

Process and temperature switch applications with the 740 Series DPCs

Application Note

This note discusses applications for process switches and calibrating temperature switches using the Fluke 740 Series Documenting Process Calibrators (DPCs). Let's begin by looking at what a process switch is and what it does.

Process switches

A process switch is a device that can sense a process variable — such as temperature or pressure — and change the state of one or more sets of switch contacts when that variable reaches a predetermined value. This value is called a setpoint. A switch can have multiple setpoints. Let's look at some important concepts of how process switches work.

Contacts. Contacts come in pairs, and a pair is either normally open or normally closed. "Normally" means without energization — just the way the contacts would be on the shelf or if you disconnected the power wires from the switch.

Many process switches have four sets of contacts — two normally open and two normally closed. But, there are many variations. A single switch may operate just one set of contacts, or it may operate multiple sets

of normally open *and* normally closed contacts. You select which contacts to use based on the desired output for a given condition and a given failsafe condition.

Control logic. You must think of switch actuation and contact state separately. Actuating the typical process switch means opening one set of contacts and closing another at the same time. Whether actuation opens or closes a set of contacts depends on whether you are using the normally open or normally closed contacts and whether the switch is in an activated or deactivated state during normal operation.

Failsafe operation is the first criterion to assess when deciding which set of contacts to use. For example, you should use normally closed contacts if breaking the circuit will result in a failsafe condition. Because loss of power and an open circuit (via a broken circuit wire, broken connection, or intentional operation) have the same effect on circuit operation, the normally open contacts would be the correct ones to use. Upon loss of power, these contacts will open. So, you would want them to be closed for normal operations and to open when operations go into alarm or control change conditions.

It is not true that, for example, a high level switch will necessarily close contacts when you reach a high level condition. Good control practices usually dictate the opposite.

What about actuation? You might want the switch to failsafe upon loss of level in a cooling tank. So, normal level would activate the switch (compared to its shelf position). Upon loss of level, the switch deactivate — that is, it will assume the same state that it would be in if it were on the shelf. For an example of this control logic, look at a typical toggle-style light switch. You will notice the word "ON" under the toggle handle and the word OFF above it. To reveal the word "ON," you must flip the switch up. If the toggle mechanism were to fail mechanically — which could happen if, for example, it were to melt due to arcing — the toggle handle would drop into the "OFF" position due to gravity. That is the failsafe position of these switches. It's common to implement process switches the same way.

Setpoint. A switch may have multiple setpoints. For example, many level switches come with low-low, low, high, and high-high sets of contacts — each with its own setpoint.

But, it can get more complex than that, depending on the required control scheme and the type of switch used. There are many ways to accommodate complex switching schemes — including the use of an analog transmitter serves as the input to a virtual switch (implemented in software).

