Technical Note 153

Process variable measurement using a RTD

Programming and wiring for Pt100 and Pt1000 RTD

The ABB 580 series drive hardware and firmware manuals document the support of direct connection to the drive of a single or multiple Pt100 or Pt1000 RTDs (Resistance Temperature Detector) for motor thermal protection. Besides measuring motor temperature, other applications of using an RTD with a variable frequency drive (VFD) include monitoring the discharge gas temperature on a refrigeration compressor, the temperature of water in pipe, or internal air temperature of an enclosure. The drive can use the RTD temperature as feedback to vary the speed of a motor in a PID control loop or in a system safety circuit.

Traditionally a transmitter or controller exists electrically between the RTD and the drive's analog input to convert the input signal. Being able to directly connect the RTD to the drive without the need for an external controller or transmitter reduces hardware and installation costs. This technical note details how to setup the 580 series drive with a single Pt100 or Pt1000 RTD for non-motor thermal overload protection applications where high temperature accuracy is not required.

Background

To measure the temperature from an RTD, the drive first needs to output an excitation current from one of its two analog outputs. The current passes through the RTD (a resistor) creating a voltage drop across the resistor. The drive then reads the voltage on an analog input and converts the reading to a temperature. The amount of current that passes through the RTD, and the scalable range of the analog input are user adjustable. The accuracy of the temperature measurement by the drives depends on the settings for the excitation current from the analog output, and scaled range of the analog input. As will be discussed in this technical note the accuracy of the temperature measurement will vary depending on parameter settings. With proper parameter settings, measurement error can be minimized to a few degrees.

Wiring connections

Use of a single Pt100 or Pt1000 RTD are discussed in this technical note. Also, the Pt100 or Pt1000 can be a two wire or three wire design. Figure 1 applies to a 2-wire RTD. A jumper wire needs to be placed between drive terminals AI1 and AO1 as shown in Figure 1. Figure 2 applies to a 3-wire RTD. Three wire RTDs have two wires already connected together on one side of the RTD resistor, and the third wire is on the other side of the resistor. Connect the two wires that are internally connected together to terminals AI1 and AO1. Connect the third wire to AGND.

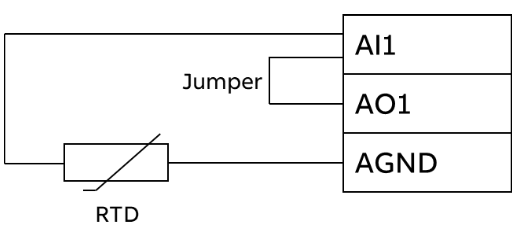

Figure 1: 2-wire RTD

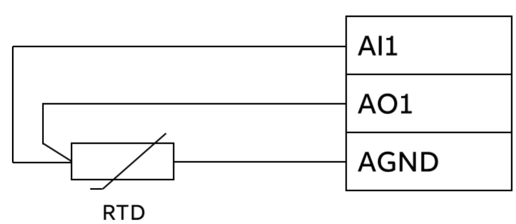

Figure 2: 3-wire RTD

Programming

Most Pt100 and Pt1000 RTDs comply to the IEC standard 60751 which states that a Pt100 at 0 ^{o}C it will have a resistance of 100 Ω and for a Pt1000 at 0 ^{o}C it will have a resistance of 1000 Ω. The change in resistance per 1^{o}C above and below 0 ^{o}C is close to linear. This nearly linear relationship between resistance and temperature allows for the drive to interpret the temperature with some simple parameter adjustments.

Before starting to program the drive, it is important to have a Pt100 or Pt1000 resistance table that shows the RTD's resistance at each degree Celsius or Fahrenheit. Some simple mathematical calculations using data in the table is required to program the drive's parameters. At the end of this technical note in the appendix Tables 3 and 4 provide partial resistance values from -50 to 200 ^{o}C for a Pt100 and Pt1000. More complete tables with larger temperature ranges exist that can be found online if needed or from the RTD vendor.

To obtain the most accurate temperature reading a few concepts need to be discussed respective to Pt100 and Pt1000 RTDs.

