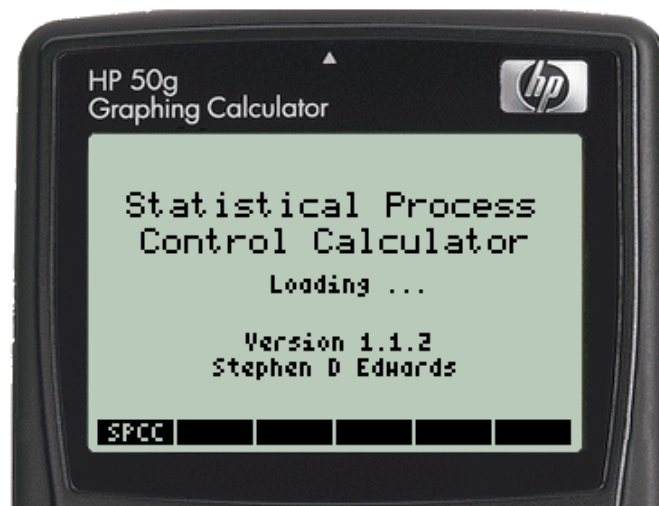


STATISTICAL PROCESS CONTROL CALCULATOR USER'S GUIDE



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SECTION 1 - INTRODUCTION

Statistical Process Control Calculator (SPCC) is a program for the HP50g calculator that aids in the prediction and analysis of process yield. Each parameter can be entered or found. SPCC can also be run on a PC using the free program HPUserEdit 5.4, found at www.hpcalc.org, or the calculator page at www.maximintegrated.com.

The following eight parameters can be entered or found

1. Defects Per Million, **DPM**, in PPM
or, Long term Yield, **Yld**, in %
or, Long term Defects, **Def**, in %
2. Long term Process Shift, $\Delta\sigma$, in Z
3. Short term Standard Deviation, σ , in user units, U
4. Short term Mean, μ , in user units, U
5. Lower Specification Limit, **LSL**, in user units, U
6. Lower Specification Limit, **LSL**, in Z
7. Upper Specification Limit, **USL**, in user units, U
8. Upper Specification Limit, **USL**, in Z

SPCC can find any parameter as a function of the others, making it useful for both predicting yield, and for finding the conditions necessary to produce a desired yield. It also allows you to plot the probability density of a population based on these parameter values.

These parameters appear in SPCC as shown below:

```
DPM = 3.39774 PPM
Δσ = 1.50 Z
σ = 1.00 Unit
μ = 10.0000 Unit
LSL = -∞ Unit
LSL = -∞ Z
USL = 16.0000 Unit
USL = 6.00 Z
=
```

NAME STO RCL PLOT FIND EXIT

A small dot to the right of the selection arrow serves as a reminder that an alternative parameter is available. Press the right arrow key to select the alternative parameter.

By default SPCC uses standard SPC terminology of μ , **LSL**, and **USL**. Alternatively, **Typ**, **Min**, and **Max**, can be used, which are commonly found in the electrical specification of integrated circuits and other electronic components.

```
Yld = 99.999660 %
Δσ = 1.50 Z
σ = 1.00 Unit
Typ = 10.0000 Unit
Min = -∞ Unit
Min = -∞ Z
Max = 16.0000 Unit
Max = 6.00 Z
=
```

NAME STO RCL PLOT FIND EXIT

```
Def = 0.003398 %
Δσ = 1.50 Z
σ = 1.00 Unit
Typ = 10.0000 Unit
Min = -∞ Unit
Min = -∞ Z
Max = 16.0000 Unit
Max = 6.00 Z
=
```

NAME STO RCL PLOT FIND EXIT

Refer to Section 7 for an explanation of these parameters and how they are calculated.

SECTION 2 - INSTALLATION

SPCC can be installed on the HP50g calculator or a Windows PC.

