D2000 SERIES SCALING OVERVIEW

A SENSOR AT EVERY COMPUTER

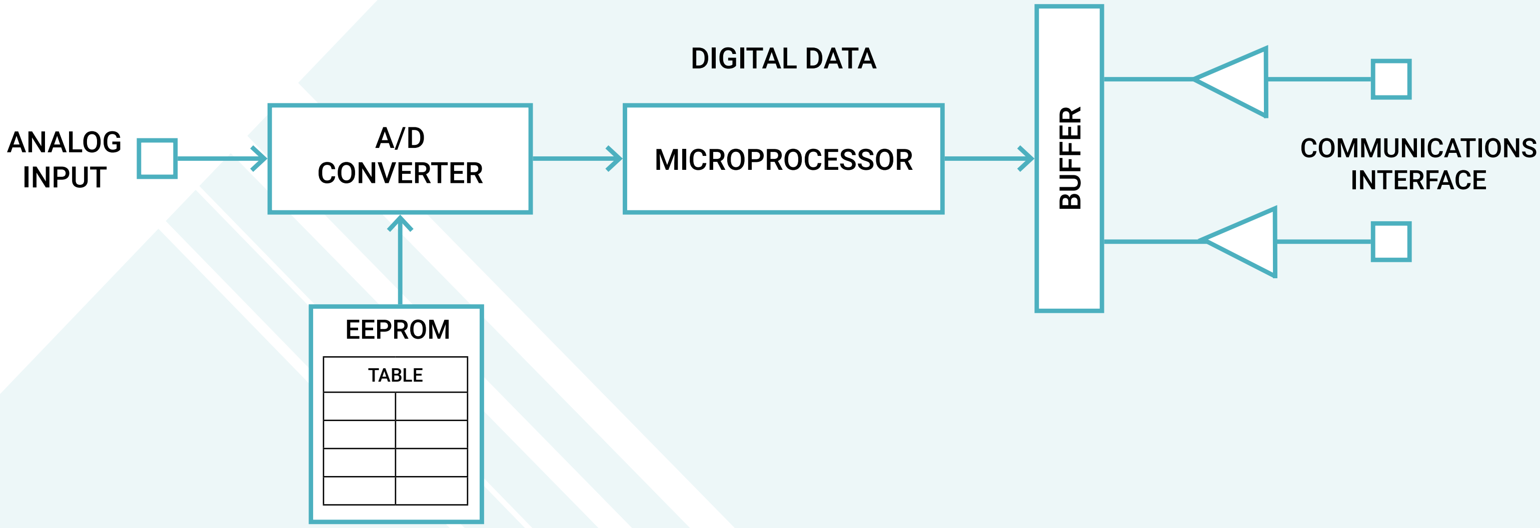
The D2000 series programmable analog input modules contain enhanced firmware for rescaling output data values into engineering units that match the application. Both linear and non-linear transfer functions can be programmed into the module. All scaling and nonlinear function data is stored in a table contained in EEPROM nonvolatile memory. Scaling data stored in the memory will remain intact indefinitely even if power is removed. D2000 modules may be re-scaled up to 10,000 times.

The D2000 series command set encompasses all the D1000 commands plus additional enhanced commands to perform the rescaling function. All rescaling commands are transmitted to the module through its communications port. There is no need to open the module. In many cases the modules may be rescaled remotely after they have been installed.

Figure 3 is a simplified block diagram of the D2000, showing only the portions related to re-scaling. The microprocessor (µP) reads the raw Analog-to-Digital Converter (ADC) data after every conversion. The µP takes the raw ADC data and looks it up in a table held in EEPROM. The table contains entries which map the raw ADC data to user-defined output data values scaled in engineering units. If an exact match is not found, the data is interpolated between the two closest table entries. The resulting data value is scaled in engineering units and stored in a memory buffer that can be read using the Read Data (RD) or New Data (ND) Commands.