Pt100

The recommended minimum excitation current is 4.0 mA. If the current is set below 4.0 mA the risk increases for very small changes in voltage across the RTD will result in large changes in the measured temperature. The maximum recommended excitation current is 9.0 mA. This is the same fixed level the drive uses in group 35 for motor thermal overload protection. A large excitation current in theory is desirable as this will increase signal resolution by creating a larger measurable voltage drop range across the RTD, however setting the level above 9.0 mA can create "self-heating" in the RTD. The RTD self-heating can cause increased measurement error. For the minimum and maximum temperature range being measured, select a range as small as possible for the application to increase measurement accuracy. The shorter the wire distance between the RTD and drive the better, along with using a low resistance wire removes measurement error caused by wire lead resistance.

Pt1000

The recommended minimum excitation current is 2.0 mA. If the current is set below 2.0 mA the risk increases for very small changes in voltage across the RTD will result in large changes in the measured temperature. The maximum recommended excitation mA current is 4.0 mA. The logic of 4.0 mA as a recommended maximum is to avoid self-heating of the RTD, and to avoid creating a voltage on drive terminal AI1 above its maximum value of 10 VDC. For the minimum and maximum temperature range being measured, select a range as small as possible for the application to increase measurement accuracy. The shorter the wire distance between the RTD and drive the better, along with using a low resistance wire removes measurement error caused by wire lead resistance.

Table 1 lists the drive parameters that will be adjusted or read for this application. Steps on how to program each parameter follow Table 1.

Table 1

Parameter number	Parameter description	Setting	Notes
12.12	AI1 scaled value	Read only	This is the temperature that the drive is reading from the RTD.
12.15	AI1 unit selection	[2] V (default)	
12.17	AI1 min	(P13.18 / 1000) x Ohm value	Convert mA to Amps and multiply by the resistance in the Pt100 or Pt1000 chart that corresponds to the low end of the temperature range.
12.18	AI1 max	(P13.18 / 1000) x Ohm value	Convert mA to Amps and multiply by the resistance in the Pt100 or Pt1000 chart that corresponds to the high end of the temperature range.
12.19	AI1 scaled at AI1 min	°C or °F value corresponding to P12.17 Ohm value	Most Pt100 and Pt1000 charts are in °C. If desired to have scaled temperature in °F use equation ((9/5) x °C + 32) = °F
12.20	AI1 scaled at AI1 max	°C or °F value corresponding to P12.18 Ohm value	Most Pt100 and Pt1000 charts are in °C. If desired to have scaled temperature in °F use equation ((9/5) x °C + 32) = °F
13.12	AI1 source	[0] Zero	
13.17	AO1 source min	Same value as P13.18.	Parameters 13.17 and 13.18 are set to the same value to create a constant mA output signal.
13.18	AO1 source max	Same value as P13.17	

The following steps and example should be followed to determine the values of what to program into group 12 and 13 parameters.

1. Determine the temperature range, minimum and maximum °C or °F, to be measured and viewed on the drive for the application.
    a. Program parameter 12.17 with the lower temperature in °C or °F.
    b. Program parameter 12.18 with the higher temperature in °C or °F.
2. Determine a fixed mA excitation current value, and program into both parameters 13.17 and 13.18
3. Using the chart at the end of this technical note, provided with the RTD, or found online, calculate the two voltages the drive will see at the minimum and maximum °C or °F selected in step 1 by multiplying the current x the resistance value in the chart. Make sure to convert mA to Amps before multiplying by the resistance value in the chart.
    a. Program parameter 12.19 with the calculated voltage that corresponds to the lower temperature.
    b. Program parameter 12.20 with the calculated voltage that corresponds to the higher temperature.
4. The value in parameter 12.12 is the measured temperature in °C or °F from the RTD.

Application Example

In this scenario, room temperature is desired to be measured using a Pt100. Room temperature is around 20 ^{o}C on average.

The temperature range will be 10 – 40 ^{o}C. Per Table 3 of the Appendix, 10 ^{o}C = 103.90 Ω and 40 ^{o}C = 115.54 Ω. Selecting 4.0 mA as the excitation current. Table 2 shows the parameter settings for this example.

