. 2.11.

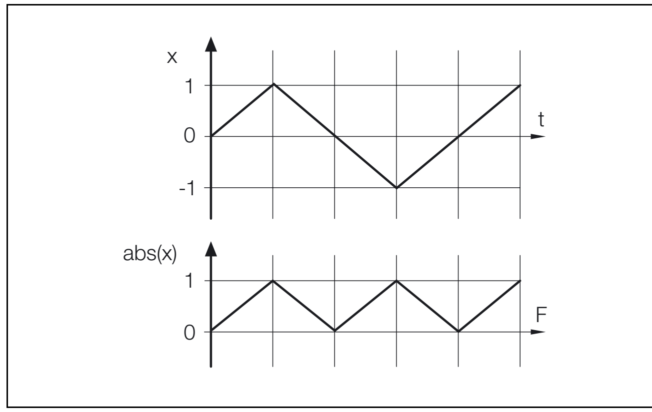


Fig. 2.11 Absolute Value Function

Therefore, if the Absolute Value Function is used to monitor the difference between two flows A and B, where Flow A could be greater than or less than Flow B, the function will always return a positive value, which represents the unsigned magnitude of the difference between the flow rates.

2.10 Application Examples

2.10.1 Liquid Flow – Fig. 2.12

Liquid Flow is measured in two ways:

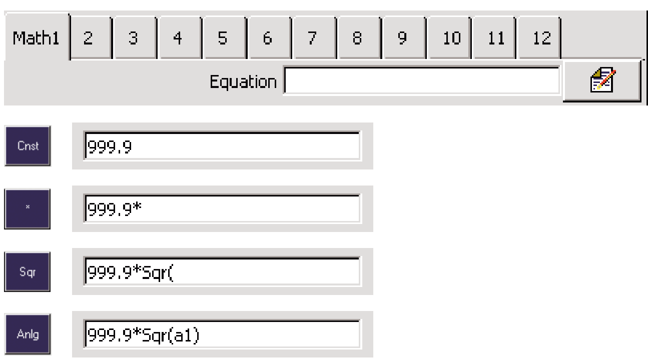
1. Using a linear flow device such as Vortex, Swirl, Ultrasonic, Turbine and Magnetic Flowmeters
2. Using a differential pressure transmitter across an orifice plate or wedge.

Corrections can be applied to compensate for variations in temperature and density – see Fig. 2.12, page 16.

Square Root Extraction and Scaling

Normally, square root extraction and scaling ($Q = K\sqrt{h}$) is achieved in the DP transmitter or using an input linearizer within the instrument.

If this is not possible, a math block can be used as follows:



Temperature Compensation

Assuming linearization and scaling has been achieved on either the DP transmitter or linearizer input, temperature compensation can be calculated as follows:

$$Qc = \frac{Q}{1 + (t_r - t_b)a}$$

This is implemented in the instrument (assuming the linearized flow is on input a1) as follows:

$$Qc = \frac{a1}{t_r - t_b \times a + 1}$$

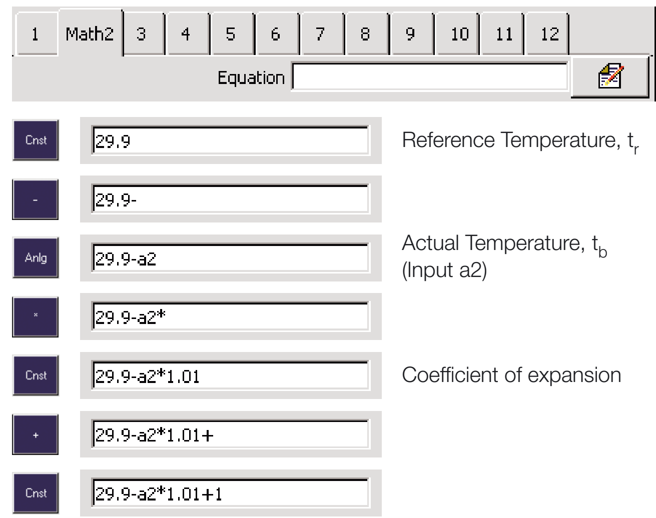
This requires two math blocks:

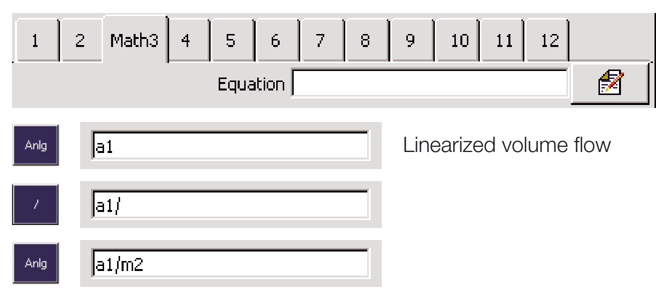
$$m2 = t_r - t_b \times a + 1$$

and

$$m3 = a1 / m2$$

created as follows:





Mass Flow Calculation – Average density correction

The average density over a given temperature range is used to calculate the mass flow as follows:

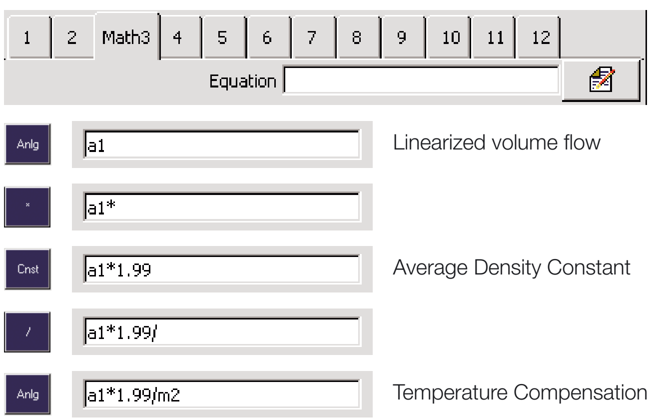
Qma = Qc x Da,

where Qc is the temperature compensated flow and Da (a constant) is the average density.

This is implemented as follows:

$$m3 = \frac{a1 \times Da}{m2}$$

where a1 and m2 are the linearized flow and temperature compensation from the previous example:



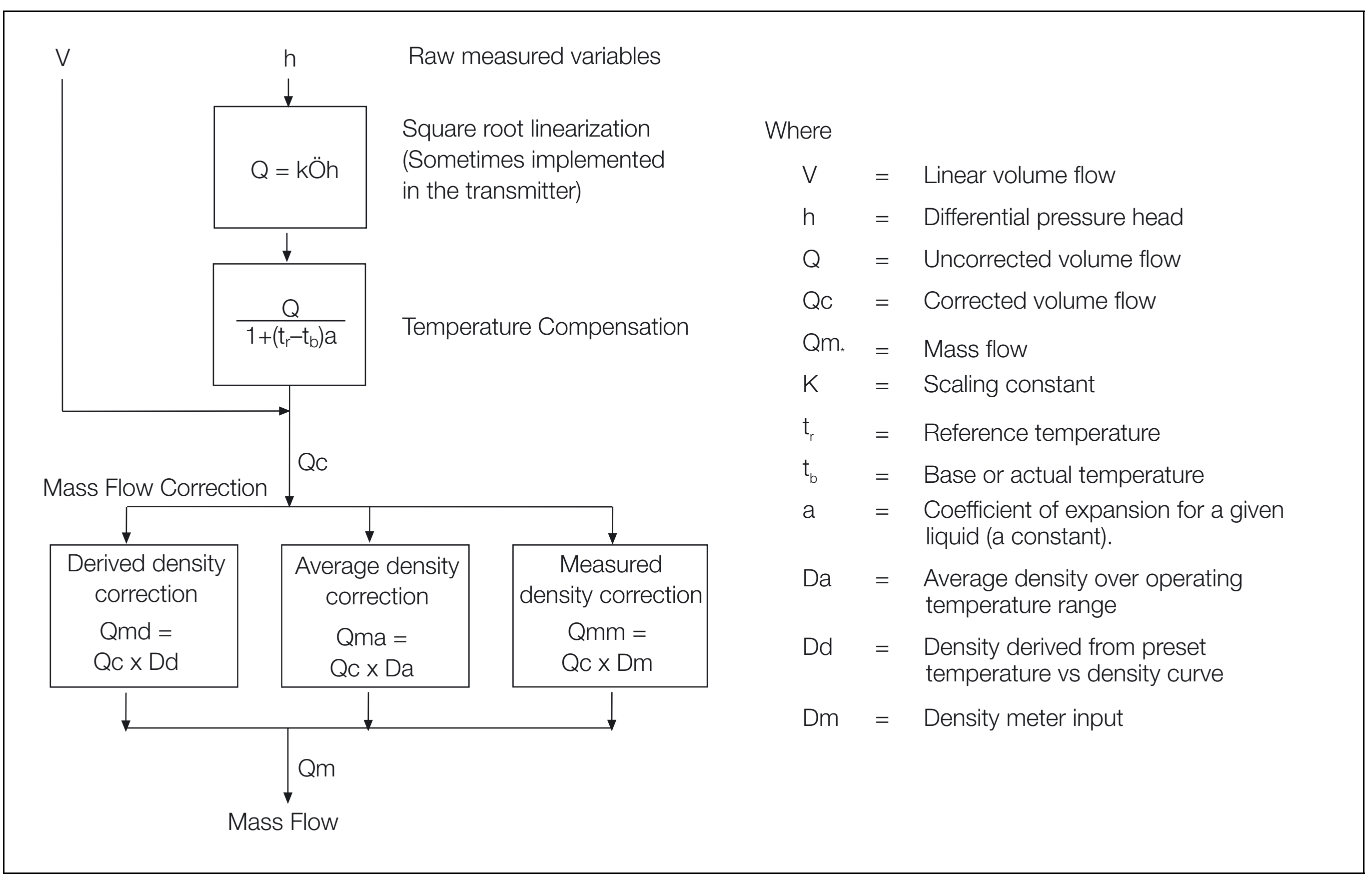


Fig. 2.12 Temperature and Density Compensation

Mass Flow – Derived density correction

This method uses a preset table of temperature and density values to define the correction, which is calculated as follows:

Qmd = Qc x density correction

$$m3 = \frac{a1 \times a3 \times \text{scaling factor}}{m2}$$

Note. Input a3 is the actual product temperature input (as a2 in previous examples) but with the density correction applied using a custom linearizer – see Section 4.8.1 of the User Guide (IM/SM3000).

Mass Flow – Measured Density Correction

Qmm = Qc x input from density meter.

$$m3 = \frac{a1 \times a3 / m2}{m2}$$

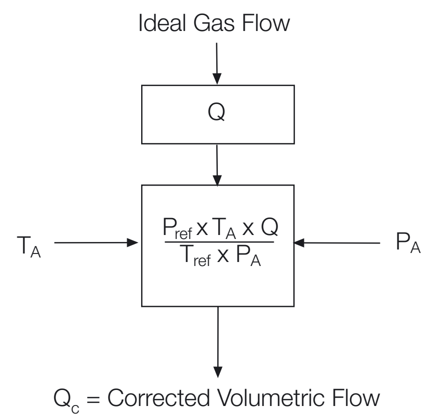
Where a3 is the input from an external density meter.

Note. With all of the above calculations the engineering range should allow for the extremes of all the input variables.

2.10.2 Ideal Gas Flow

Gas flow is usually measured using a differential pressure device across orifice plates and wedges.

Corrections can be applied to compensate for variations in temperature and pressure – see Fig. 2.13.



Q	=	Volumetric uncorrected flow
T_{ref}	=	Reference temperature in K or ºR
T_A	=	Actual temperature in K or ºR
P_{ref}	=	Reference pressure in Absolute
P_A	=	Actual pressure in Absolute

Fig. 2.13 Temperature and Pressure Compensation

Where $Q = K\sqrt{h}$, the square root extraction and scaling can be achieved on the DP device or on the input set up of the instrument.

Let m1 = constant 1 x a3

Qc = m2 = a1 x constant2 x a2/m1

Note. The engineering range should allow for the extremes of all the input variables.

