

Remote programming and measuring uncommon RTDs with the Fluke 726

Application Note



Using custom RTD temperature constants

The Fluke 726 Multifunction Process Calibrator can measure temperature with most common resistance temperature detectors (RTD's). But what about the many "legacy" non-standard RTD's still in use, as well as standard RTDs that have been specially calibrated? The 726 allows you to enter custom RTD constants so you can measure any RTD for which you have the constants. You can also use custom constants to take advantage of the Fluke 726 ability to measure with 0.01° resolutions by coupling it with a characterized RTD. This application note explains how to use the 726 to measure non-standard or characterized RTD's. It covers the basic theory of RTD conversion formulas and shows how to load custom constants into the Fluke 726 using a Windows PC with an RS-232 serial port.

RTD Temperature Curves

RTD's take advantage of a natural property of metals, namely that a metal's resistance increases with temperature. An RTD is a precisely manufactured metal wire or film, and by measuring its resistance we can derive its temperature.

Resistance of an RTD is a function of the length and cross sectional area of the wire or film used to make it, and the resistivity of its metal. Resistivity is a characteristic of a metal's chemical makeup. Most RTD's are made of platinum, nickel, or copper. The alloy of the platinum or copper must be tightly controlled to produce precise resistivity. International standards like IEC 60751 and ASTM 1137 define the geometry and resistivity of standard RTD's. RTD manufacturers work to build their product to meet these standards.

In addition to defining the physical parameters of standard RTD's, international standards also define equations and constants used to convert resistance readings to temperature. Over a limited range the relationship between temperature and resistance is approximately linear, and you can convert temperature to resistance using Equation 1.

$$\text{Equation 1: } R_t = R_0 (1 + \alpha t)$$

Where: t is the temperature of the sensor

R_0 is the resistance at 0 °C.

α is a constant slope that describes resistance change per degree C.

R_t is the resistance at temperature t , in degrees C.

Using this simple linear equation delivers fairly good results, especially at temperatures between 0 and 100 °C. To extend the range of the RTD and to get more precision, IEC and ASTM standards specify a more complex polynomial that fine-tunes the resistance-temperature relationship. One form of that equation is given here as Equation 2. The RTD standards also specify values for the constants R_0 , A, B, C. (The C constant is only used for temperatures less than 0 °C.)

