
Vernier Digital Control Unit (DCU)

Order Code DCU-BTD



The DCU is an electronic device that allows on/off control of motors, lamps, LEDs, buzzers, and other DC electrical components. It works with any Vernier interface that has at least one DIG port (SensorDAQ, LabPro, and all LabQuest models). The DCU can be used to create sensor-based projects, such as alarm systems, temperature-controlled environments, automated scientific instruments, kinetic sculptures, and smart robots. DCU projects are a great way to introduce STEM, engineering, electronics, programming, or the mathematics of feedback and control.

Overview

The DCU is a small unit with a circuit board extending from one end. On the side opposite the circuit board is a short cable, which connects to any DIG port on a Vernier interface. On the circuit board are a variety of header pins and a detachable terminal strip connector for connecting electronic devices. There are eight connections to six digital lines, plus a power and a ground connection.

The circuit board also includes six red LEDs that indicate the status of the six digital output lines—D1, D2, D3, D4, D5, and D6. There is one green LED labeled EN (for engaged) that indicates when the DCU is properly connected to the interface. There is also one blue LED labeled XP (for external power) that indicates that a power supply is attached. Learn to check the EN and XP LEDs; they can warn you if things are not set up correctly.

The DCU can be used as a set of six remote-controlled switches. These electronic switches use transistors to function like mechanical switches. If you connect an electrical device, such as a motor or lamp, between a DCU output line and a ground connection, you can control this device by switching the output line on or off.

The basics of digital output control can be taught without complicated programming by using the DCU. This booklet explains how to use the DCU to create simple projects using Vernier's *Logger Pro* software or National Instrument's LabVIEW™ software. You can control three digital lines with *Logger Pro* and all six lines with LabVIEW. Both *Logger Pro* and LabVIEW can be used on Windows or Macintosh computers.

Users wishing to control the DCU with Arduino should refer to the Engineering section of the Vernier website, www.vernier.com/engineering/arduino

Users wishing to control the DCU using a LabPro with LabVIEW or with a TI graphing calculator should refer to the previous version of the DCU manual at www.vernier.com/files/manuals/dcu-btd_20050425.pdf

Suggested Activities

The following examples show how you might use the DCU in your classroom.

Note: Each of these examples requires at least one Vernier sensor and an output device, in addition to the DCU.

Incubator Alarm

Using a temperature sensor, set an output line to activate a buzzer when the temperature climbs too high.

Hand Dryer

Using a Motion Detector, set an output line to turn on a fan if the position reading is below a threshold, i.e., detects the presence of someone's hands.

Night Watering System

Using both a Light Sensor and Soil Moisture Sensor, set an output line to activate a pump and water your plant if the ambient light level and water content of the soil are low.

Heater with a Dead Zone

Using a temperature sensor, set an output line to turn on a heater if the temperature falls below a lower threshold value and stay on until the temperature rises above an upper threshold value.

Drinking Fountain

Using a Motion Detector, set an output line to turn on a water pump/fountain if a person's position is close, and they have stopped moving toward the fountain.

Noise Indicator

Using a Sound Level Meter, set an output line to activate lights to give feedback on the noise level in a classroom—a green light when the noise level is acceptable and a red light when it gets too loud.

Light Follower

Using two Light Sensors, set two output lines to control the movement of a motor and the position of the sensors, such that they always point in the direction of the light.

Additional Examples

For more DCU engineering activities using *Logger Pro* and Vernier sensors, visit www.vernier.com/engineering/stem. Included in each Engineering Extension Activity are a student handout and teacher information with follow up questions and extra challenges, as well as an example solution (*Logger Pro* cmlb file and student design sheet).

Power Source

There are two different ports on the DCU for connecting power supplies. Both are near the short cable that connects to the interface. A LabQuest Power Supply can be connected to the smaller port. Alternatively, a LabPro or ULI Power Supply can be connected to the larger port. A complete list of power sources that can be used with the DCU is provided below:

- LabQuest Power Supply (order code LQ-PS): 5 V DC, regulated, 1.5 A
- LabPro Power Supply (order code IPS): 6 V DC, regulated, 600 mA
- ULI Power Supply (order code ULI-PS): 9 V, unregulated, 1000 mA

- Battery power supply: one lantern battery or four to eight 1.5 V cells connected in series. You can use either port for a battery power supply if you follow the polarity guides in Table 1.

Table 1 Power specifications

Input supply voltage	4–12 V
LabQuest Power Supply	5 V
LabPro Power Supply	6 V
ULI Power Supply	9 V
Polarity	LQ-PS 3.5 mm OD Socket (Center Positive) IPS or ULI-PS 5.5 mm OD Socket (Center Negative)
Output voltage	Set by input supply voltage
Max output current per line	600 mA steady; 1200 mA momentary
Max overall DCU current	1800 mA

If power supplies are connected to both ports at the same time, only the power supply connected to the larger port will be used.

Note: When building projects, you should always keep the power limitations of the DCU in mind. Never apply more than 12 V DC to the DCU or use AC power supplies. The total current drawn by your project should not exceed the capability of your power source.

Connecting the DCU to an Interface

1. Connect the DCU to any DIG port on the interface.
2. Connect a power supply to the DCU.
3. Connect the interface to the USB port on the computer.
4. If you are using LabQuest 2 or original LabQuest, make sure it is turned on.