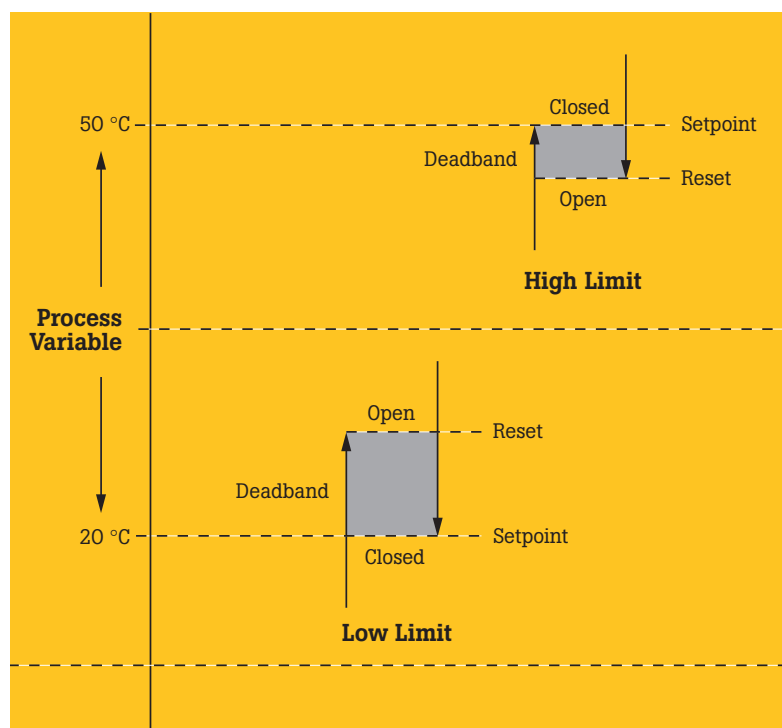


Figure 1. 2-point switch with settings for low and high setpoints.

Here's an example of a complex application. A level switch may allow a "normal" indication (such as a light) to display at any level up to 82 %. At 82 %, the switch causes normal indication to go off — placing the indication between a normal state and an alarm state. At 85 %, the switch may trigger a high level alarm light. At 90 %, the switch may trigger a high-high level alarm light plus an audio alarm. At 93 %, it may trigger a feed valve closure. At 95 %, it may trigger dump valve operation. At 97 %, it may trigger drain pump operation. At 98 %, it may actuate isolation doors in the room containing the tank. And those actions are just for high level. This same switch, or another, might control low level operations. In some configurations, you might have separate switches for each setpoint.

Setpoint tolerance. This is the amount of error you can have between the desired setpoint and the one you actually set. It's not always easy to calibrate a switch directly on the desired setpoint — for a variety of reasons. For example, if you must open a valve when the temperature reaches 313 degrees, your setpoint tolerance might allow you to consider the switch calibrated if it trips within 5 degrees of the setpoint. Tolerances may be expressed in engineering units or in percent. When expressed in percent, that normally means percent of the control *band* (we explain band below), not in percent of the setpoint value.

Direction. Switch actuation (and, therefore, control) is directional, due to hysteresis. Sometimes, the hysteresis value can exceed the setpoint tolerance. For non-critical applications with wide setpoint tolerances, you can probably ignore hysteresis. But, standard practice is to observe direction when calibrating a setpoint. When you calibrate a low level switch, you do so with the level dropping.

When you calibrate a high level switch, you do so with the level rising. This is standard practice with all process variables, not just level — you get a more accurate calibration by accounting for hysteresis.

Trip. This is the value at which the switch will change the state of a given set of contacts. Where a switch trips is a function of its setpoint and direction. For a pressure switch with a setpoint of 500 PSI, the switch should trip at 500 PSI as pressure rises. Trip is also called "set." The opposite of that is reset.

Reset. Some switches reset automatically, while others require a manual reset. In either case, the reset will not occur until the switch actuator has moved in the direction opposite its triggering direction enough to overcome hysteresis (and/or deadband — see below) and allow the switch to change contact states back to normal. An exception to this is when the switch is used to indicate a normal condition. For such switches, reset is usually not an issue.

Hysteresis. This is the tendency of the switch to stay in the last position it was in. This means that when you are calibrating a switch to trip at 500 PSI, the hysteresis of the switch may cause it to trip at 501 PSI when you are increasing pressure and 499 PSI when you are decreasing pressure. If this is a high pressure switch (control function requires a trip on rising pressure), you would calibrate it to trip at 500 PSI on an increasing pressure input and let the 498 PSI trip serve as the maximum reset value.

Band. This is the area around the setpoint where the switch is controlling the process. For example, if the switch will control a tank to maintain a level between 6 feet of water and 9 feet of water, it has a band of 3 feet.

Deadband. This is closely related to reset. Deadband prevents a switch from cycling around a setpoint. Hysteresis provides some deadband, automatically. But for some processes, hysteresis is not enough to prevent undesirable on/off cycling. So, many switches have additional deadband intentionally designed into them. That deadband may be fixed, fixed selectable, or variable. For example, an electronic thermostat used for a heat pump may have a fixed selectable deadband of 1.5 degrees or 3 degrees.