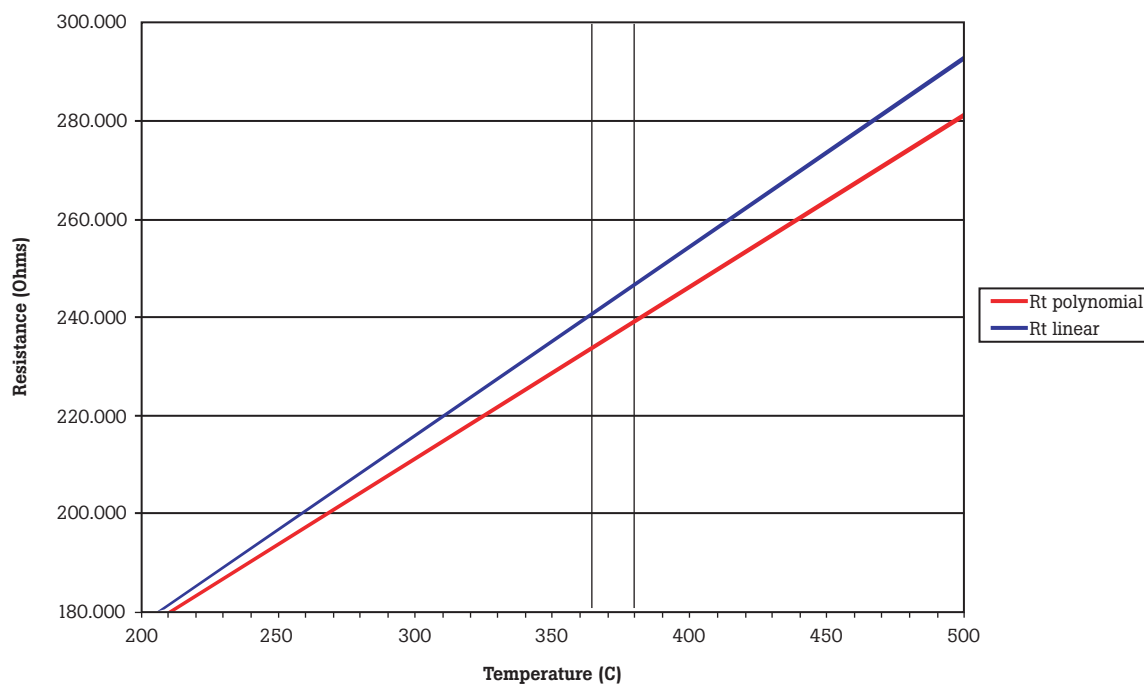


Figure 1. RTD Curves.

Equation 2: $R_t = R_0 [1 + At + Bt^2 + C(t - 100)t^3]$

Figure 1 shows the difference between temperature values produced by the linear equation and the polynomial between 200 and 500 °C. Note that at 240 ohms, the polynomial curve of Equation 2 gives a more accurate temperature 16 °C higher than the linear equation.

The Fluke 726 uses the polynomial in Equation 2 and it has built-in constants to support most common RTD's. Standard RTD's supported by the Fluke 726 are shown in Table 1.

Older or specialized equipment may use non-standard RTDs. Well-equipped standards labs can improve the accuracy of an RTD by adjusting the constants to suit a particular sensor. The Fluke 726 allows you to check less common RTD's or take advantage of RTD's that have been characterized, by specifying your own values for R_0 , A, B and C.

For example, for the common Pt 385 RTD with 100 Ω resistance at 0 °C, the constants are:

$$R_0 = 100 \Omega$$

$$A = 3.9083 \times 10^{-3}$$

$$B = -5.775 \times 10^{-7}$$

$$C = -4.183 \times 10^{-12}$$

Note: Instruments installed before and up to the early 1990s used a slightly different temperature scale (IPTS-68) than newer instruments (ITS-90). When a calibrator using ITS-90 RTD curves is used to calibrate an instrument using IPTS-68 errors will result. The errors are extremely small at room temperature and increase to a maximum of 0.36 °C at 760 °C.

RTD Type	Reference R0, Ohms	Metal	α $\Omega/\Omega/^\circ\text{C}$	Range $^\circ\text{C}$
Pt 100 (3916)	100	Platinum	0.003916	-200 to 630
Pt 100 (385)*	100	Platinum	0.00385	-200 to 800
Pt 200 (385)	200	Platinum	0.00385	-200 to 630
Pt 500 (385)	500	Platinum	0.00385	-200 to 630
Pt 1000 (385)	1000	Platinum	0.00385	-200 to 630
Pt 100 (3926)	100	Platinum	0.003926	-200 to 630
Ni 120 (672)	120	Nickel	0.00672	-80 to 260
Cu 10 (42)	10	Copper	0.0042	-10 to 250

Table 1: Standard RTDs types included in the Fluke 726. Pt 100 (385) is the IEC and ASTM standard.

Another common form of Equation 2, the Callendar Van Dusen or CVD, uses the constants α , δ , and β . This alternative form is directly derived from Equation 1 and uses the same constant α . And even though the two polynomials produce the same results, the constants are different. The Fluke 726 uses the constants A, B, and C. If you know the α , δ , and β constants for an RTD you can convert them to A, B, C constants by using Equations 3, 4 and 5.

Equation 3: $A = \alpha + \frac{\alpha \cdot \delta}{100}$

Equation 4: $B = -\frac{\alpha \cdot \delta}{100^2}$

Equation 5: $C = -\frac{\alpha \cdot \beta}{100^4}$

Loading custom RTD constants into the Fluke 726 Setting up communications



Figure 2.

The Fluke 700SC Serial Interface Cable (PN 667425) is used to communicate with the Fluke 726. The serial cable connects to the round multi-pin connector at the top of the 726 and to a 9-pin serial port on your PC. The serial cable can only interface with one instrument or module at a time.