Installing SPCC on the HP50g Calculator

SPCC may be installed in any one of three ways:

A. Best when installing one calculator:

Copy the executable file SPCC.hp to the home directory or subdirectory of the HP50g calculator. Launch SPCC.hp.

B. Best when installing between two and six calculators:

Copy the executable file SPCC.hp to the root directory of an SD card, and the much smaller file SPCC to the home directory or subdirectory of the HP50g calculator. Launch SPCC.

C. Best when installing six or more calculators:

Install ACCU using the Calculator Launcher (CALC) utility found at www.maximintegrated.com/design/tools/calculators/hp50g/. Refer to the CALC User's Guide for an explanation of this utility.

Refer to the HP50g Graphing Calculator User's Guide for instructions on how to copy files to the calculator.

Installing SPCC on a Windows PC


SPCC can be run on a Windows PC using the free program HPUserEdit 5.4. HPUserEdit is an IDE for the HP50g and contains a suitable emulator.

To install HPUserEdit:



Download and install HPUserEdit 5.4, found at www.hpcalc.org. Search for "HPUserEdit5". The default language is Spanish. However, other languages can be selected as follows,

1. Select 'Opciones' (Options)
2. Select 'Idiomas' (Language)
3. Select the preferred language (English is assumed in this document)

To run SPCC:

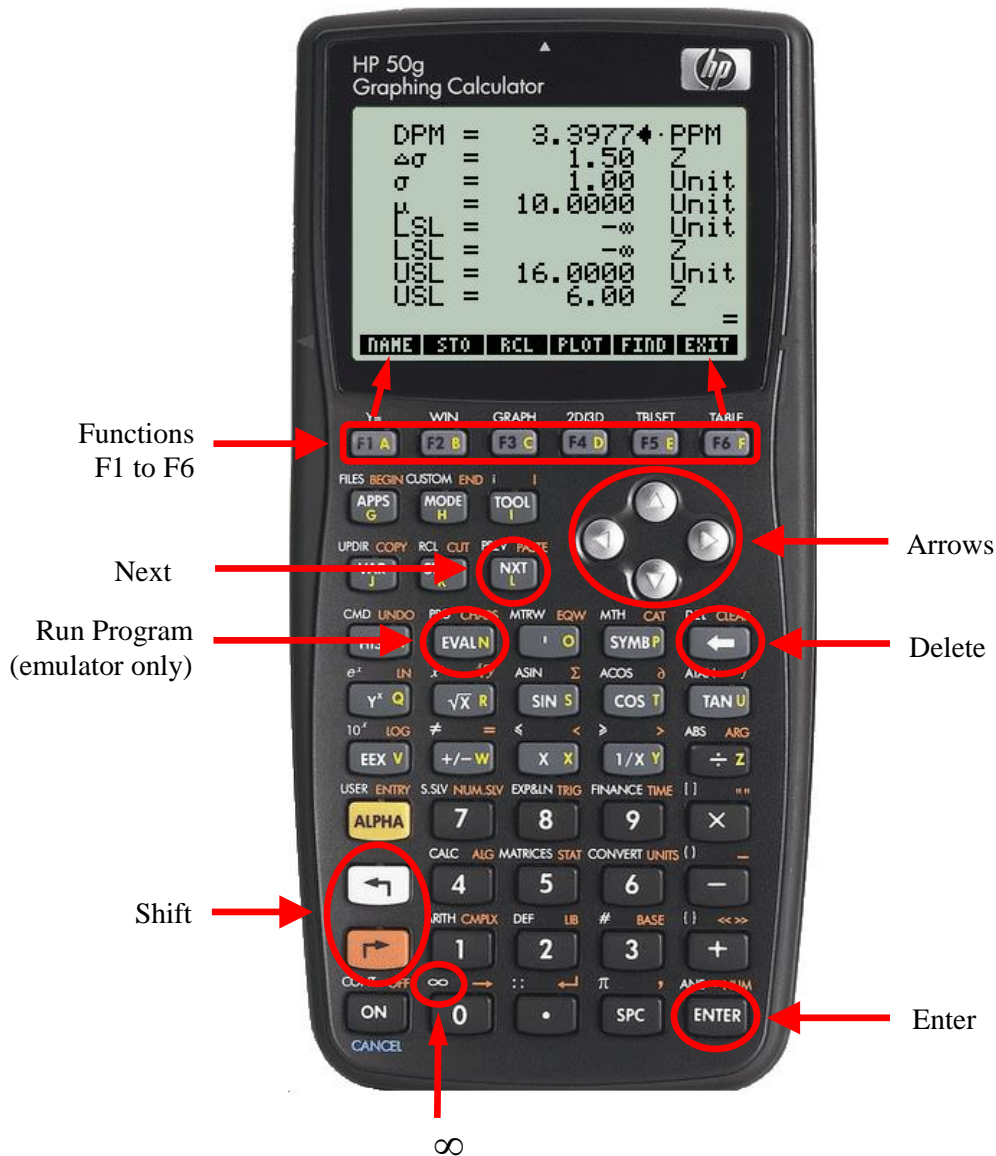
1. Launch HPUserEdit
2. Launch the HP50g emulator by selecting Emulator/Run_the_Emulator from the menu bar. A virtual HP50g appears.
3. Drag and drop SPCC.hp to the calculator screen and click the  key.