Connecting Output Devices to the DCU

The DCU provides two easy ways to connect your electronic device: a screw terminal or header pins.

- To connect to the screw terminal, loosen the screw, insert the lead (wire) into the hole, and then tighten the screw to secure the lead. The screw terminal is detachable. Therefore, you can easily connect and disconnect your electronic device.
- To connect to the header pins, use header connectors or small alligator clips to attach the leads of your device to the appropriate pins. One row of header pins connects to the D1–D6 lines while the other row of pins connects to ground, as shown in Figure 1. This minimizes crossing wires when connecting two-lead devices such as motors.

Whichever option you choose to connect your device to the DCU, you must insulate the metal leads on all components so that they cannot accidentally touch each other.

The DCU also includes a third connection option: a cluster of three pins providing connections to the power supply, ground, and line D4. This facilitates connection to many servo motors. Servo motors require pulse width modulation (PWM) digital output that can only be used with LabVIEW software.

Table 2

Pin	DCU line
1	D1
2	D2
3	D3
4	D4
5	D5
6	D6
7	XP
8	GND

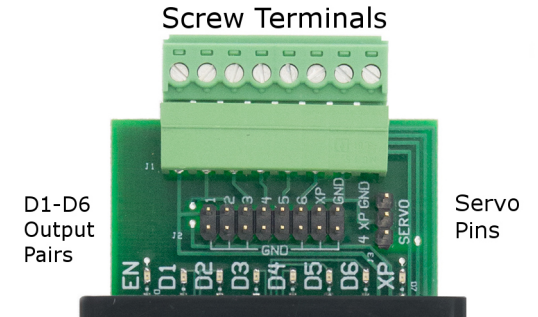


Figure 1 DCU output connectors

What can you connect to the DCU outputs?

In general, you can connect any electrical device that runs on DC electricity at a voltage that matches your power supply. The DCU output voltage can range from 5 to 12 volts, as shown in Table 1. You can find thousands of different 5 to 12 volt devices at most hobby and electronic stores, such as Mouser, DigiKey, or Radio Shack.

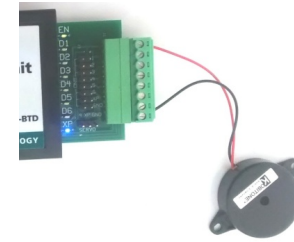


Figure 2 Buzzer connected to Pin 1 (D1) and Pin 8 (GND) via screw terminals

One common application is using the DCU to turn on an electronic device when a sensor reading reaches a threshold value. For example, the circuit in Figure 3 shows a small 5 volt hobby fan connected between the D1 and GND lines of the DCU. If the temperature reading of a sensor connected to the interface gets too hot, you would like the fan to automatically turn on just like the air conditioning system in your home. Conversely, when the temperature cools down, you would like the fan to turn off. The DCU gives you this on/off control.

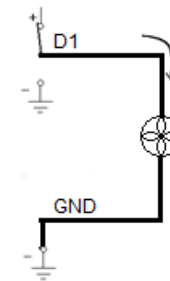


Figure 3 Wiring diagram for connecting a fan to the DCU

Sometimes you would like to use an electronic device that has the ability to operate in two different directions. Pairs of DCU lines can be used together to allow you to switch the polarity or direction of current flow in your device. Consider the circuits shown in Figure 4 of a motor wired between the D1 and D2 lines of the DCU. The circuit on the left has D1 turned on and D2 turned off, so current will flow from D1 to D2 causing the motor to spin in a clockwise direction. The circuit on the right has D1 turned off and D2 turned on, so current will flow from D2 to D1 causing the motor to spin in the opposite direction.

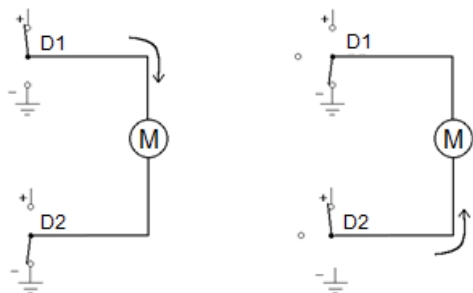


Figure 4 Wiring diagram for running a motor in two directions

It is a good practice to first check your hardware set up, using the Test DCU section of the Digital Out dialog box in *Logger Pro*. Check each line that has hardware connected to ensure that it activates correctly.

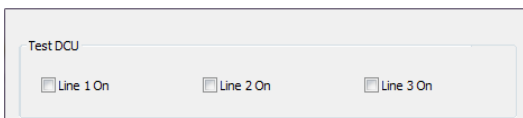


Figure 5 Test DCU section of Digital Out dialog box

Using the DCU with *Logger Pro*

Logger Pro is Vernier's data-collection and analysis program. The *Logger Pro* Digital Out feature allows you to control up to three output lines of a DCU connected to the DIG 1 or DIG 2 port of a LabQuest or LabPro. Each of the three lines can be individually controlled based on user-configured conditional statements. This allows you to develop projects that turn DC motors, lamps, LEDs, buzzers, and other DC electrical devices on and off based on sensor readings, time, or calculated columns.