After connecting the cable, make sure the 726 is turned on. Call up the Windows HyperTerminal Program. It is usually listed in the Windows Start Programs menu under Accessories, Communications. The HyperTerminal program will ask you to set up a file name to store your communication settings. You can select any icon and click OK to continue.



Figure 3.

A second dialog box, "Connect To", will pop up. Skip down to the bottom, where it says "Connect Using:" Select the COM port you connected to the 726.

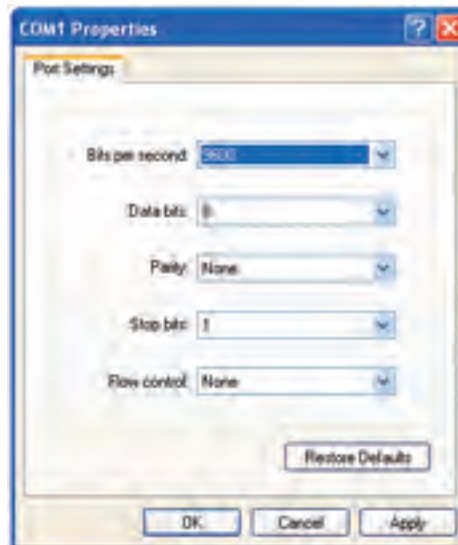


Figure 4.

Next, a COM Properties box will come up. Set baud rate (9600 in Figure 4), data bits, parity, stop bits and flow control as shown in the Figure 4. Once your settings match Figure 4, click OK to continue.

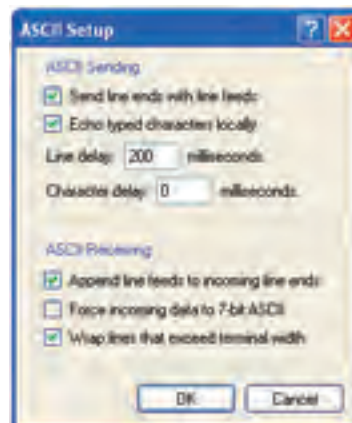


Figure 5.

To make it easier to read the commands and responses, you can make some adjustments to the way the HyperTerminal program treats screen text. Under the File menu select Properties and click on the Settings tab. Click on the button labeled ASCII Setup. You will see a dialog like the one shown in Figure 5. Match the settings shown in the figure. Note that adding the 200 ms line delay makes it possible to send short scripts to the 726. More on this later.

To test the connection, type: ***idn?**
After you hit Enter, the 726 should respond with "FLUKE,726,0,X.X" where X.X is the version of the firmware in the instrument.

Sending custom RTD constants to the Fluke 726

Once communication is established you can load custom constants into the 726. You can also send queries to the 726 to check the current settings and to verify your changes. Here is an overview of the steps to modify the constants:

1. Set the RTD type to the one of the custom types (CUST1, CUST2 or CUST3)
2. Set the minimum and maximum temperatures for the custom RTD
3. Set the constants R0, A, B, and C
4. Assign a six-character name that will appear on the front panel of the instrument to help the operator choose RTD types

The best way to show the detailed process is through an example. Let's say we need to measure an RTD with the following attributes:

Range is from 0 to 630 °C

$$R_0 = 100 \Omega$$

$$A = 3.9692 \times 10^{-3}$$

$$B = -5.8495 \times 10^{-7}$$

C = unknown and unnecessary since range is 0 °C or greater

Rather than having to type all of the commands each time we want to change the constants, we can define short text files and send them using the HyperTerminal program. The Windows Notepad program may be used to create and edit the command scripts.

The text file in Figure 6 is designed to query all of the parameters associated with the RTD type CUST1. Try building and sending this query file first. It is a good practice script and is useful for verifying any changes you make to the constants later.

When you finish editing the script file, make sure you hit Enter after the last command (in this example "cust1_alias?"). The cursor should be blinking below the last command when you save the file. This will ensure that the 726 sees the newline after the last command and processes it.

To send a script file to the 726, click on Transfer, Send Text File in HyperTerminal. The 726 will respond to each of the queries with the current values of each constant.