Range. This is specified with the low and high points of operation. For example, if the switch will control a tank to maintain a level between 6 feet of water and 9 feet of water, it has a calibration range of 6 to 9 feet. The switch itself might have an actual range of 0 to 50 feet – this range would appear on the nameplate of the switch.

Testing a temperature switch

The switch in the following example is a temperature switch with a type K thermocouple input and a low temperature setpoint of 20 °C. This switch functions in much the same way as the thermostat in your home. The Low Limit example in Figure 1 illustrates the terminology.

We will be using the normally open contacts of this switch. These contacts will close upon switch actuation, which will occur with a drop in temperature. This switch does not have adjustable reset. The contacts will re-open upon automatic reset, which occurs as the temperature moves back up and past the setpoint in an amount greater than its deadband. The deadband is a minimum of 1 °C and maximum of 3 °C across the range of the switch.

To set up the Fluke 740 Series DPC to calibrate the switch, follow these step-by-step instructions. Keystroke entries for the DPC are surrounded by quotation marks.

1. Beginning in the power up state of the calibrator, or Measure mode, depress the "ohms/continuity" key twice to enable continuity mode.
2. Simulate the temperature input.
 - a. Depress the "MEAS/SOURCE" key once to obtain the Source mode.
 - b. Depress the "TC/RTD" key, move the cursor with the "↓" key to "K" and depress "ENTER" to select a type K thermocouple.
 - c. Depress "ENTER" again to select "Linear T."
 - d. Enter a temperature output of "25" and depress "ENTER."
 - e. Depress the "MEAS/SOURCE" key to obtain the split screen display. The display of the 74X should be as per Figure 2.
3. Connect the DPC, per Figure 3.
4. Take As Found measurements.
 - a. Select the "As Found" softkey.
 - b. Move the cursor to "1 Pt. Switch Test" with the "↓" key and depress "ENTER." You should now see the switch test setup screen.
5. Enter the setpoint.
 - a. Depress "Enter" and enter a setpoint of "20" °C, then depress "ENTER" again. The Setpoint Type is set for low and the Set State is a short by default – perfect for this particular test. (If these conditions were different, we would change them here.). These setup conditions describe a switch that has a setpoint of 20 °C and closes a set of contacts as long as the input temperature to the switch is below 20 °C.
 - b. Depress the "Done" softkey.

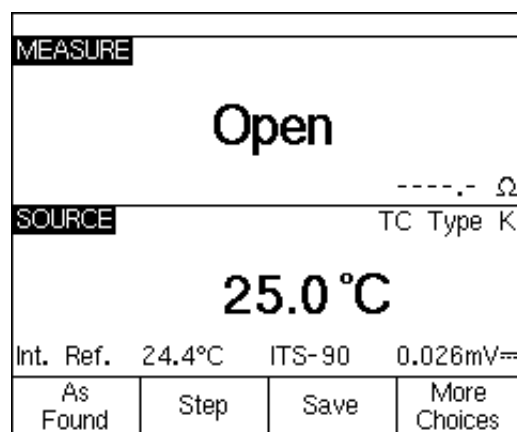


Figure 2. MEASURE/SOURCE split screen, contacts open.

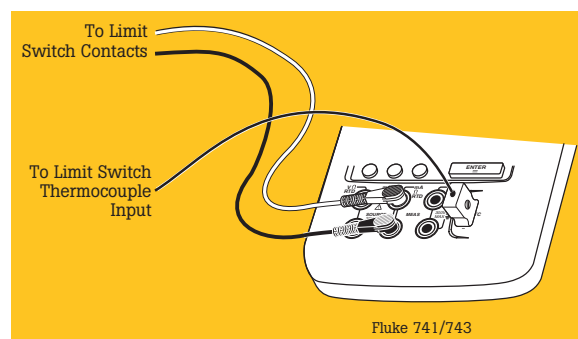


Figure 3. Connecting the DPC.