The splash screen shown on page 1 of this guide is displayed when the calculator is loading. It appears momentarily, and may not be visible when run on a PC.

SPCC creates a file named 'CalcDB' in the calculator's home directory the first time it is run. 'CalcDB' holds the parametric values used by SPCC when launched, and is used by the  and  commands to store and recall the parameters.

SECTION 3 - KEYBOARD

The following diagram shows the location of all keys used by SPCC:



For convenience, when using the emulator, the calculator keys map to the PC keyboard as follows:

Calculator Keys	↔	PC Keyboard
Numbers	↔	Numbers
Enter and Delete	↔	Enter and Delete
Yellow Letters	↔	Letters
Arrows	↔	Arrows
Left Shift	↔	Shift
Right Shift	↔	Control

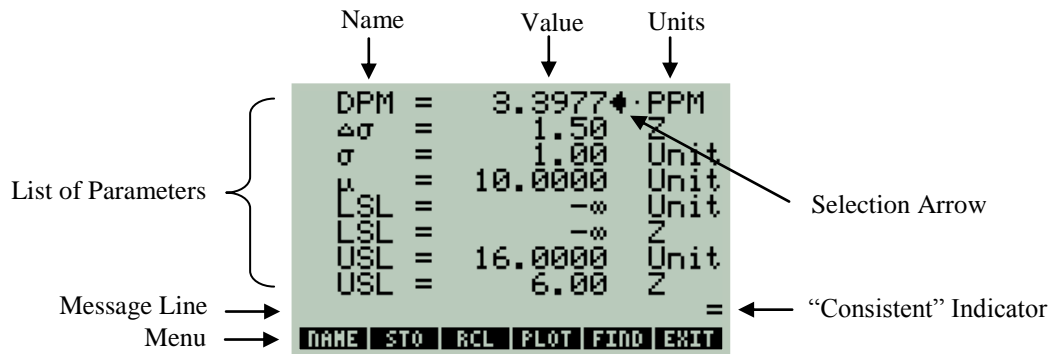
SECTION 4 - COMMANDS

SPCC has three sets of commands:

- Main Menu Commands
- Extended Menu Commands
- Help Command
- Plot Commands

Main Menu Commands

After launching SPCC for the first time, the following screen appears, listing eight related parameters.




Use the ∇ and \triangle keys to select a parameter.


Use the \triangleright key to display an alternative parameter (**DPM, $\Delta\sigma$, σ , μ , LSL, and USL** only)

Use the \triangleleft (insert) or \blacktriangleleft (delete) key to enter or edit a parameter. Press ENTER when finished.