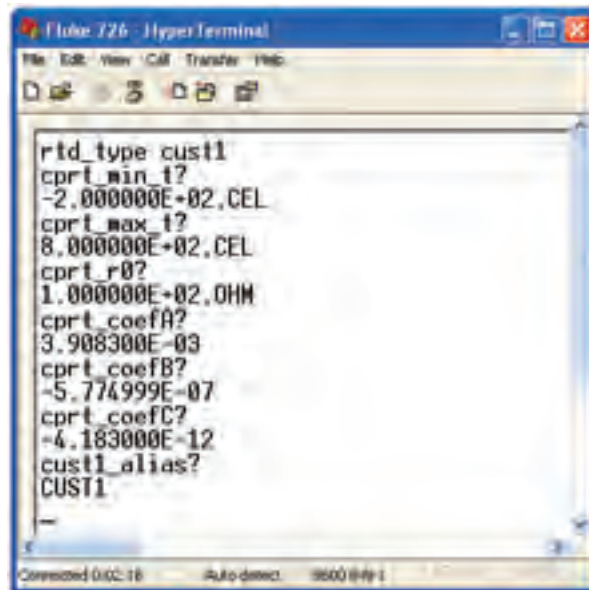


Figure 6. A script used to query custom RTD settings and the results of sending it to the 726. Each query command is followed by a response from the 726.

The HyperTerminal window shown in Figure 6 shows the response of the 726 to sending the query commands. Each command that ends in a question mark is followed by a response from the 726. These responses are the factory default values for the CUST1 RTD.


```

726 Custom RTD Set Constants Script - Notepad
File Edit Format View Help
rtd_type cust1
cprt_min_t 0 CEL
cprt_max_t 630 CEL
cprt_r0 1.000000E2 OHM
cprt_coefA 3.969200E-03
cprt_coefB -5.849500E-07
cprt_coefC 0
cust1_alias PTO40
    
```

Note: The cursor should be here before you save the file.

```

Fluke 726 - HyperTerminal
File Edit View Call Transfer Help
3.908300E-03
cprt_coefB?
-5.774999E-07
cprt_coefC?
-4.183000E-12
cust1_alias?
CUST1
rtd_type cust1
cprt_min_t 0 CEL
cprt_max_t 630 CEL
cprt_r0 1.000000E2 OHM
cprt_coefA 3.969200E-03
cprt_coefB -5.849500E-07
cprt_coefC 0
cust1_alias PTO40
    
```

Figure 7. A script used to define custom RTD constants and the results of sending it to the 726.

Figure 7 shows a script to change the constants for the CUST1 type RTD. The script can be developed in Windows Notepad, just like the previous example. Here's how it works:

- The script activates the RTD measurement and sets the RTD type to CUST1.
- It sends commands to establish new min and max limits for the new RTD type.
- The next three commands set the A, B, and C constants. In this example we are limiting the sensor to temperatures of 0 °C or greater, and setting the C coefficient to 0.
- The alias command will name the new RTD PTO40.

Note that numbers may be in integer, decimal or scientific notation.

Once the file is prepared, click on Transfer, Send Text File in HyperTerminal to send the file to the 726. You can verify that the 726 has the correct constants by using the query script from Figure 6.

Your 726 is now ready to make measurements using your custom RTD curve.

Using custom-defined RTD's with the Fluke 726

To use a custom RTD with the Fluke 726 you simply select it by pressing the RTD button on the front panel. This will cycle you through all of the available RTD types, including the three custom ones.



Calculating the combined uncertainty of any meter and transducer

The combination of the Fluke 726 and an RTD will have an uncertainty that considers both the meter and the transducer. Since the uncertainties of the meter and probe are independent of each other, rather than simply adding the uncertainties, we can take the square root of the sum of the squares.

The uncertainty of the Fluke 726 is expressed as a percentage of reading with a noise floor that is determined by the range. The temperature specifications are 0.15 °C uncertainty for the meter, 0.1 °C uncertainty for the probe. Here's an example of how to calculate the uncertainty for the Fluke 726 in °C at 100 °C.