Note that the re-scaling operation acts on the output of the analog-to-digital converter. The basic input-to-output transfer function of the ADC is fixed and cannot be changed. For example, a D2131 module with a ±5V input range cannot be re-scaled to ±10V or any other range. Analog input scaling is performed by selecting the D2000 model that best matches the sensor output signal. The ADC data is then manipulated with the function table to provide output data in engineering units.

FIG 3: D2000 SERIES BLOCK DIAGRAM



BREAKPOINT PROGRAMMING TABLE

FIG 4: BREAKPOINT TABLE

	ANALOG INPUT	DATA OUTPUT
MINIMUM	X_{MIN}	Y_{MIN}
MAXIMUM	X_{MAX}	Y_{MAX}
BREAKPOINTØØ	$X_{ØØ}$	$Y_{ØØ}$
BREAKPOINTØ1	$X_{Ø1}$	$Y_{Ø1}$
BREAKPOINTØ2	$X_{Ø2}$	$Y_{Ø2}$
BREAKPOINTØ3	$X_{Ø3}$	$Y_{Ø3}$
BREAKPOINTØ4	$X_{Ø4}$	$Y_{Ø4}$
BREAKPOINTØ5	$X_{Ø5}$	$Y_{Ø5}$
BREAKPOINTØ6	$X_{Ø6}$	$Y_{Ø6}$
BREAKPOINTØ7	$X_{Ø7}$	$Y_{Ø7}$
BREAKPOINTØ8	$X_{Ø8}$	$Y_{Ø8}$
BREAKPOINTØ9	$X_{Ø9}$	$Y_{Ø9}$
BREAKPOINTØA	$X_{ØA}$	$Y_{ØA}$
BREAKPOINTØB	$X_{ØB}$	$Y_{ØB}$
BREAKPOINTØC	$X_{ØC}$	$Y_{ØC}$
BREAKPOINTØD	$X_{ØD}$	$Y_{ØD}$
BREAKPOINTØE	$X_{ØE}$	$Y_{ØE}$
BREAKPOINTØF	$X_{ØF}$	$Y_{ØF}$
BREAKPOINT1Ø	$X_{1Ø}$	$Y_{1Ø}$
BREAKPOINT11	X_{11}	Y_{11}
BREAKPOINT12	X_{12}	Y_{12}
BREAKPOINT13	X_{13}	Y_{13}
BREAKPOINT14	X_{14}	Y_{14}
BREAKPOINT15	X_{15}	Y_{15}
BREAKPOINT16	X_{16}	Y_{16}

Figure 4 shows a programmer's model of the breakpoint table used to program the input-output transfer function of the D2000. The table values are intentionally left blank so that it may be copied and used as a worksheet to help program the modules.

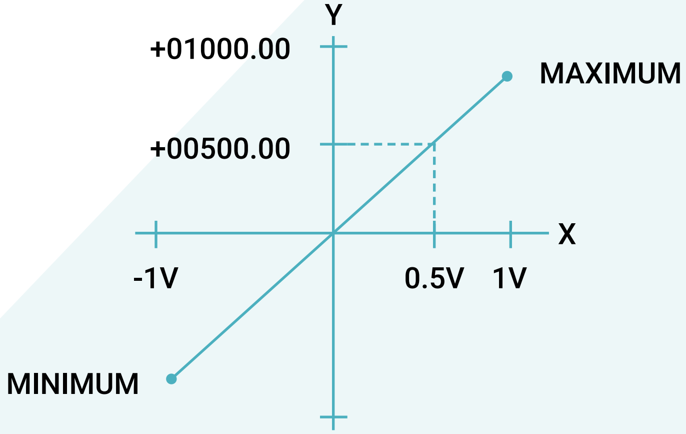
LINEAR RESCALING

The two most important points in the table are the Minimum and Maximum points. These two table entries specify the minimum and maximum endpoints of the transfer function curve. For example, a D2121 has a range of ±1V, and the standard table values are:

	ANALOG INPUT	OUTPUT DATA
MINIMUM	-1V	-01000.00
MAXIMUM	+1V	+01000.00

Plotted on a graph in Figure 5, these two points specify the endpoints of the transfer function curve. In this case, the analog input variable X represents voltage. The X values in the table specify the minimum and maximum voltages that may be applied to the analog input that will result a linearized output. (The X voltage values are stored in memory in terms of ADC binary data). Any voltage values applied to the analog input that are more negative than Xminimum will result in an overload output of -99999.99. Similarly, voltage values greater than Xmaximum will result in +99999.99.