Note: *Logger Pro* does not support the SensorDAQ interface. To use the Vernier SensorDAQ with a DCU, you must use LabVIEW software.

Setting up the DCU in *Logger Pro*

1. Connect the DCU and at least one Vernier sensor to the data-collection interface.
2. Choose Set Up Sensors from the Experiment menu and select your interface.

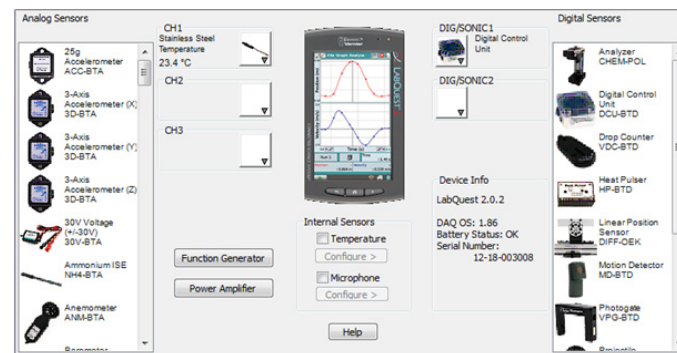


Figure 5 *Logger Pro* sensor setup window

Note: Some Digital Control Units are not auto-ID. If your DCU has not been identified by *Logger Pro* and therefore does not show up under the DIG/SONIC button, you will need to set it up manually. To do this, click on the DIG/SONIC button and select Choose Sensor ► Digital Control Unit.

3. Click the DIG/SONIC button and select Digital Out from the drop-down menu.

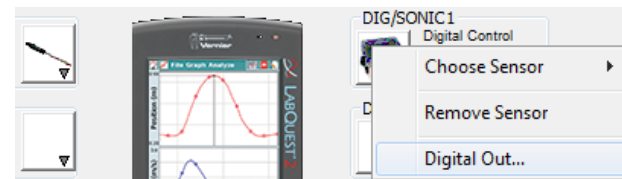


Figure 6 Digital port drop-down menu in *Logger Pro*

Use the options in the Digital Out dialog box to configure your DCU output lines to activate if the condition being evaluated is true. For more information about the configuration options, see the following section, "Configuring the DCU Activation in *Logger Pro*."

Configuring the DCU Activation in *Logger Pro*

First, test the 3 output lines of the DCU by selecting the check box for **Line 1 On**, **Line 2 On**, and/or **Line 3 On**. The LEDs on the circuit board extending from the DCU will turn on when the line is on. If you already have an output device connected to the DCU, this is a good way to test that your DCU and electrical device are working properly before running your experiment.

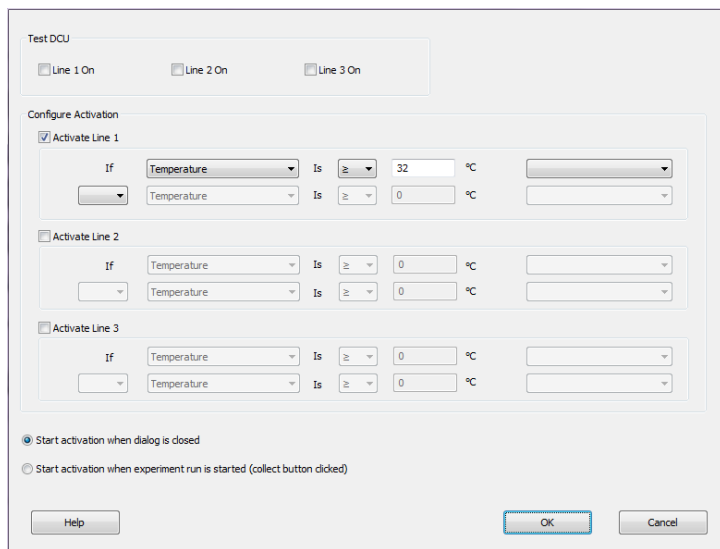


Figure 7 Digital Out dialog box

To set up the DCU output lines,

1. Select the output line you want to control.
2. Create an appropriate conditional statement for the output line based on your project.
 - a. Select a sensor reading, calculated column, or Time from the drop-down menu as the basis of the comparison.
 - b. Select an operator.
 - Select \geq to cause the digital line to be turned on if the value of the selected sensor, calculated column, or Time is greater than or equal to the comparison value.
 - Select \leq to turn the line on if the value of the selected sensor, calculated column, or Time is less than or equal to the comparison value.
 - c. Set the comparison value. The comparison value is a value you define by one of the following methods:
 - Method 1: Manually enter a value directly into the Digital Out dialog box. Using this method, the comparison value is static during the experiment.
 - Method 2: Choose and configure a User Parameter from the drop-down menu at the far right. This provides the user with a dynamic comparison value.
3. You have the option of creating a compound logic statement by selecting AND, OR, or UNTIL:
 - Select “AND” to turn the DCU line on when both threshold values have been reached.
 - Select “OR” to turn the DCU line on when either threshold value is reached.
 - Select “UNTIL” to turn the DCU line on when the first threshold value is reached and stay on until the second value is reached.

You can set the second criteria for the compound logic statement based on the same sensor, another sensor connected to a different channel, a calculated column, or Time.

