

SPINOFFS

Spinoffs are relatively short learning modules inspired by the LTAs. They can be easily implemented to support student learning in courses ranging from prealgebra through calculus. The Spinoffs typically give students an opportunity to use mathematics in a real world context.

LTA - SPINOFF 7A

Orbits Versus Altitude Regression with
TI™ Graphing Calculators

LTA - SPINOFF 7B

Curve Fitting for the Spacelab
for Calculus III

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SPINOFF 7B

Curve Fitting for the Spacelab and Calculus III

The following project is based on actual events encountered by Carlos Rodriguez, an engineer for NASA at Kennedy Space Center in Florida.

CONGRATULATIONS!!! You have just been hired by NASA/Kennedy Space Center. Your job includes working on a team that performs testing of Spacelab experiments. Spacelab is the container that is loaded into the Space Shuttle bay which will hold the astronauts and the many experiments they will perform in space.

Because of the extreme importance of success, all experiments are tested several times on the ground before being sent into space. Your team performs the first round of testing the experiments. It involves using a computer to simulate many of the processes that will be used on the Space Shuttle when performing the experiments in space.

NASA engineers have discovered that temperature readings on a power supply are not being displayed accurately by the computer. Your team's job is to investigate the current system and determine the cause for the inaccuracy, and suggest possible improvements. You know that this is extremely important, as failure could result in the loss of many important things, such as expensive equipment, valuable time, and your job.

In order for the temperature to be transmitted to and displayed by the computer, the following process must be performed (see Figure 1 below). First, a data collection device called a sensor/signal conditioner senses the temperature of the power supply and emits a corresponding voltage. This voltage is sent to an "analog to digital converter" (A/D converter), which outputs an integer measured in units called counts. Finally, the computer takes the integer and, using an equation that you provide, converts it back to the original temperature or at least a close approximation. As a point of interest, many systems on the Space Shuttle have sensors that operate in the same fashion.

The following is an example. When the power supply has a temperature of 41.9°C , the sensor/signal conditioner emits a voltage of 2.5 volts. The A/D converter takes that 2.5 volts and returns 512 counts. The computer then uses the equation you provide to convert 512 counts back to 41.9°C . To get this equation for the computer you will need to do the following: (1) find an equation to model the conversion from temperature to voltage performed by the sensor/signal conditioner, (2) find an equation to model the conversion from voltage to counts performed by the A/D converter, and (3) use these two equations to find one single equation that the computer will use to convert counts back to temperature. The following activities will lead you through this process.

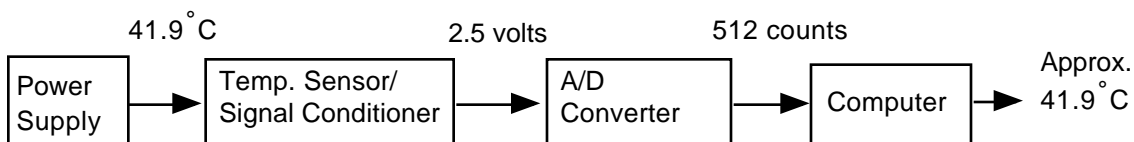


Figure 1

Part A

- 1) You have been told that this A/D converter has been configured to have an input minimum of 0 volts which gives an output of 0 counts. It has an input maximum of 5 volts which gives an output of 1024 counts. You know that the A/D conversion is linear. Find the equation of this line.
- 2) Below is the graph for the sensor/signal conditioner provided by the system's manufacturer. The horizontal axis gives temperature measured in degrees Celsius and the vertical axis gives the corresponding emitted voltage. The curve gives actual outputs, and the line is the company's suggested approximation for the curve. Comment on why the company suggested approximating with a line rather than using the sensor/signal graph.