3 Logic Configuration

3.1 Logic Equation Description

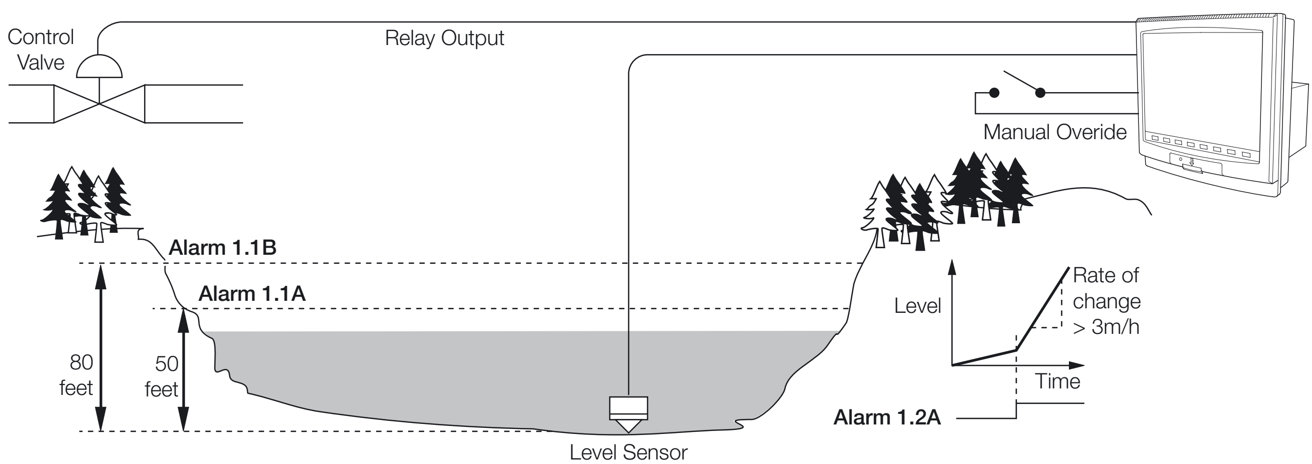
Note.

- 12 logic equations
- Up to 6 operands and 5 operators per equation
- OR/AND/NOR/XOR/NAND/NOT operators – see Table 3.1 overleaf
- Can combine internal and external digital signals – i.e. alarms, digital inputs, other logic equation results and real time events (timer option).

3.2 Worked Example – Reservoir Level Control – Fig. 3.1

Note. This example uses an optional Hybrid I/O Module in position C – see Appendix E in the User Guide (IM/SM3000).

- Channel 1.1 records the reservoir level, with an engineering range 0 to 100 feet.
- Alarms 1.1A, 1.1B and 1.2A monitor the reservoir level.
- Digital output G2 drives the control valve from Logic Equation 1.
- Digital input G1 operates the manual override.



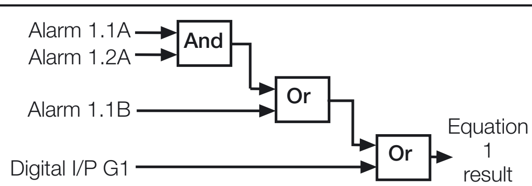
Flow Conditions

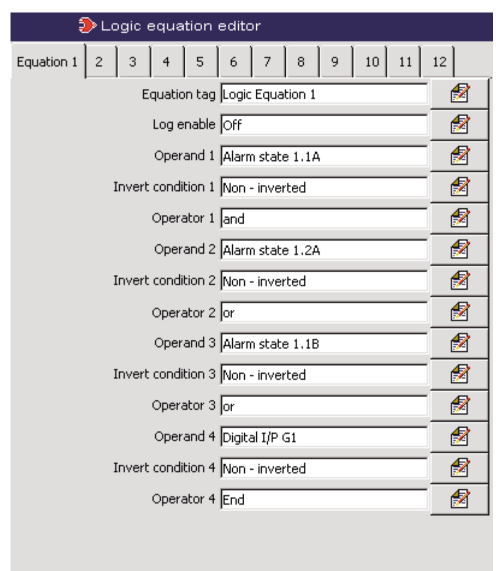
Close reservoir control valve if:

- Reservoir level >50 feet AND rate of change >10 ft/hr
  OR
- Reservoir level >80 ft
  OR
- Manual override switch operated

Input Elements

- Alarm 1.1A – set to high process trip at 50 ft
- Alarm 1.1B – set to high process trip at 80 ft
- Alarm 1.2A – set to fast rate trip at 10% of range per hour (10 ft/hr)
- Manual override switch – connected to (optional) digital input G1





Note. Elements within each equation are calculated sequentially.