0.004 A x 103.90 Ω = 0.416 VDC

0.004 A x 115.54 Ω = 0.462 VDC

Table 2

Parameter number	Parameter description	Setting
12.12	AI1 scaled value	Temperature RTD reads
12.15	AI1 unit selection	[2] V
12.17	AI1 min	0.416
12.18	AI1 max	0.462
12.19	AI1 scaled at AI1 min	10.000
12.20	AI1 scaled at AI1 max	40.000
13.12	AI1 source	[0] Zero
13.17	AO1 source min	4.000
13.18	AO1 source max	4.000

The temperature value reported in parameter 12.12 *AI1 scaled value*, can now be applied to different uses within the drive. For example, this value could be used in group 40 *Process PID set 1* to control the speed of the motor against a temperature setpoint. Another example would be to setup supervisory logic of the returned temperature in group 32 *Supervision*. The drive could be setup to declare a warning, fault, or trigger a relay output if the temperature exceeds a certain level. The temperature could also be read by the building automation system over a communication protocol such as BACnet, Modbus, or Ethernet/IP.

Conclusion

The 580 series drive can support a direct connection of an RTD to an analog input for applications where high temperature measurement accuracy is not required. This direct wiring connection to the drive simplifies the installation and reduces cost by eliminating the need for extra hardware. Remember to select as narrow a temperature range as possible for the application to improve accuracy. Also, select an excitation current that will yield the most accurate results. Testing of different excitation currents and scaled ranges is recommended to compare the drives measured temperature against a known true temperature measurement.

Tables 3 and 4 provide a limited range of the degrees Celsius to resistance relationship for a Pt100 and Pt1000

Table 3

Pt100										
Degrees °C	0	1	2	3	4	5	6	7	8	9
-50	80.31	79.91	79.51	79.11	78.72	78.32	77.92	77.52	77.12	76.73
-40	84.27	83.87	83.48	83.08	82.69	82.29	81.89	81.50	81.10	80.70
-30	88.22	87.83	87.43	87.04	86.64	86.25	85.85	85.46	85.06	84.67
-20	92.16	91.77	91.37	90.98	90.59	90.19	89.80	89.40	89.01	88.62
-10	96.09	95.69	95.30	94.91	94.52	94.12	93.73	93.34	92.95	92.55
0	100.00	99.61	99.22	98.83	98.44	98.04	97.65	97.26	96.87	96.48
	0	1	2	3	4	5	6	7	8	9
0	100.00	100.39	100.78	101.17	101.56	101.95	102.34	102.73	103.12	103.51
10	103.90	104.29	104.68	105.07	105.46	105.85	106.24	106.63	107.02	107.40
20	107.79	108.18	108.57	108.96	109.35	109.73	110.12	110.51	110.90	111.29
30	111.67	112.06	112.45	112.83	113.22	113.61	114.00	114.38	114.77	115.15
40	115.54	115.93	116.31	116.70	117.08	117.47	117.86	118.24	118.63	119.01
50	119.40	119.78	120.17	120.55	120.94	121.32	121.71	122.09	122.47	122.86
60	123.24	123.63	124.01	124.39	124.78	125.16	125.54	125.93	126.31	126.69
70	127.08	127.46	127.84	128.22	128.61	128.99	129.37	129.75	130.13	130.52
80	130.90	131.28	131.66	132.04	132.42	132.80	133.18	133.57	133.95	134.33
90	134.71	135.09	135.47	135.85	136.23	136.61	136.99	137.37	137.75	138.13
100	138.51	138.88	139.26	139.64	140.02	140.40	140.78	141.16	141.54	141.91
110	142.29	142.67	143.05	143.43	143.80	144.18	144.56	144.94	145.31	145.69
120	146.07	146.44	146.82	147.20	147.57	147.95	148.33	148.70	149.08	149.46
130	149.83	150.21	150.58	150.96	151.33	151.71	152.08	152.46	152.83	153.21
140	153.58	153.96	154.33	154.71	155.08	155.46	155.83	156.20	156.58	156.95
150	157.33	157.70	158.07	158.45	158.82	159.19	159.56	159.94	160.31	160.68
160	161.05	161.43	161.80	162.17	162.54	162.91	163.29	163.66	164.03	164.40
170	164.77	165.14	165.51	165.89	166.26	166.63	167.00	167.37	167.74	168.11
180	168.48	168.85	169.22	169.59	169.96	170.33	170.70	171.07	171.43	171.80
190	172.17	172.54	172.91	173.28	173.65	174.02	174.38	174.75	175.12	175.49
200	175.86	176.22	176.59	176.96	177.33	177.69	178.06	178.43	178.79	179.16