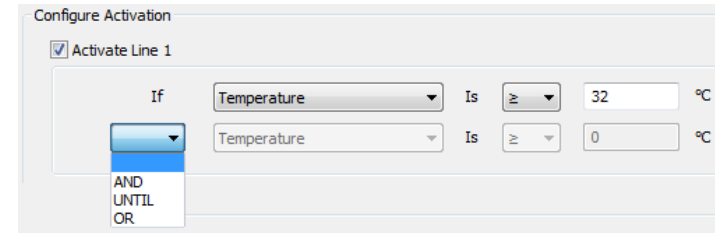


Figure 8 Activation options for the DCU

4. From the Digital Out dialog box, you can also choose when to activate the digital output. As shown in Figure 6, the dialog box includes two radio buttons:
 - Select **Start activation when dialog is closed** to have your settings take effect when you select OK to close the Digital Out dialog box.
 - Select **Start activation when experiment run is started (collect button clicked)** to have your settings take effect when you click the Collect button.

Note: The Digital Out feature is unable to scan all data at fast data-collection rates. This may mean that peaks or valleys that fall above or below the user-defined comparison value, but are of very short duration, might not activate or deactivate a line as configured. In such a case, LabVIEW provides higher rates and response times.

Example Logic Statements

Below we explore some uses of the *Logger Pro / DCU Logic* in more detail. These examples can be used as a tutorial or simply as a reference. To make each example clearer, we use a temperature sensor, connected to Channel 1, to control a 5V DC buzzer, connected to DCU Line D1 and GND, as shown here in Figure 9. If you do not have a buzzer, you can use the D1 line LED as your output.



Figure 9 Stainless Steel Temperature sensor, paired with a 5V DC buzzer

Using a simple threshold

The most common control situation is to turn on a device based on a single sensor reading. Follow these steps:

1. Plug the DCU into DIG 1, although it will work in any DIG port.
2. Plug a temperature sensor into Channel 1, although any of the analog channels will work. **Note:** You MUST have a sensor connected to setup the DCU.
3. In *Logger Pro*, click the Set Up Sensors button.
4. Click on the picture of the DCU in the DIG/SONIC 1 slot and select Digital Out.
5. Select the “Activate Line 1” check box.
6. From the drop-down menus, select “Temperature” and “ \geq ” (greater than). Then, enter a threshold value, e.g. 25°C.

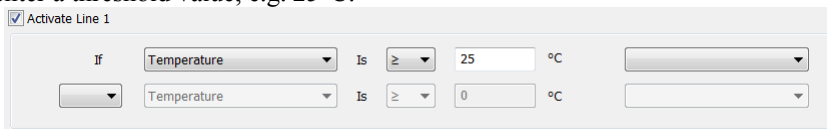


Figure 10 Simple threshold logic statement

7. Select “Start Activation When Experiment Run is Started.”

Note: The Collect/Stop button can be used as an emergency shut-off while testing your output device. Additionally, pulling the input power plug from the DCU will also turn off your output device, should you need to do so quickly.

8. Click to close the setup window.
9. From the menu bar, select “Experiment” » “Data Collection,” and change the time to 60 s and select “Repeat.”
10. Click the button. Warm the temperature probe with your hand. When the sensor warms up to the threshold value, the D1 LED will light up and the buzzer will sound, indicating that that line has been activated. The buzzer will sound until you let the temperature probe cool below the threshold value or you stop data collection.

Using the Compound Logic Statements

Using the AND, UNTIL, and OR functions to create compound logic statements allow you to control your output devices under a variety of conditions.

Using AND: Creating an inclusive range

Using a single sensor it is possible to activate the output line only when the value of a certain sensor reading is between two thresholds. For example, you might want a buzzer to sound when the temperature was above a lower threshold but also below an upper threshold.

1. In the Digital Out dialog box, select the “Activate Line 1” check box.
2. On the first line, select “Temperature” and “ \geq ” (greater than) from the drop-down menus. Then, enter a lower threshold temperature, e.g., 25°C.
3. On the second line, select “AND”. Select “Temperature” and “ \leq ” (less than) from the drop-down menus. Then, enter an upper threshold value (higher than first value, e.g., 28°C).



Figure 11 Inclusive range logic statement

When you run this program and warm the temperature probe in your hand, the buzzer will only activate when the sensor reading is between the two values you set.

Using OR: Creating an exclusive range

Using the OR function it is possible to set up a situation where a line is activated only if the reading from a sensor is outside of a given range.

1. In the Digital Out dialog box, select the “Activate Line 1” check box.
2. On the first line, select “Temperature” and “ \leq ” (less than) from the drop-down menus. Then, enter a lower threshold temperature value, e.g., 25°C. Choose a lower threshold that is above room temperature.
3. On the second line, select “OR”, “Temperature”, and “ \geq ” (greater than) from the drop-down menus. Then, enter an upper threshold value, e.g., 28°C.



Figure 12 Exclusive range logic statement

Now when you start data collection, the buzzer will sound right away because the temperature is below the lower threshold. As you warm the temperature probe up with your hand from room temperature, the buzzer will go silent when the lower threshold temperature is reached, and then start again when the upper threshold is reached.

Using UNTIL

The UNTIL function may be used in two different ways. It can be used to control a time based function, or may be used to allow cycling an output signal.