Fig. 3.1 Logic Equation Example

3.3 Creating Logic Equations – Fig. 3.2

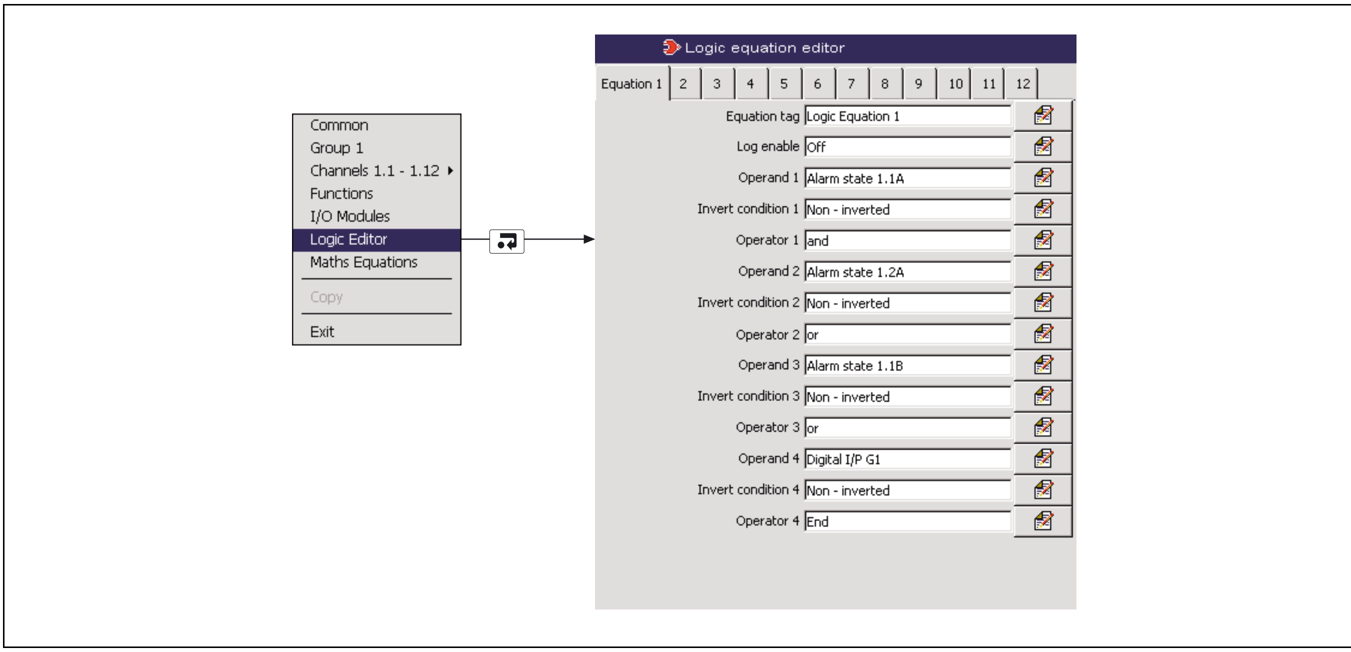
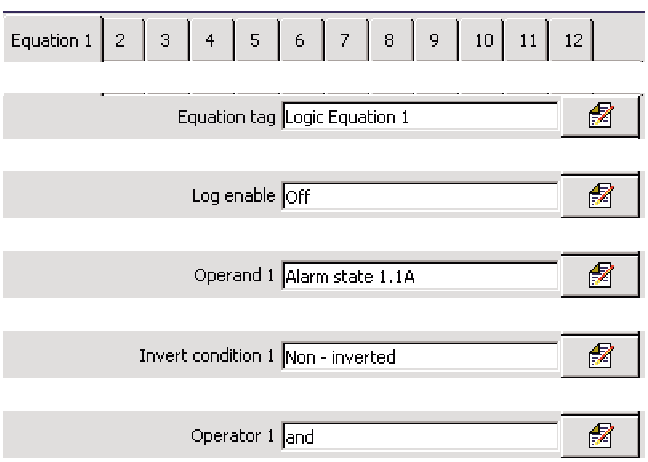


Fig. 3.2 Launching the Equation Editor



Select the logic equation to create or modify.