Once you have the uncertainties of both the meter and the probe at a particular point, you can combine these uncertainties to come up with the uncertainty of the system. The formula for combining these independent uncertainties is:

$$U_{system} = \sqrt{U_{probe}^2 + U_{meter}^2} *$$

For example, the uncertainty of the Fluke 726 at 100 °C is 0.15 °C as calculated above. If we have an RTD whose uncertainty at 100 °C is 0.1 °C, then the combined accuracy will be plus or minus

$$\sqrt{0.1^2 + 0.15^2} = 0.18 \text{ } ^\circ\text{C}$$

*The above equation assumes that the U values follow a normal distribution. A metrology standpoint would recommend dividing the 'U' values by $\sqrt{3}$ and then doing the root sum square, when using the manufacturer's specification.

726 Serial Command List

Command	Response/Actions	Command Arguments	Comment	Ch 1	Ch 2
*IDN?	Returns the ID string "FLUKE,726,0,{sw_rev}" where sw_rev is the firmware revision		Verify model number, serial number and firmware rev.	•	•
FUNC?	Returns {Upper},{Lower} {Upper} responses (Channel 1) DCI, DCI_LOOP, DCV, DCI_ERROR, DCI_ERROR_LOOP {Lower} responses DCI, DCMV, DCV, DCI_SIM, TC, RTD, FREQUENCY, PULSE_TRAIN		Answers with the configured function for the upper and lower display.	•	•
VAL?	Returns the measured value with base units for the upper and lower display {upper_val},{upper_units},{lower_val},{lower_units}, upper units: V, A, PERCENT lower units: V, CEL, FAR, A, OHM, CPM, HZ, COUNT			•	•
UPPER_MEAS		1 argument, valid settings: DCI, DCI_LOOP, DCV, DCI_ERROR, DCI_ERROR_LOOP	Set upper channel measure mode.		•
OUT		Arguments: {value} {units} Multipliers u for micro, m for milli, and k for kilo are accepted. units: -V used for mV and Volts, the V_range command can be used to switch ranges -CEL used for RTD, TC AND TC mV -FAR used for RTD and TC -A used for mA (see SIM for mA SIM) -OHM used for RTD ohms, RTD_TYPE must be set to ohms -CPM used for frequency -HZ used for HZ and KHZ frequency (unit will auto range) -COUNT used for pulse	Configures the output source function. If the {value} and {units} are valid, this command will change modes if necessary and set the output value to {value} and {units} in that mode.		•
OUT?	Returns the output (source) value with units or none.		Verify the output function and units.		•
FREQ_UNIT		1 argument: CPM, HZ or KHZ	Set the output frequency range.		•
FREQ_UNIT?	Returns CPM, HZ, KHZ		Verify the frequency range.		•
LOWER_MEAS		1 argument, Valid Modes: DCI, DCMV, DCV, TC, RTD, FREQUENCY, PULSE_TRAIN	Configures the measurement function. Sets the specified measure mode.		•
SIM		1 Argument {value} Multipliers u for micro, m for milli, and k for kilo are accepted,. A is for amps	If the value is valid, this command will change modes if necessary and set the output value to {value} in that mode.		•
SIM?	Returns the simulate value in Amps with units or none		Verify the SIM output.		
V_RANGE		1 Argument VOLTS or MVOLTS	Sets the voltage range.		•
V_RANGE?	Returns the voltage range VOLTS or MVOLTS		Verify the voltage range.		•
PULSE_FREQ		2 arguments {number}{units}. (units CPM ,Hz ,Khz)	Sets the pulse output frequency and range.		•
PULSE_FREQ?	Returns the pulse output frequency with units.		Verify the pulse frequency.		

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726 Serial Command List cont.