Using UNTIL: Turn on a device for a set time frame

1. In the Digital Out dialog box, select the “Activate Line 1” check box.
2. On the first line, select “Temperature” and “ \geq ” (greater than) from the drop-down menus. Then, enter a threshold value, e.g., 25°C.
3. On the second line, select “UNTIL”. This time, select “Time” from the drop-down menu of sensors/columns.
Note: Time refers to the actual measurement reading on the horizontal axis. It does not refer to elapsed time. There is currently no way to keep a line on for a specific amount of time once the line has been activated.
4. Next, select “ \geq ” (greater than) and enter a time of 10 seconds.



Figure 13 Set time frame logic statement

- At the bottom on the window, make sure to select “Start Activation When Experiment Run is Started.”

Note: This function will only work with “Start Activation When Experiment Run is Started” selected because the Time variable is not available until data collection begins.

Start by warming the temperature probe until the live reading on *Logger Pro* is close to the temperature threshold you set. Then click **Collect**. The buzzer will come on when the temperature rises past the threshold, and stay on until the time is 10 seconds, even if the temperature has dropped below your threshold.

Now do a second run, warming the probe until the temperature is above the threshold, and clicking **Collect**. Immediately put the probe into an ice water bath. Even though the temperature drops below your threshold before the 10 seconds is up, the buzzer will stay on until the time reaches 10 seconds.

Using UNTIL: Cycling an output

In some situations, using UNTIL will function the same as AND. But there are subtle differences between them. For example, consider using a heater to maintain the temperature in your home. You might feel a comfortable temperature range is between 25°C and 30°C. Programming the heater using AND and UNTIL will result in different outcomes. Consider four logic cases:

- Activate heater if Temperature ≤ 25 °C: In this case, the heater will come on and warm the house until the temperature reaches 25°C, then shut off. Once the house cools below 25°C, the heater will turn back on. The temperature in the house will fluctuate around 25°C, and will likely never reach 30°C.
- Activate heater if Temperature ≥ 25 °C AND Temperature ≤ 30 °C: In this case, the heater will not come on until the temperature reaches 25°C. Once it does, the heater will warm the house until it reaches 30°C, then turn off. Once the house cools below 30°C, the heater will turn back on. The temperature in the house will fluctuate around 30°C, and will likely never return to 25°C.
- Activate heater if Temperature ≥ 25 °C UNTIL Temperature ≤ 30 °C: In this case, the heater will not come on until the temperature reaches 25°C. Once it does, the heater will warm the house until it reaches 30°C, then turn off. Once the house cools below 30°C, the heater will turn back on. In this case, as with the AND example above, the temperature in the house will fluctuate around 30°C, and will likely never return to 25°C.
- Activate heater if Temperature ≤ 25 °C UNTIL Temperature ≥ 30 °C: In this case, the heater will come on and warm the house until the temperature reaches 30°C. But the heater will not turn on again until the house cools below 25°C. Then it will warm the house back to 30°C. In this case, the temperature in the house will cycle between 25°C and 30°C.

Note: In this case you may click either the “Start Activation when Dialog Is Closed” or the “Start Activation when Experiment Run Is Started” as you exit the set up dialog. The UNTIL function will work either way since you are not explicitly using the Time variable.

Now, try setting up the conditions in case 4 above. If you heat the temperature probe with your hand the buzzer will light while the temperature is below 25°C and go off at 30°C. It will not sound again until the temperature has first dropped below 25°C. Check what happens if the temperature again drops below 25°C before it has a chance to reach 30°C.

Advanced Logger Pro Options

By using multiple sensors at once, parameter controls, and calculated columns, you can add an extra layer of usefulness and convenience to your projects.

Thresholds on Multiple Sensors

The AND function can also be used to control an output based on inputs from multiple sensors. In this case the readings from two sensors are compared to their threshold and if both conditions are true the line is activated. For this example, we will assume we are using both a temperature probe and a light sensor.

- In the Digital Out dialog box, select the “Activate Line 1” check box.
- On the first line, select “Temperature” and “ \geq ” (greater than). Then, enter a threshold temperature, e.g., 25°C.
- On second line, select “AND”, “Illumination”, and “ \geq ” (greater than). Then, enter a threshold light level, e.g. 200 lux.



Figure 14 Thresholds on multiple sensors

Now the line will only activate when both sensors’ readings meet the threshold and conditions you have set, i.e. when the temperature rises above 25 °C and the light level exceeds 200 lux. How would you set the thresholds if you wanted to turn on a fan when it was too hot at night? In that case, the correct conditions would be Temperature ≥ 25 °C (i.e., “too hot”) and Illumination ≤ 20 lux (i.e., “at night”).

The OR function can also be used if the result of either of two sensors meets the needed criteria. Such a situation is set up the same way as the above. For example with two temperature sensors, a fan could come on if the temperature was too high at either of two locations.

Use a User Parameter for an adjustable threshold

User Parameters offer an easy way to adjust a threshold from the *Logger Pro* screen while an experiment is running.

- From the menu bar, choose “Insert” » “Parameter Control”. A Parameter control will open in your *Logger Pro* window.

