FUTUREDESIGN CONTROLS

Which Input Resolution would you choose for your Temperature Control?

Thermocouple Type	18 Bit Input	16 Bit Input	14 Bit Input	12Bit Input
Type J	0.008F	0.035F	0.142F	0.57F
Type K	0.014F	0.056F	0.228F	0.91F
Type R	0.046F	0.186F	0.744F	2.97F
Type B	0.072F	0.289F	1.16F	4.63F

Input Resolution is an important specification to a process control's performance & accuracy. FDC's 18 Bit A/D and 15 Bit D/A is the highest Input & Output resolution in the industry. Couple this to our 200 ms input scan and proprietary Fuzzy PID auto-tuning results in a high performance control with the industries lowest pricing.

FDC 300, 100, C Series controls and VR18 paperless recorder all have common input and output resolution and scan rate specifications.

What Does Scan Rate really mean?
Typically scan rate refers to how often the input value is updated to the microprocessor; a 200 ms scan specification the sensor value is taken and its' value updated to the microprocessor 5 times per second Typically controls offer a filter to average the input values. FDC's filter, configurable in steps from 0 [none] to 60 seconds, averages the value provided to the PV display, not to the control algorithm.

FDC scan specification also includes control calculations, control output and optional communications, all with 200ms updates. The benefit is a higher performing control.

What does input and output resolution really mean?
A/D Input Resolution [Analog to Digital]: Controls utilize microprocessors, digital devices that do not accept the infinite resolution of a traditional analog device. Microprocessors require the analog input signal be converted to digital values. These digital values are used as input to the control logic and display values. The higher the resolution on the analog input results in a more precise and accurate input value to the microprocessor. As an example, if an A/D of 10,000, a temperature range of 2,000 F the microprocessor would see temperature values in half-degree increments [2,000F/10,000 units resolution = 0.2F].

D/A Output Resolution [Digital to Analog]: Analog outputs, whether control or retransmission, are not infinite in their resolution. The microprocessor increments the analog output to values dependent upon its' D/A resolution specification. As an example, with a D/A of 10,000, a retransmitted temperature range of 2,000F would have values in 0.2F increments.

How A/D and D/A Resolution is Specified:
The input & output resolution specifications are normally described in the number of bits; i.e. 18 bits. Bits are a numeric value defined as the number 2. 18 bits = 2 x 2 x 2….. for 18 times = 262,144 bytes. This Bit value is used to determine an instruments input and output resolution to and from the microprocessor. The calculation to determine resolution in degrees includes the number of bits, mV and gain of the specific span.

A/D Specifications and real world "Effective A/D":
A/D Input specification is defined in bits, i.e. 18 Bit. The calculated A/D resolution per degree using the number of bits specified assumes no degradation from electrical noise or other influences. Although there may be some variance from one instrument vendor to another, typically electrical noise up to the levels used in CE testing degrades the calculated resolution per degree by a factor of three. Future Design Controls 18 Bit specification has a real world "effective A/D" of between 16 & 17 Bit.

Calculations and examples shown in the balance of this document show both 18 & 16 Bit as the technical & effective A/D for FDC controls.

Shown below are examples of input & output resolution for FDC products for type K and R thermocouple ranges.

1) Input resolution for input A/D can be calculated as followings;
18 Bit Input Resolution = 2 x 2 x 2 ..... for 18 times = 262,144
16 Bit Input Resolution = 2 x 2 x 2……fir 16 times = 65,536
The full span of the input circuit of FDC "100", "300" & "C" Series controls is 80mV. This means the resolution of the input circuit expressed in volts is:
18 Bit: 80mV / 262,144 = 0.305uV. [.00030509mV]
16 Bit: 80mV / 65,536 = 1.22uV. [.0012207mV]

1.2) Sample for Type K t/c:
FDC controls type K range = -328 to 2,498F.
This range has an mV span of -5.891 to 54.819 = 60.71 mV span.
60.71mV divided by 2826F span = .02148mV per degree F; [22uV]
The gain of K type thermocouple is approx 22uV [.022mV] per degree F.

The resolution of our controllers for Type K t/c can be expressed in degree F as;
18 Bit: 0.305uV/22uV = 0.01386 degree F or 0.014F.
16 Bit: 1.22uV/22uV = 0.0555 degree F or 0.056F.