6. Enter the setpoint tolerance and deadband settings.
 - a. Move the cursor to tolerance and enter a setpoint tolerance of "1" °C.
 - b. Move the cursor to Deadband Min and enter a minimum deadband of "1" °C.
 - c. Move the cursor to Deadband Max and enter a maximum deadband value of 3 °C. The test setup screen should now be as per Figure 4. Depress the "Done" softkey.

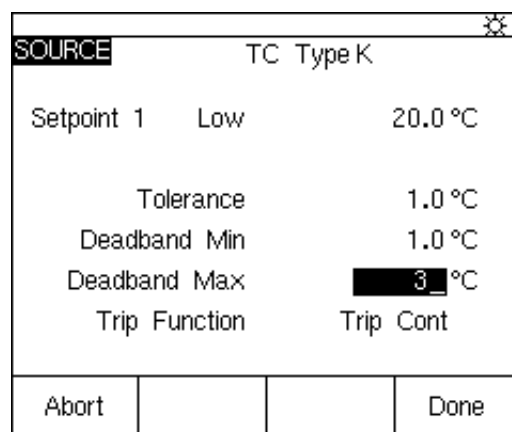


Figure 4. Test setup screen.

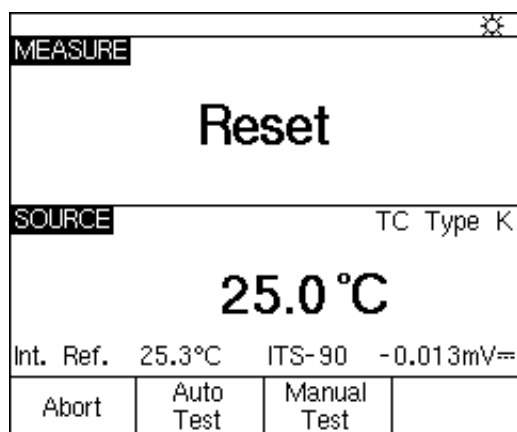


Figure 5. MEASURE/SOURCE split screen, contacts reset.

7. You should now see the split screen (Figure 5). Select the "Auto Test" softkey and the "Continue" softkey. The DPC will now ramp the simulated thermocouple potential into the limit switch back and forth past the nominal setpoint and record the sourced temperature values for the actual setpoint, and then show that value in the upper left-hand corner of the DPC display. Once that is done, the DPC will then test the reset point of the switch by ramping the simulated thermocouple potential into the switch back and forth past the nominal (21 °C - 23 °C) expected reset value. Once that value is recorded, you should be presented with a post test summary similar to that in Figure 6. Errors exceeding test tolerance are recorded in inverse video.

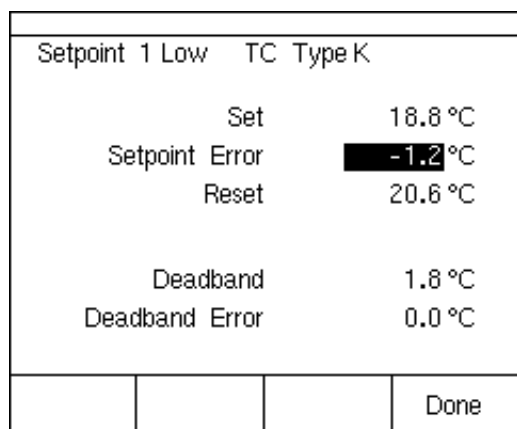


Figure 6. Post-test summary, with reverse video.