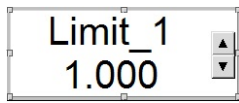


Figure 15 Default parameter control

2. Double-click on Parameter Control to edit and click the User Parameters button.
3. Click Add button.
4. In the blank line, enter “Threshold” for Name, the value to 20.000, and the units to “°C”. Then, click OK.
5. Under the User Parameter pull-down menu, select “Threshold” and click OK.

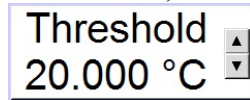


Figure 16 Parameter control set to show/adjust the Threshold value

6. In the Digital Out dialog box, select the “Activate Line 1” check box.
7. On the first line, select “Temperature” and “ \geq ” (greater than).
8. Rather than enter a threshold value, click on far-right drop-down menu and select your new User Parameter “Threshold.” Then, click to close the setup window.

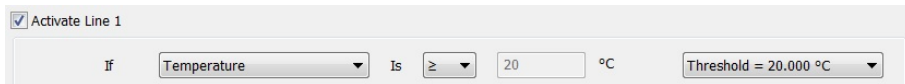


Figure 17 Using a user parameter as the threshold value

9. In your Logger Pro window, click on the up or down arrows to adjust the value of the Threshold Parameter Control to a temperature just above room temperature.
10. Warm the temperature probe in your hand. Line 1 will activate when the temperature exceeds the Threshold value. With the Threshold Parameter Control, you can adjust the threshold value on the fly, as your application demands.

A parameter control can be very helpful when fine-tuning the threshold at which a line activates and it can give users more control over when a line activates.

Use a Calculated Column as a threshold

A Calculated Column may be used in place of a sensor to control line activation, as well. The calculation can be based on any sensor, on Time, or on another Calculated Column. In the example below, we will use two temperature sensors to activate Line 1 under one condition and Line 2 under another condition:

1. Connect two temperature sensors to the interface.
2. Create a new calculated column called “Difference” to subtract the second temperature readings from the first (“Data” » “New Calculated Column”).
3. In the Digital Out dialog box, select the “Activate Line 1” check box.
4. On the first line, select “Difference” for the variable.

Note: Once you create a calculated or manual column, it will appear as a choice in the drop-down list.
7. Then, select “ \geq ” (greater than) and enter a threshold value of “0.1”.
8. Select the “Activate Line 2” check box.

9. As before, on the first line select “Difference” for the variable. But, select “ \leq ” (less than) and enter “-0.1” as the threshold.

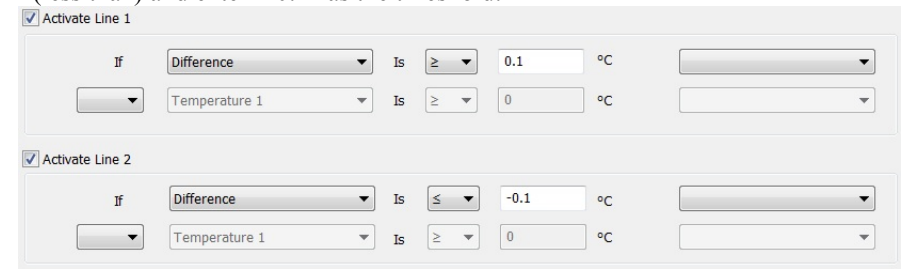


Figure 18 Using a calculated column as a threshold value

In this example, the output device connected to Line 1 will activate when the first temperature is greater than the second, i.e., the Difference is positive. The Line 2 output device will activate when the second temperature is greater, i.e., the Difference is negative.

Note: If using the DCU to run a motor connected between Line 1 and Line 2, the motor will turn clockwise if the difference is positive and counterclockwise if the difference is negative.

Another way to use a calculated column is to cycle an output device on and off. For instance, a calculated column can be used to cause an LED to flash, rather than simply light up. Set the LED line to activate if the temperature is above a set point AND a calculated column, defined as $\sin(2*\pi*Time)$, has a value above 0. The speed of the flash is set by the period of the $\sin()$ function. In this case, the LED will cycle once a second.

Troubleshooting Logger Pro Projects

Here are a few suggestions of things to look for when troubleshooting your setup.

- Test that the DCU is connected correctly and working by opening the Digital Out dialog box. When you select the Test DCU option “Line 1 On” the DCU should immediately turn on the green D1 LED. If the on-board LEDs light, then the DCU functioning properly.
- Make sure the DCU is connected to an external power supply. An external power supply is especially important when connecting electronic components, such as motors, that draw a lot of current.
- Check for a loose or improperly-wired connection between the output devices and the DCU. Frequently, the problem is that the output device is connected to the wrong pin or terminal.
- Use the Test DCU option in the Digital Out dialog box to check that the LEDs, buzzers, and other output devices connected to the DCU are wired correctly.
- Check the logic assignments in the DCU Digital Out dialog box. If your threshold values are too high or too low, the corresponding line will either activate too soon, or will never activate. Likewise, check that you have used AND, OR, and UNTIL appropriately for your situation; you may have accidentally set conditions that will never be true.