1.3) Sample for Type R t/c:
FDC controls type R range = 32F to 3,308F.
This range has an mV span of 0.00 to 21.719 = 21.719 mV span
21.719mV divided by 3,276F span = .006629mV per degree F; [6.6uV]
The gain of R thermocouple is approx. 6.6uV [.0066mV] per degree F.

The resolution of our controllers for Type R t/c can be expressed in degree F as;
18 Bit: 0.305uV/6.6uV = 0.05 degree R or 0.5F
16 Bit: 0.122uV/6.6uV = 0.19 degree F or 0.19F.

1.4) Comparison to instruments with other resolution, similar thermocouple ranges and mV input spans:

Input Resolution	Counts of Resolution	Type K	Type R	
15 bit	32,768	0.14F	0.37F	
14 bit	16,384	0.23F	0.74F	
12 bit	4,098	0.91F	2.95F	
FDC 18 Bit	262,144	0.014F	0.05F	Technical resolution
FDC 16 Bit	65,536	0.056F	0.19F	Real World effective resolution

2) Output resolution for output D/A can be calculated as followings;
The 15 bits resolution for retransmission is 2 x 2 x 2 ..... for 15 times = 32,768.
[Electrical noise has minimal effect on output resolution.]

mA Output: The full range of the mA output is 22.2 mA; resolution is 22.2mA/32768 = 0.000677mA.
4-20 mA =16 mA span. 16mA/0.000677 = 23,633 counts.
0-20 mA = 20 mA span. 20mA/0.000677 = 29,542 counts.

VDC Output: The full range for all VDC output is 11.1 VDC; resolution is 11.1VDC/32768 = 0.000338 VDC
1-5VDC: span is 4.0V, resolution is 4.0V/0.0003387 = 11,809 counts.
0-5VDC: span is 5.0V, resolution is 5.0V/0.0003387 = 14,762 counts.
0-10VDC: span is 10.0V, resolution is 10.0V/0.0003387 = 29,524 counts.

2.1) Analog Output - Control
The calculations above show the number of counts or increments in the mA/VDC 15 Bit control outputs. The microprocessor calculates the output based upon setpoint, PV and PID settings with the 15 Bit analog outputs providing the industries highest control resolution output.
Simply stated, higher output resolution means improved control

2.2) Analog Output – Process Variable Retransmission

Engineering Unit Resolution: Take the span in engineering units divided by the number of counts.
Examples:
4-20 mA; 1,000 units/23,633 counts = 0.0423 incremental units
1-5VDC; 1,000 units/11,809 counts = 0.0847 incremental units
0-10VDC; 1,000 units/29,524 counts = 0.0339 incremental units

However, output resolution is only part of the equation; Input resolution is necessary to calculate output resolution. If input resolution is equivalent to 0.1F, regardless of output resolution, 0.1F is best the instrument is capable.

Thermocouple Input Temperature Retransmission: With an effective input A/D of 16Bits, FDC worst thermocouple input resolution is type B with 0.29F resolution. With configured retransmitted range of 2000F span, 15 Bits = 32,768 steps or .06F increments. However, since input resolution is 0.29F, the best resolution = 0.29F

Sample; Output span 2000F			Input	Input		
Input	Input	Type	Type	Output	Output	Calculated
Resolution	Resolution	K	B	Resolution	Resolution	Output/F
FDC 18 Bit	262,144	0.014F	0.07F	FDC 15 Bit	32,768	0.061F
Technical resolution						
FDC 16 Bit	65,536	0.057F	0.29F	FDC 15 Bit	32,768	0.061F
Real World effective resolution						
15 bit	32,768	0.14F	0.58F	FDC 15 Bit	32,768	0.061F
14 bit	16,384	0.23F	1.52F	14 bit	16,384	0.122F
12 bit	4,098	0.91F	4.63F	12 bit	4,098	0.488F
10 bit	1,024	3.64F	18.5F	10 bit	1,024	1.953F
8 bit	256	14.5F	74.1F	8 bit	256	7.813F

PV Retransmission Summary: Although the temperature retransmission, even over a range as broad as 2000F appears to be good even with output resolution as low as 12 bit, unless the effective input resolution is at least 15 Bit, the output resolution cannot be less than 1F regardless of range transmitted.
No matter how calculated, the output resolution cannot be better than the input resolution.