FIG 5: FUNCTION ENDPOINTS



The corresponding Y values in the table specify the output data of the minimum and maximum points. In this case, a -1V input corresponds to an output of -01000.00mV. The Y values are always stored in the standard data format of sign, 5 digits, decimal point and two additional digits.

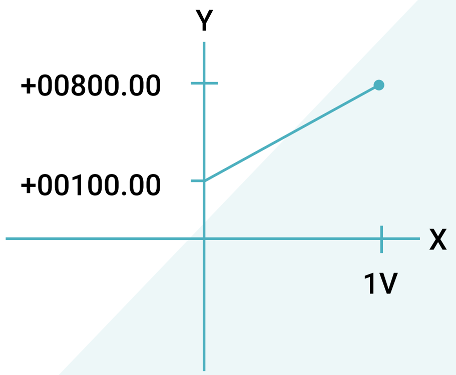
The minimum and maximum points are the only table values necessary to specify a linear transfer function. For analog input values between Xminimum and Xmaximum, the output values are determined by linearly interpolating between the minimum and maximum points. For instance, in the case of the D2121, an analog input value of +.5V is linearly interpolated to an output value of +00500.00 (See Figure 5).

It should be apparent at this point that a D2000 module may be re-scaled by modifying the minimum and maximum values in the table. This may be accomplished by using the Minimum (MN) command and the Maximum (MX) command. Using the D2121 ±1 volt module as an example, we may use the MN and MX commands to alter the table to look like this:

	ANALOG INPUT	OUTPUT DATA
MINIMUM	0V	+00100.00
MAXIMUM	+1V	+00800.00

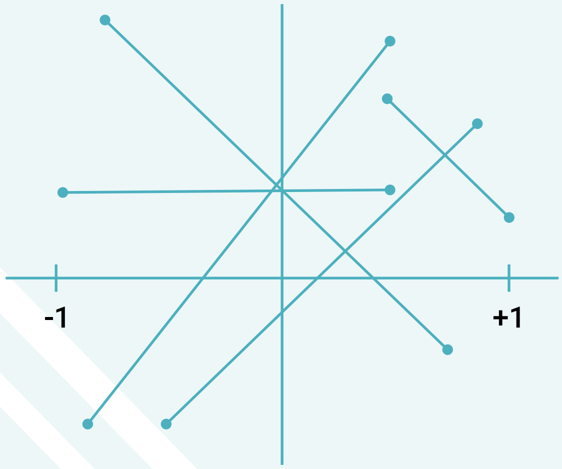
In this case the minimum point is 0V, corresponding to the output data +00100.00. The maximum point is +1V input and +00800.00 output. The graph of this equation is shown in Figure 6.

FIG 6:



By changing the minimum and maximum values in the table, an infinite number of linear functions may be specified, bounded by X values of ±1V and Y values of ±99999.99. Figure 7 shows a few possibilities.

FIG 7:

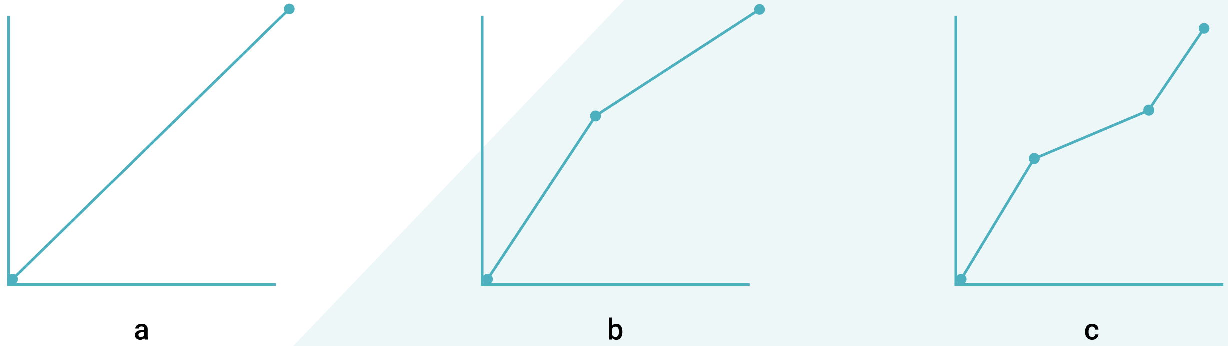


NON-LINEAR RESCALING

From Figure 4, we can see that most of the transfer function table is reserved for "Breakpoints". Breakpoints are used to modify the basic linear curve defined by the Minimum and Maximum points to create nonlinear functions. Nonlinear functions in the D2000 are approximated by using linear segments which are specified by the data values held in the Breakpoint Table.

Up to 23 breakpoints may be programmed to specify up to 24 linear segments. Figure 8 illustrates the action of the breakpoints. Figure 8a shows a basic linear transfer function described by the Minimum and Maximum points. Figure 8b shows the effect of one breakpoint used to modify the linear function. Notice that the breakpoint has created a nonlinear function described by two linear segments joined at the breakpoint. Figure 8c shows that two breakpoints may be used to specify a nonlinear curve described by three linear segments. Up to 23 breakpoints may be used to create complex nonlinear curves.

FIG 8: BREAKPOINT EXAMPLES



Breakpoints are stored in the EEPROM table in the same fashion as the minimum and maximum points. Each breakpoint is described by an X-Y pair specifying the analog input value at which the breakpoint occurs and the corresponding output data value. When the microprocessor reads the analog (X) data from the ADC, it searches the breakpoint table to find the X value closest to the input data. The micro then linearly interpolates between two breakpoints to calculate the resulting output data.

Any number of breakpoints up to 23 values may be specified. The breakpoint table must be filled progressively starting with Breakpoint 00 to Breakpoint 16 (hex). Unused or "erased" breakpoints are not used in the function calculation.

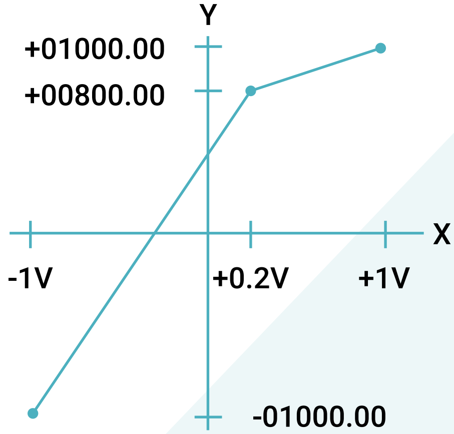
Let's use the D2121 ±1V module again as an illustrative example to show the effect of a breakpoint. Figure 9 shows the D2121 function table with 1 breakpoint programmed:

	ANALOG INPUT	OUTPUT DATA
MINIMUM	-1V	-01000.00
MAXIMUM	+1V	+01000.00
BREAKPOINT 00	+0.2V	+00800.00
BREAKPOINT01	------	-----
....		

Breakpoints 01 through 16 (hex) are erased and do not enter the function calculation. The Minimum and Maximum table entries contain the standard data values of ±01000.00mV. The new curve is shown in Figure 9.

Notice how the breakpoint has affected the whole curve, creating a nonlinear function. Here are a few samples of the input-output values that may be obtained from this curve:

FIG 9:



ANALOG INPUT	OUTPUT DATA
-.8V	-00700.00
-.6V	-00400.00
-.4V	-00100.00
-.2V	+00200.00
0V	+00500.00
+.2V	+00800.00
+.4V	+00850.00
+.6V	+00900.00
+.8V	+00950.00