- F1 (INFO) displays a description of the selected parameter in the message line
- \triangleleft F1 (INFO) displays the full precision of the selected parameter in the message line
- F2 (STO) stores all parameters
- F3 (RCL) recalls all stored parameters
- F4 (PLOT) plots the probability density specified by the parameters
- F5 (FIND) finds the selected parameter
- F6 (EXIT) or ON (Cancel) exits the program
- \triangleleft F6 (CALC) launches previous run calculator (for physical calculators only - requires CALC)
- \triangleright ON turns off the calculator

Enter or edit a parameter value by using one of the following keys:

the delete key (),

and the left arrow (insert) key ()

```


DPM = 3.3977 PPM
Δσ = 1.50 Z
σ = 1.00 Unit
μ = 10.00
LSL = -∞ Unit
LSL = -∞ Z
USL = 16.0000 Unit
USL = 6.00 Z
=
NAME STO RCL PLOT FIND EXIT



```

```



DPM = 3.3977 PPM
Δσ = 1.50 Z
σ = 1.00 Unit
μ = 10.00
LSL = -∞ Unit
LSL = -∞ Z
USL = 16.0000 Unit
USL = 6.00 Z
=
NAME STO RCL PLOT FIND EXIT

```

Press  when finished.

The equal sign (=), in the lower right hand corner of the display, indicates that all the parameters are consistent with each other. That is to say, **DPM**, **Yld**, and **Def**, result from the values of **Δσ**, **σ**, **μ**, **LSL**, and **USL** entered. The parameters are always consistent immediately following a  () command, and the “=” will appear. Any entry of a parameter value will show the “≠” sign, indicating that the parameters may no longer all be consistent.

Extended Menu Commands










Press the  key to display the Extended Menu showing four additional commands. Press  again to return to the Main Menu.

```

DPM = 3.3977 PPM
Δσ = 1.50 Z
σ = 1.00 Unit
μ = 10.0000 Unit
LSL = -∞ Unit
LSL = -∞ Z
USL = 16.0000 Unit
USL = 6.00 Z
=
NAME STO RCL PLOT FIND EXIT





```

← The Extended Menu

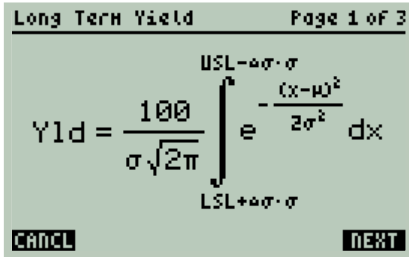
-  () displays the equations used by SPCC
-  () exports the selected parameter to the stack upon exiting
-  () imports a number present in level 1 of the stack when SPCC was launched, to the selected parameter. The import value is automatically displayed on the message line.
-  () enters all default parameter values. Parameters are not stored until  is executed.

The Main Menu reappears after executing an extended menu command.

Help Command

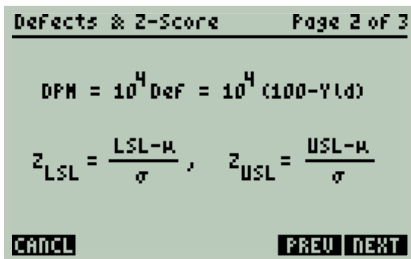
Press F1 () to display the help screen, and F5 () and F6 () to view pages 1 through 3 shown below. Press F1 () to return to the parameter display.