Table 4

Pt1000										
Degrees °C	0	1	2	3	4	5	6	7	8	9
-50	803.10	799.10	795.10	791.10	787.20	783.20	779.20	775.20	771.20	767.30
-40	842.70	838.70	834.80	830.80	826.90	822.90	818.90	815.00	811.00	807.00
-30	882.20	878.30	874.30	870.40	866.40	862.50	858.50	854.60	850.60	846.70
-20	921.60	917.70	913.70	909.80	905.90	901.90	898.00	894.00	890.10	886.20
-10	960.90	956.90	953.00	949.10	945.20	941.20	937.30	933.40	929.50	925.50
0	1000.00	996.10	992.20	988.30	984.40	980.40	976.50	972.60	968.70	964.80
	0	1	2	3	4	5	6	7	8	9
0	1000.00	1003.90	1007.80	1011.70	1015.60	1019.50	1023.40	1027.30	1031.20	1035.10
10	1039.00	1042.90	1046.80	1050.70	1054.60	1058.50	1062.40	1066.30	1070.20	1074.00
20	1077.90	1081.80	1085.70	1089.60	1093.50	1097.30	1101.20	1105.10	1109.00	1112.90
30	1116.70	1120.60	1124.50	1128.30	1132.20	1136.10	1140.00	1143.80	1147.70	1151.50
40	1155.40	1159.30	1163.10	1167.00	1170.80	1174.70	1178.60	1182.40	1186.30	1190.10
50	1194.00	1197.80	1201.70	1205.50	1209.40	1213.20	1217.10	1220.90	1224.70	1228.60
60	1232.40	1236.30	1240.10	1243.90	1247.80	1251.60	1255.40	1259.30	1263.10	1266.90
70	1270.80	1274.60	1278.40	1282.20	1286.10	1289.90	1293.70	1297.50	1301.30	1305.20
80	1309.00	1312.80	1316.60	1320.40	1324.20	1328.00	1331.80	1335.70	1339.50	1343.30
90	1347.10	1350.90	1354.70	1358.50	1362.30	1366.10	1369.90	1373.70	1377.50	1381.30
100	1385.10	1388.80	1392.60	1396.40	1400.20	1404.00	1407.80	1411.60	1415.40	1419.10
110	1422.90	1426.70	1430.50	1434.30	1438.00	1441.80	1445.60	1449.40	1453.10	1456.90
120	1460.70	1464.40	1468.20	1472.00	1475.70	1479.50	1483.30	1487.00	1490.80	1494.60
130	1498.30	1502.10	1505.80	1509.60	1513.30	1517.10	1520.80	1524.60	1528.30	1532.10
140	1535.80	1539.60	1543.30	1547.10	1550.80	1554.60	1558.30	1562.00	1565.80	1569.50
150	1573.30	1577.00	1580.70	1584.50	1588.20	1591.90	1595.60	1599.40	1603.10	1606.80
160	1610.50	1614.30	1618.00	1621.70	1625.40	1629.10	1632.90	1636.60	1640.30	1644.00
170	1647.70	1651.40	1655.10	1658.90	1662.60	1666.30	1670.00	1673.70	1677.40	1681.10
180	1684.80	1688.50	1692.20	1695.90	1699.60	1703.30	1707.00	1710.70	1714.30	1718.00
190	1721.70	1725.40	1729.10	1732.80	1736.50	1740.20	1743.80	1747.50	1751.20	1754.90
200	1758.60	1762.20	1765.90	1769.60	1773.30	1776.90	1780.60	1784.30	1787.90	1791.60