Enter the equation tag to be displayed in the alarm event log (20 characters minimum).

Set to 'On' to enable changes in the equation's state to be recorded in the alarm event log.

Specify the first operand – can be any digital signal.

Invert the signal, if required.

Select an operator for the next input – see Table 3.1.

Repeat these steps until equation is complete.

Operand Values		Result				
A	B	AND	NAND	OR	NOR	XOR
0	0	0	1	0	1	0
0	1	0	1	1	0	1
1	0	0	1	1	0	1
1	1	1	0	1	0	0
		Active if all inputs high	Active if any (or all) input(s) low	Active if any (or all) input(s) high	Active if no inputs high	Active if any (but not all) input(s) high

Table 3.1 Logic Operators

4 Diagnostics

4.1 Introduction

> **Note.** Math blocks and logic equations can be tested for correct operation and monitored using the diagnostics facility in the Set Up level. For information on accessing the Set Up level, see Section 3 of the User Guide (IM/SM3000).

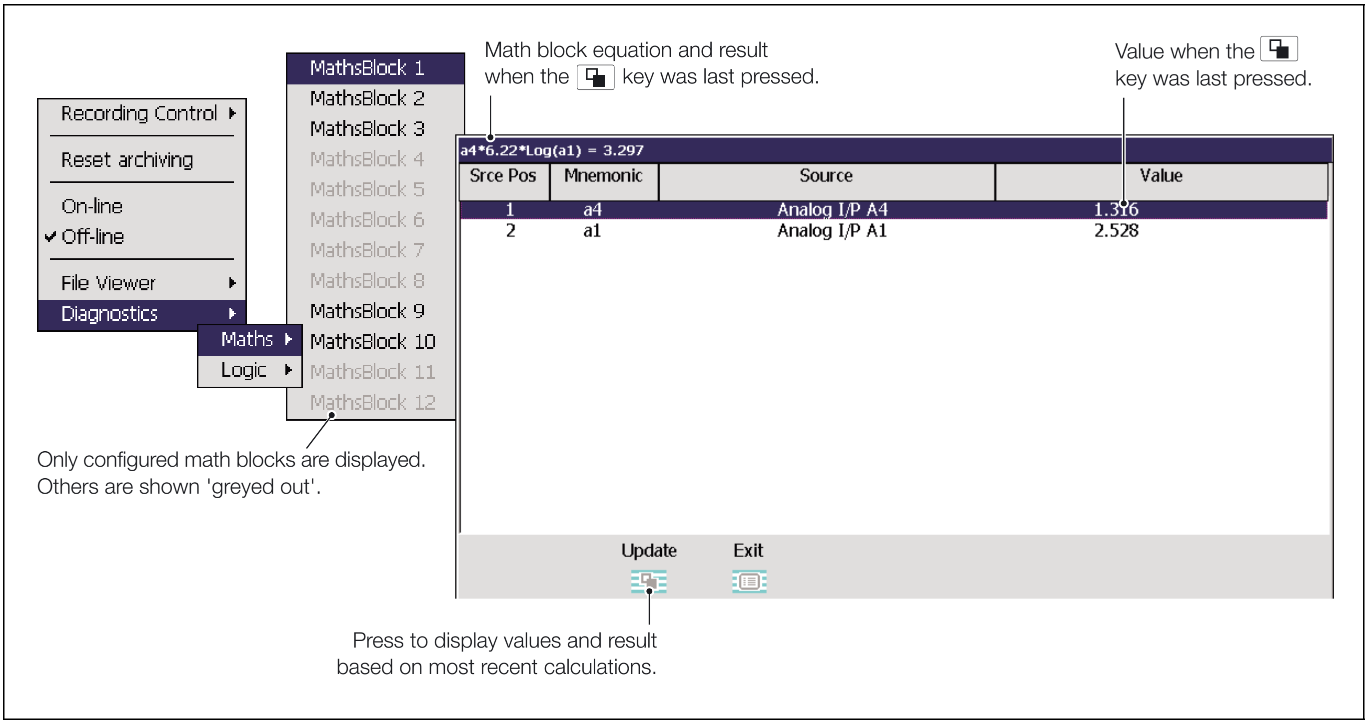