The help screens displays the equations used by the calculator, and shows the relationships between the parameters.



$$Yld = \frac{100}{\sigma \sqrt{2\pi}} \int_{LSL + \mu - 3\sigma}^{USL - \mu + 3\sigma} e^{-\frac{(x - \mu)^2}{2\sigma^2}} dx$$

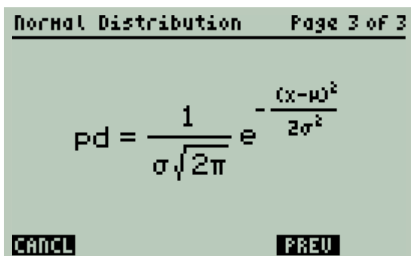
This equation defines the relationship between parameters, **Yld**, σ , $\Delta\sigma$, **LSL** in user units, and **USL** in user units.



$$DPM = 10^4 \text{Def} = 10^4 (100 - Yld)$$


$$Z_{LSL} = \frac{LSL - \mu}{\sigma}, \quad Z_{USL} = \frac{USL - \mu}{\sigma}$$

These equations define the alternative parameters for **Yld**, **Def** and **DPM** and define **LSL** in Z, and **USL** in Z.



$$pdf = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x - \mu)^2}{2\sigma^2}}$$

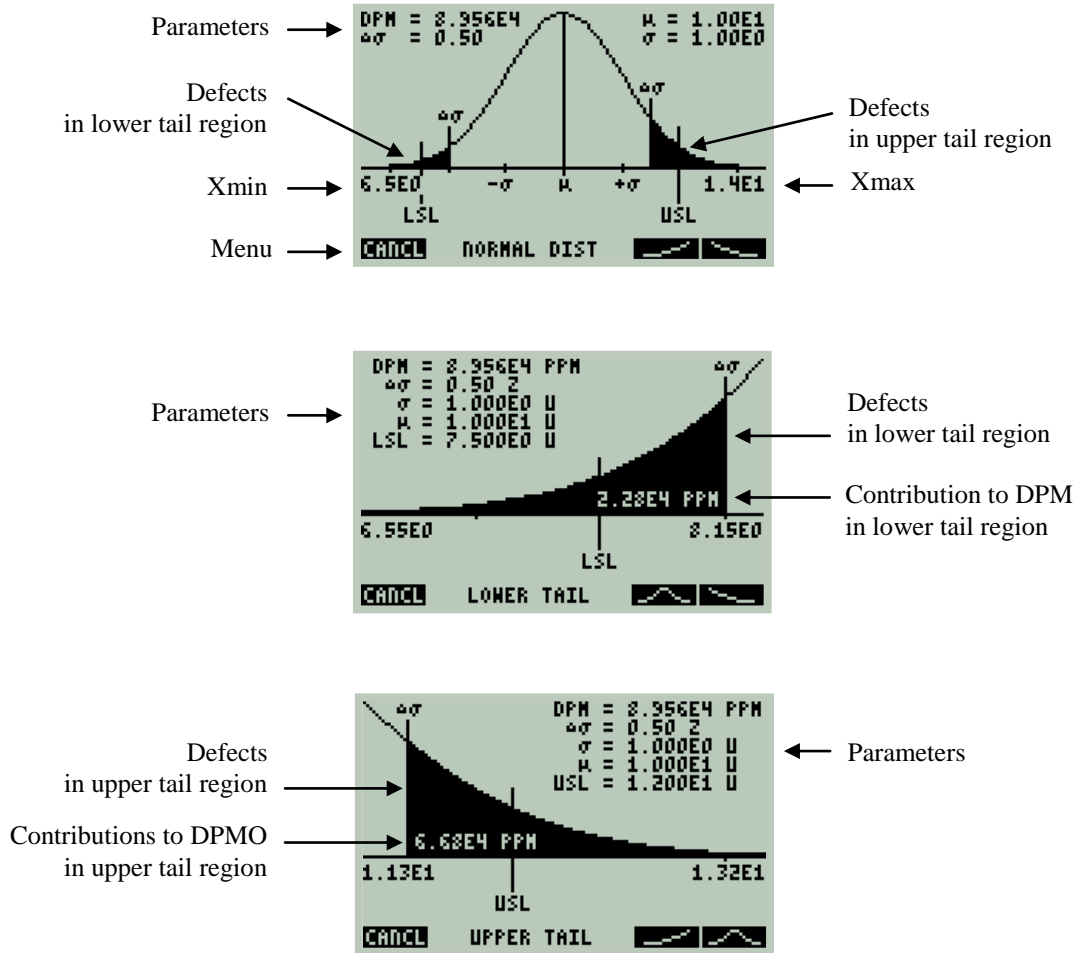
This is the probability density function used when plotting.