8. Enter Tag information.
 - a. Depress the "Done" softkey and enter the Tag information for your test.
 - b. Depress the "Done" softkey when tag entry is complete.
9. Adjust setpoints or reset points.
 - a. If the switch failed any of the test parameters, it is necessary to adjust the set and/or reset points. To do that, first select the "adjust" softkey.
 - b. Depress the "Step Size" softkey, then enter a step size of ".1" °C.
 - c. Depress the "Done" softkey.
 - d. Depress the "↓" key until the DPC source value is 20 °C (the setpoint).
 - e. Slowly adjust the setpoint on the limit switch until the measure screen toggles from reset to set. Depress the "↑" key until the DPC measure screen toggles to Reset. If the DPC toggles from set to reset between 21 °C and 23 °C, the deadband should be correctly set. If it does not toggle properly, adjust the reset point until it toggles within that band.
 - f. Verify the set and reset points toggle correctly, by depressing the "↓" and "↑" keys to slew the DPC source temperature across the set and reset values.
 - g. Once that is complete, depress the "Done" softkey.
10. Confirm the As Left settings.
 - a. Depress the "As Left" softkey.
 - b. Confirm the test settings.
 - c. Depress the "Done", "Auto Test" and "Continue" softkeys. Monitor the DPC as it performs the As Left evaluation.
 - d. Once the post test summary is displayed, review the results. If all results are in normal video (as in Figure 7), the As Left test passes.
 - e. Depress the "Done" softkey, and "Done" again to save the Tag information.
 - f. If there were inverse video indications of a failure, repeat the adjustments performed in Step 9 until a passing result is obtained.
11. Review results in memory,
 - a. Depress the "Done" and "Review Memory" softkeys.
 - b. Move the cursor to the tag entry associated with this test and depress "ENTER."
 - c. Move the cursor to the As Found entry and depress "Enter" to review your As Found result.
 - d. Depress the "Done" softkey.
 - e. Move the cursor to the As Left entry and depress "Enter" to review that result.
 - f. Depress the "Done" softkey, then depress the "Tag" softkey to review your Tag information.

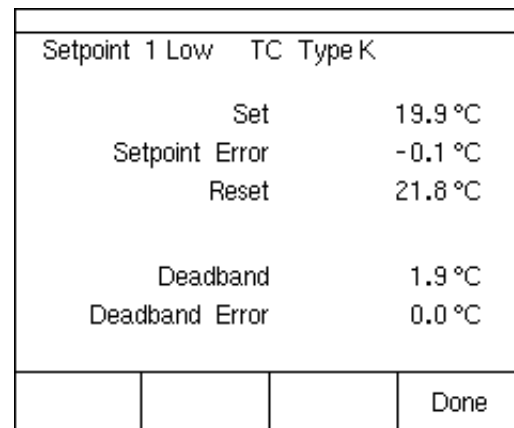


Figure 7. Post-test summary, with all results normal.

Other switch tests

In the preceding step by step description, the switch has been removed from its operational circuit and the switch contact closure is monitored to determine state change.

You can perform this test with the switch installed in its circuit. In this instance, the switch contacts will open and close and you can use the 740 Series DPC to measure the presence or absence of system voltage (e.g. 120VAC) as switch contacts change state. A typical example would be measuring the voltage applied to a heater as controlled by the output of the switch. The 740 series DPCs can work with dc voltage in addition to the continuity and ac voltage examples previously described.

Our examples in this application note have been for temperature switches. The 740 series DPCs allow you to test pressure switches, too — in fact, in 11 different engineering units. Pressure switch tests are similar to temperature switch tests — you vary the process variable (source) at the input, and monitor for a change of state at the output. You need to use a hand pump to source pressure into a pressure module and the switch. You can manually document the results by depressing the “Accept Point” soft key when the test has been completed.

With the 740 series DPCs, you can source and measure many key variables. And these tools are useful for calibrating any process switch. Of course, you will need to supply your own inputs for many types of process variables — such as level, flow, and pH. The principles of switch operation outlined here apply universally.

For detailed information on calibrating pressure switches, reference Fluke Application Note 2069058.

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