Fig. 4.1 Math Block Diagnostics

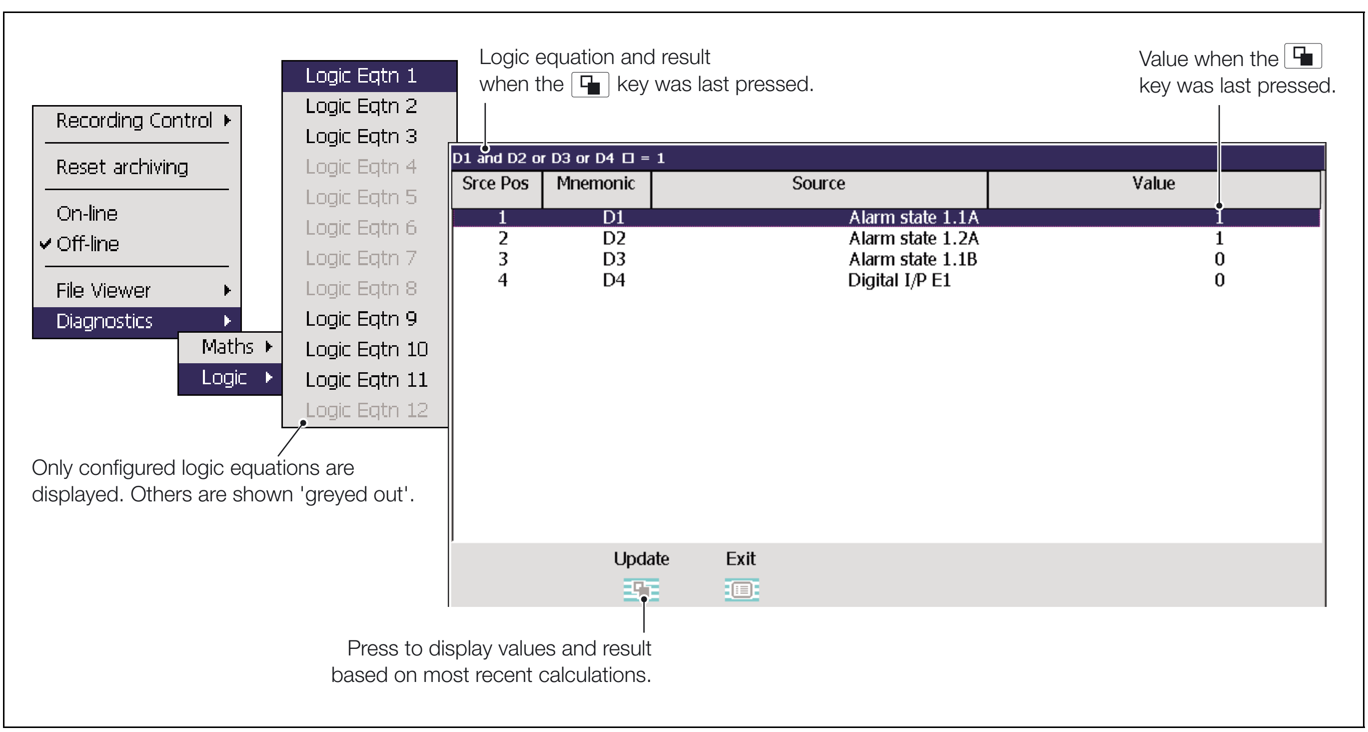


Fig. 4.2 Logic Equation Diagnostics

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Customer Support

We provide a comprehensive after sales service via a Worldwide Service Organization. Contact one of the following offices for details on your nearest Service and Repair Centre.

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Client Warranty

Prior to installation, the equipment referred to in this manual must be stored in a clean, dry environment, in accordance with the Company's published specification.

Periodic checks must be made on the equipment's condition. In the event of a failure under warranty, the following documentation must be provided as substantiation:

1. A listing evidencing process operation and alarm logs at time of failure.
2. Copies of all storage, installation, operating and maintenance records relating to the alleged faulty unit.

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