Press F1 () to return to the parameter display.












Plot Commands

 (F4) in the Main Menu) plots the probability density curve specified by the parameters

The key elements of the plot display are show below:



The following keys are active when a plot is displayed:

-  (F1) () return to the parameter display
-  or  () plot the lower tail
-  or  () plot the whole probability density
-  or  () plot the upper tail

SECTION 5 - MESSAGES


SPCC displays five types of messages on the message line:

1. Name Messages

```

DPM = 3.3977 PPM
Δσ = 1.50 Z
σ = 1.00 Unit
μ = 10.0000 Unit
LSL = -∞ Unit
LSL = -∞ Z
USL = 16.0000 Unit
USL = 6.00 Z
Short Term Standard Deviation =
NAME STO RCL PLOT FIND EXIT

```

Name messages describe the selected parameter when  is active.

2. Busy Messages

```

DPM = 89557.333 PPM
Δσ = 0.50 Z
σ = 1.00 Unit
μ = 10.0000 Unit
LSL = 7.5000 Unit
LSL = -2.50 Z
USL = 12.0000 Unit
USL = 2.00 Z
Finding ... =
NAME STO RCL PLOT FIND EXIT

```

Busy messages explain what the program is doing.

3. Error Messages

```

DPM = 89557.333 PPM
Δσ = 1.50 Z
σ = 1.00 Unit
μ = 10.0000 Unit
LSL = 18.0000 Unit
LSL = 8.00 Z
USL = 16.0000 Unit
USL = 6.00 Z
Requires Long Term LSL ≤ USL ! ≠
NAME STO RCL PLOT FIND EXIT

```



Error messages warn of an illegal entry, command, or result.

4. Full Precision Messages

```

DPM = 3.3977 PPM
Δσ = 1.50 Z
σ = 1.00 Unit
μ = 10.0000 Unit
LSL = -∞ Unit
LSL = -∞ Z
USL = 16.0000 Unit
USL = 6.00 Z
Precisely 3.39767312473 =
NAME STO RCL PLOT FIND EXIT

```

Full Precision messages show the full precision of the selected parameter, when   is active.

5. Import Messages

```

DPM = 3.3977 PPM
Δσ = 1.50 Z
σ = 1.00 Unit
μ = 10.0000 Unit
LSL = -∞ Unit
LSL = -∞ Z
USL = 16.0000 Unit
USL = 6.00 Z
Import value 14.1421 =
HELP EXP IMP RESET FIND EXIT

```

Import messages show the value to be imported.

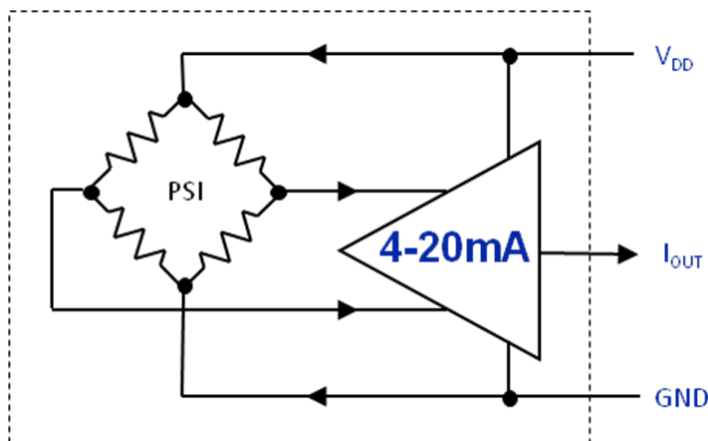
SECTION 6 - EXAMPLES

SPCC can find any parameter as a function of the others, making it useful for both predicting yield, and finding the process conditions necessary to produce a desired yield. The following examples are used to show how SPCC can be used to predict and improve production yield.