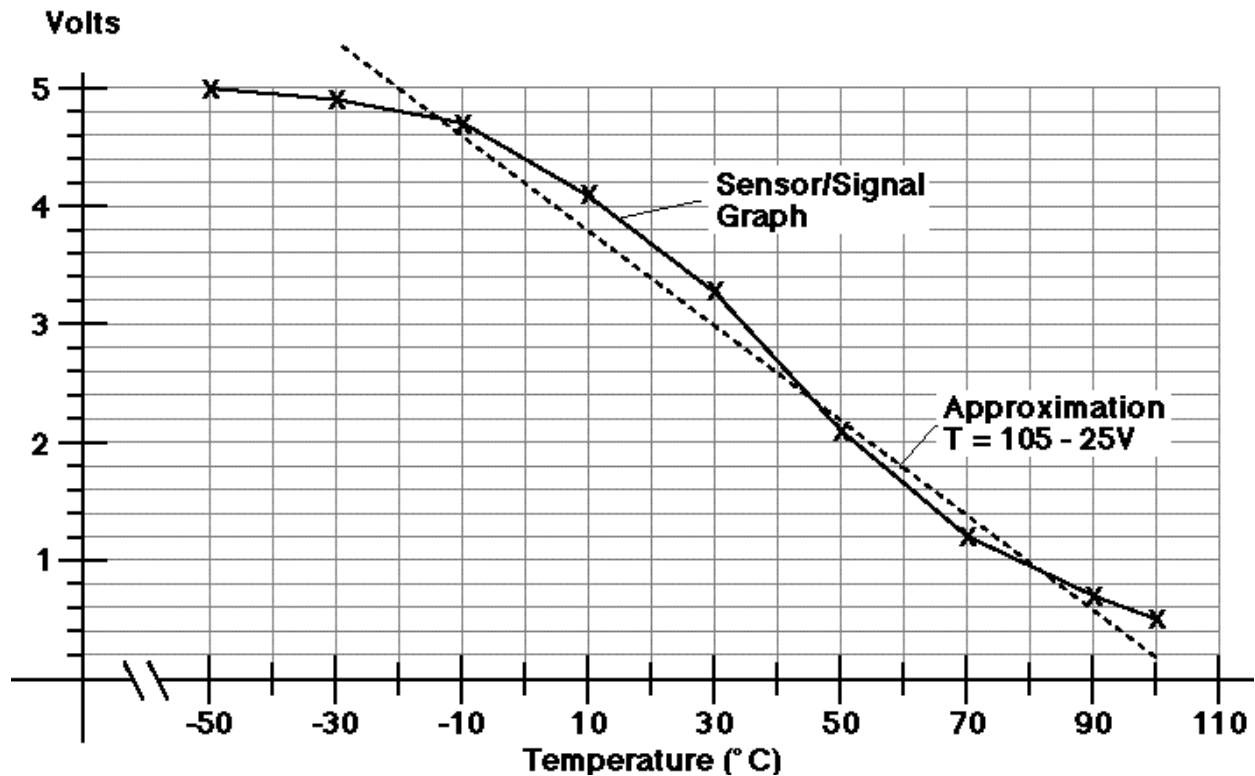


Figure 2

- 3) Using Exercise 1 (for the A/D converter) and the company's equation (for the sensor/signal conditioner), write a single equation that converts directly from temperature to counts.
- 4) Rewrite the equation from Exercise 3 with temperature written in terms of counts. This is the equation that the computer will use to convert counts back to the original temperature for the computer user to read.

- 5) Fill in the following table to see how well the company's line allows you to monitor temperature:

Actual temperature of power supply (degrees C)	Actual voltage from sensor/signal conditioner curve (volts) (Use the graph in Figure 2)	Number of counts from A/D converter (Use the equation from Exercise 1)	Temperature that the computer will read (Use the equation from Exercise 4) (degrees C)
30			
40			
50			
60			
70			

- 6) Are the temperatures the computer shows close (say within 2.5%) to the actual temperatures?

Part B

It turns out that the temperature range in which the power supply generally stays is 30°C to 70°C. Your group believes that the company may have found the least-square regression equation using the entire domain. You reason that it may be better to restrict your domain to the interval from 30 to 70. Recall that the linear least-square regression equation is found by minimizing the sum of the squares of the differences between the actual y-values on the graph and the $f(x)$ values obtained from the linear equation $f(x) = ax + b$ for each data point. For example, if we had the points (30, 3) and (50, 2) we would want to minimize $f(a,b) = [3 - (30a + b)]^2 + [2 - (50a + b)]^2$.

- 1) Write an equation for the sum of the squared differences of the points in your table between 30 and 70 inclusive and the line $f(x) = ax + b$. It should be a function of a and b .
- 2) Use Calculus to minimize the equation in Exercise 1. (Be sure to verify that you have found a minimum.) If you have a calculator that does linear regression, use it to check the answer you found by using Calculus.
- 3) Perform the steps as in Part A to fill in the following table using your new equation. Compare these results with those from the company's equation.

Actual temperature of power supply (degrees C)	Actual voltage from sensor/signal conditioner curve (volts)	Number of counts from A/D converter (use equation from Part A, Exercise 1)	Temperature that the computer will read (degrees C)
30			
40			
50			
60			
70			

Extensions (optional)

Try using a different type of regression to model this problem. Perhaps you could try a quadratic function ($f(x) = ax^2 + bx + c$), a trigonometric function ($f(x) = a \sin(bx + c) + d$), or some other non-linear function.