Using the DCU with LabVIEW Software

LabVIEW is a graphical programming language developed by National Instruments for creating sophisticated measurement and automation systems. Vernier supports the use of the Vernier DCU and sensors with LabVIEW version 9.0 or newer. A package of Express VI's and a variety of examples for the Vernier SensorDAQ and all versions of LabQuest interfaces can be downloaded from www.vernier.com/engineering/ni-labview/downloads

We designed a Digital Express VI (found in the Vernier functions palette) to simplify the use of the DCU for four application areas: direct control of six output lines, pulse train generation, and control of servo and stepper motors. The first time you connect the DCU to the interface, you may notice one or more red LEDs are illuminated. This depends on the interface, the current state of the digital channel, and/or the model of your DCU. When you set up the DCU in LabVIEW or run a VI for the first time, all DCU lines should initialize to the off position.

Controlling a Digital Output Line

Direct control of the six digital output lines, D1–D6, is the most commonly chosen configuration when using the DCU. The line can be connected to the positive side of the DCU power supply, to the negative side of the power supply, or left unconnected. If a device is connected from one of the digital lines to ground and the program directs control to the + position, current will flow and the device will be on. Either of the other two positions will turn the device off.

We have developed a table of 16 patterns that allow you independent control of the first three lines, D1–D3, and limited control of the remaining three lines, D3–D6. Notice that the first 12 patterns in the table, Patterns 0–11, can be considered the binary equivalent of the pattern number.

Table 3 DCU Output Patterns

Pattern	Binary	D1	D2	D3	D4	D5	D6
0	0000	–	–	–	–	X	X
1	0001	+	–	–	–	X	X
2	0010	–	+	–	–	X	X
3	0011	+	+	–	–	X	X
4	0100	–	–	+	–	X	X
5	0101	+	–	+	–	X	X
6	0110	–	+	+	–	X	X
7	0111	+	+	+	–	X	X
8	1000	–	–	–	+	X	X
9	1001	+	–	–	+	X	X
10	1010	–	+	–	+	X	X
11	1011	+	+	–	+	X	X
12	1100	X	X	X	X	–	–
13	1101	X	X	X	X	+	–
14	1110	X	X	X	X	–	+
15	1111	X	X	X	X	+	+

- + indicates the line is connected to the positive side of the DCU power supply
- indicates the line is connected to the negative side of the DCU power supply
- X indicates the line is disconnected

You can test the 16 different patterns within the configuration window of the Digital Express VI. To do this, click the increment/decrement button next to the DCU pattern to see the LEDs illuminate on the graphical display. For example, configuring a DCU for Pattern 3 means that digital lines D1 and D2 will be turned on simultaneously. If the DCU is connected to the interface, click Run to activate these lines on your hardware.

You are given the option of having the lines stay on indefinitely or for a fixed length of time. Choosing to keep the lines on indefinitely allows you to place the Express VI within a loop and continuously update the lines as needed.

The DCU Pattern is an input terminal on the Digital Express VI and can be programmed as a constant, as shown in Figure 19, or as a front-panel control, as shown in Figure 20, depending upon your application.

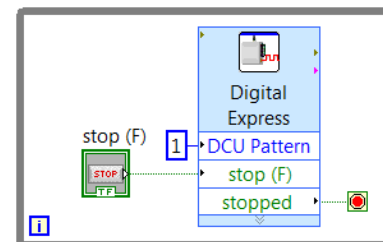


Figure 19 LabVIEW VI to control a DCU line

Alternatively, the DCU Pattern can be controlled from sensors connected to the system to create the same examples as described in the *Logger Pro* Examples section of this manual. A simple example program for a temperature monitoring system is shown in Figure 20. In this program, an Analog Express VI is used to collect data from a temperature sensor connected to the interface. DCU line D1 will turn on when the temperature exceeds a set point defined by a front-panel control.

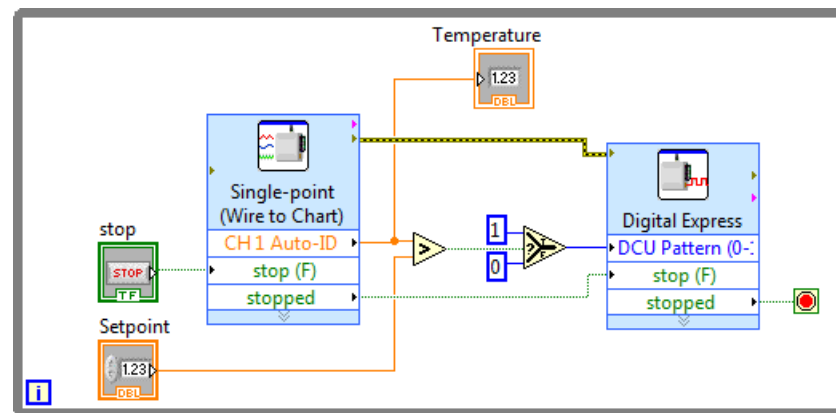


Figure 20 LabVIEW VI to control the DCU with a sensor reading

It is important when using the Digital Express VI to control a DCU output line that the “stop (F)” and “stopped” terminals are wired as shown in Figures 19 and 20. This ensures that all lines are turned off when program execution ends. Avoid using the

Abort Execution button when running your program as it will most likely leave one or more DCU lines on.

Pulse Train Generation

The DCU can generate pulse trains using LabVIEW. Pulse trains make a digital controller act like an analog controller by sending a variable voltage signal. This is called *pulse-width modulation* (PWM). One common application is a variable speed control for a DC motor.