Entering (◀, ▶) and Finding (F5)

In this example, we will use SPCC to predict the short and long term production yields of an Amplified Pressure Sensor due to variations in its output current (I_{OUT}).

Amplified Pressure Sensor

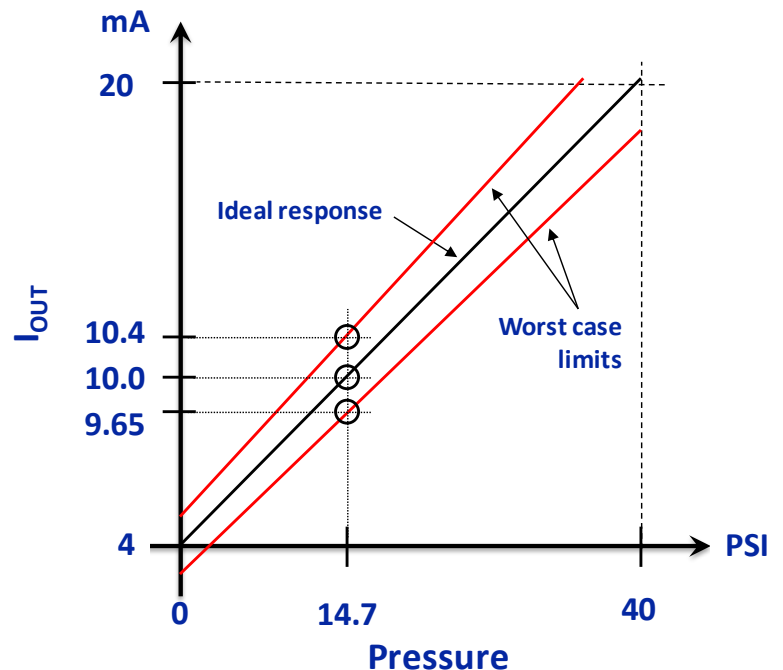


The sensor's output current is proportional to atmospheric pressure and ranges between 4 and 20mA for a pressure between 0 and 40 PSI. The product specification requires that the output current must lie between 9.65mA and 10.4mA when at sea level (14.7 PSI). Any sensor with an output current outside this range is defective and represents a production loss.

Therefore, the Lower Specification Limit (LSL) is 9.65mA, and the Upper Specification Units (USL) is 10.4mA.

Some sources of output current errors:

- Mechanical tolerances
- Bridge (transducer) errors
- Parasitic thermocouples
- Amplifier CMRR
- Amplifier input offset voltage
- Amplifier input bias current



Begin by measuring the output currents from a number of sample devices and find the population's mean (μ) and standard deviation (σ). The calculation of μ and σ from the sampled data is *not* done by SPCC, however μ and σ are used by SPCC. The number of samples must be sufficiently large to accurately predict the whole population.

These are short term measurements, because they come from one production run over one period of time. We find the mean (μ) of the population to be 10.0mA, and the standard deviation (σ) to be 0.15mA.

First, we will find the *short term* yield.

```

DPM = 3.3977 PPM
Δσ = 1.50 Z
σ = 1.00 Unit
μ = 10.0000 Unit
LSL = -∞ Unit
LSL = -∞ Z
USL = 16.0000 Unit
USL = 6.00 Z
=
NAME STO RCL PLOT FIND EXIT

```

Step 1:

Start with the default parameter values. Press the **NXT** (**F4**) (**RECALL**) to display the default parameter values.

```

DPM = 3.3977 PPM
Δσ = 0.00 Z
σ = 1.00 Unit
μ = 10.0000 Unit
LSL = -∞ Unit
LSL = -∞ Z
USL = 16.0000 Unit
USL = 6.00 Z
≠
NAME STO RCL PLOT FIND EXIT

```

Step 2:

Remove any long term process shift by setting $\Delta\sigma$ to zero. Do this by using the up or down arrow keys to move the selection arrow (\blacktriangle) from **DPM** to $\Delta\sigma$. Then use the **←** or **→** key to enter 0.