Command	Response/Actions	Command Arguments	Comment	Ch 1	Ch 2	
FREQ_LEVEL		1 Argument, valid values: 1-20 V	Sets the pulse output and frequency output voltage.		•	
FREQ_LEVEL?	Returns the pulse output and frequency output voltage 1-20 V		Verify the frequency voltage level.		•	
TRIG	Toggles the pulse mode and totalize trigger for read and source.		Initialize totalized pulse measurement or output.			
TRIG?	Returns the state of the pulse mode trigger, TRIGGERED, UNTRIGGERED or NONE.		Verify TRIG state.		•	
TC_TYPE		One argument, valid settings: B, C, E, J, K, L, N, R, S, T, U, BP, XK, MV	Set TC type.		•	
TC_TYPE?	Returns TC type B, C, E, J, K, L, N, R, S, T, U, BP, XK, MV		Verify TC type.		•	
TSENS_TYPE		1 argument TC or RTD	Sets the sensor type TC or RTD.		•	
TSENS_TYPE?	Returns the sensor type TC or RTD		Verify is set for RTD or TC.		•	
CJC_STATE		One argument ON or OFF	Thermocouple cold junction compensation.		•	
CJC_STATE?	Returns ON or OFF		Verify CJC state.		•	
RTD_TYPE		1 argument: NI120, PT392_100, PT385_100, PTJIS_100, PT385_200, PT385_500, PT385_1000, CU_10, CUST1, CUST2, CUST3, OHMS	Sets RTD type		•	
RTD_TYPE?	Returns RTD type NI120, PT392_100, PT385_100, PTJIS_100, PT385_200, PT385_500, PT385_1000, CU_10, CUST1, CUST2, CUST3, OHMS		Verify the RTD type setting.		•	
CPRT_RO		2 arguments {number} OHM. Sets the custom CPRT RO.	RTD_TYPE must be either CUST1, CUST2 or CUST3.		•	
CPRT_RO?	Returns CPRT RO with units OHM.				•	
CPRT_MIN_T		2 arguments {number} CEL.			•	
CPRT_MIN_T?	Returns {number} CEL.				•	
CPRT_MAX_T		2 arguments {number} CEL.			•	
CPRT_MAX_T?	Returns {number} CEL.				•	
CPRT_COEFA		1 argument. Sets the custom CPRT Coefficient A.			•	
CPRT_COEFA?	Returns the custom CPRT Coefficient A.				•	
CPRT_COEFB		1 argument. Sets the custom CPRT Coefficient B.			•	
CPRT_COEFB?	Returns the custom CPRT Coefficient B.				•	
CPRT_COEFC		1 argument. Sets the custom CPRT Coefficient C.			•	
CPRT_COEFC?	Returns the custom CPRT Coefficient C.				•	
RTD_WIRE		1 argument, 2W, 3W or 4W. Sets RTD read wire.			•	
RTD_WIRE?	Returns RTD read wire.			Verify connection setting.		•
TEMP_UNIT		1 argument. Sets temperature units, CEL or FAR		CEL: Celsius FAR: Fahrenheit		•
TEMP_UNIT?	Returns temperature units, CEL or FAR					•

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726 Serial Command List

Command	Response/Actions	Command Arguments	Comment	Ch 1	Ch 2
CUST1_ALIAS		1 argument, sets screen name for CUST1 RTD.			•
CUST1_ALIAS?	Returns screen name for CUST1 RTD.		Verify RTD 1 alias.		•
CUST2_ALIAS		1 argument, sets screen name for CUST2 RTD.			•
CUST2_ALIAS?	Returns screen name for CUST2 RTD.		Verify RTD 2 alias.		•
CUST3_ALIAS1		1 argument, sets screen name for CUST3 RTD.			•
CUST3_ALIAS?	Returns screen name for CUST3 RTD.		Verify RTD 3 alias		•
HART_ON	Turns HART mode on.		Switches in 250 ohm resistor.	•	•
HART_OFF	Turns HART mode off.		Switches out 250 ohm resistor.	•	•
HART?	Returns state of hart mode, ON or OFF			•	•
*CLS	Clear the error queue			•	•
FAULT	Returns error code FILO			•	•
ERROR CODES:	NONNUMERIC_ENRTY (100) EBUFFER_OVERFLOW (101) INVALID_UNITS_CODE (102) ENTRY_OVER_RNG (103) ENTRY_UNDER_RNG (104) MISSING_PARM (105) INVALID_UNIT_PARM (106) INVALID_SENSOR_TYPE (108) UNKNOWN_COMMAND (110) BAD_PARM_VALUE (111) INPUT_BUFF_OVERFLOW (112) MSG_BUFF_OVERFLOW (113) OUTPUT_BUFF_OVERFLOW (114) OUTPUT_OVERLOAD (115)			•	•
CAL_START	Initiates a password protected calibration (password = 627)		See Cal. Manual	•	•