The DCU has the ability to generate a pulse train from output line D1 when the DCU is connected to a SensorDAQ, or output line D4 when the DCU is connected to a LabQuest interface. Users must connect their projects to the correct DCU line when using the pulse train feature.

In the Digital Express VI configuration window, the duty cycle is a decimal number between 0 and 1, and indicates the ratio of “on” time to total time. An example of generating a pulse train is shown in Figure 21.

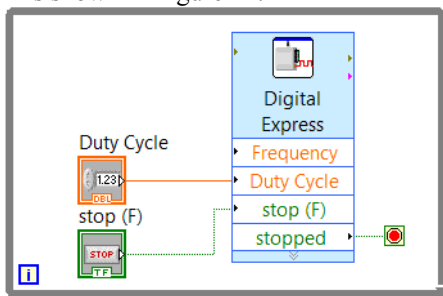


Figure 21 LabVIEW VI to generate a pulse train

Servo Motors

Another use of PWM is to control a servo motor. The shaft of the servo motor is oriented to specific angular positions within a $\pm 90^\circ$ range by sending the servo a square wave voltage pattern. The shaft position is controlled by the length of time that the square wave is at the high voltage. The servo motor will hold its position firmly as long as the square wave continues. The neutral position, (0.5 duty cycle) corresponds to 0° .

In order to use the Digital Express VI with a servo motor, the control line of the servo motor must be wired to DCU line D1 if using a SensorDAQ, or DCU line D4 if using a LabQuest. In the Digital Express VI, the default values for the Servo Pulse-Width Parameters are set for the most commonly used servo motors. These values can be modified, if necessary, to match the manufacturer’s specifications.

The Digital Express VI must be placed in a While Loop when you are controlling a servo motor because the pulse train must be sent continuously for the motor to maintain the desired position. Using a front-panel control to adjust the position of the motor will make your program more user-friendly.

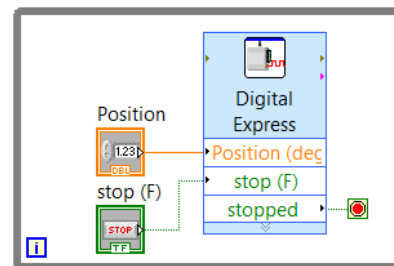


Figure 22 LabVIEW VI to control the position of a servo motor

Stepper Motors

A stepper motor is a motor that rotates in discrete (individual) steps rather than continuous movement. It is used in cases where exact control and positioning of a motion are required.

In order to use the Digital Express VI, your stepper motor must be wired to the first four output lines on the DCU. To drive a stepper motor, the Express VI sends a pattern of on/off signals to the DCU to activate the electromagnets inside the motor (“5,9,10,6” for clockwise and “6,10,9,5” for counterclockwise). This default pattern sequence will work with many stepper motors; however, it can be adjusted if necessary to match your manufacturer’s documentation.

Within the configuration window you have the option to set the total Number of Steps, the Step Speed, and the Direction, or to create front-panel controls for these parameters. Notice that the Step Speed is actually a time measurement specifying how long a motor will wait before making the next turn step; therefore, a lower number will result in a faster turn speed. For continuous movement, the Digital Express VI should be placed inside a loop.

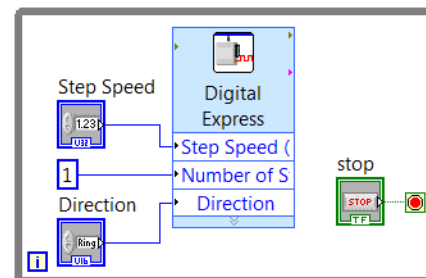


Figure 23 LabVIEW VI to control a stepper motor

LabVIEW Example Programs

We have included a nice set of example VIs with our LabVIEW files. You will find these in the LabVIEW\examples\Vernier directory. Selected examples from this directory are shown in Table 4.

Table 4

Name	Description
DCUCAR	Allows forward and reverse keypad control of two DC motors.
DCUCOUNT	Input DCU pattern from 0–15 to turn on all DCU output patterns.
DCUSTEP	Control a stepper motor.
DCUSTEP3	Advanced control of a stepper motor.
DCUSUN	Use two light sensors and a DC motor to follow the direction of a light source.
DCUTEMPC	Control temperature with a heater and fan.
DCUTOGGLE	Toggle DCU lines with the keypad.
DCUWARNV	Turn on a buzzer when a sensor reading is above a threshold.

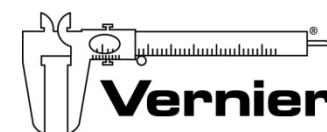
Additional LabVIEW Resources

We have developed two books that introduce LabVIEW programming and provide some great projects. The *Hands-On Introduction to NI LabVIEW with Vernier* lab book (order code LWV) introduces NI LabVIEW programming through a series of hands-on exercises using a temperature sensor and microphone.

The *Engineering Projects with NI LabVIEW and Vernier* lab book (order code EPV) contains twelve projects that introduce engineering concepts and LabVIEW programming. This includes ten DCU projects complete with wiring diagrams, materials lists, and challenge activities.

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