Notice that the consistency indicator has changed from “=” to “≠” indicating that the parameters are now no longer all consistent.

```

DPM = 3.3977 PPM
Δσ = 0.00 Z
σ = 0.15 Unit
μ = 10.0000 Unit
LSL = -∞ Unit
LSL = -∞ Z
USL = 16.0000 Unit
USL = 40.00 Z
≠
NAME STO RCL PLOT FIND EXIT

```

Step 3:

Enter the standard deviation (σ) of the population. Use the up or down arrow keys to move the selection arrow (\blacktriangle) from $\Delta\sigma$ to σ . Then use the **←** or **→** key to enter 0.15mA.

The default value the mean (μ) happens to be 10mA, so leave it unchanged. Notice that **LSL** in Z and **USL** in Z automatically update if σ or μ changes.

```

DPM = 3.3977 PPM
Δσ = 0.00 Z
σ = 0.15 Unit
μ = 10.0000 Unit
LSL = 9.6500 Unit
LSL = -2.33 Z
USL = 10.4000 Unit
USL = 2.67 Z
≠
NAME STO RCL PLOT FIND EXIT

```

Step 4:

Enter **LSL** and **USL**. Use the up or down arrow keys to move the selection arrow (\blacktriangle) to **LSL** and **USL**. Use the **←** or **→** key to enter 9.65mA in **LSL** and 10.4mA in **USL**. Notice that **LSL** in Z

and **USL** in Z automatically update to reflect the corresponding change in parameter's "Unit" values.

```

DPM = 3.3977♦ PPM
Δσ = 0.00 Z
σ = 0.15 Unit
μ = 10.0000 Unit
LSL = 9.6500 Unit
LSL = -2.33 Z
USL = 10.4000 Unit
USL = 2.67 Z
#
NAME STO RCL PLOT FIND EXIT

```

Step 5:

Select yield (**Yld**) by first moving the selection arrow (♦) to **DPM**. Notice the small dot to the right of the selection arrow. This dot serves as a reminder that this parameter has an alternative expression (**Def** and **Yld**). Pressing the right arrow key, (▶), displays these alternative parameters.

```

Yld = 99.999660♦ %
Δσ = 0.00 Z
σ = 0.15 Unit
μ = 10.0000 Unit
LSL = 9.6500 Unit
LSL = -2.33 Z
USL = 10.4000 Unit
USL = 2.67 Z
#
NAME STO RCL PLOT FIND EXIT

```

Step 6:

Select yield (**Yld**) by pressing the right arrow key, (▶), twice.

```

Yld = 98.635429♦ %
Δσ = 0.00 Z
σ = 0.15 Unit
μ = 10.0000 Unit
LSL = 9.6500 Unit
LSL = -2.33 Z
USL = 10.4000 Unit
USL = 2.67 Z
=
NAME STO RCL PLOT FIND EXIT

```

Step 7:

Finally, find the short term yield by pressing the (F5) (▣) menu key. We see that 98.6% of the production run is within specification.

Notice that the consistency indicator has changed from "≠" to "=" indicating that the parameters are now all consistent.

Long term yield is found by introducing a long term process shift ($\Delta\sigma$) into the calculation. Long term process shift represents an additional shift in the process mean and/or standard deviation over time, resulting in lower yield. In this example, experience has shown that our process can shift as much as 1.1σ over time. Therefore, $\Delta\sigma = 1.1 Z$.

```

Yld = 83.267797♦ %
Δσ = 1.10 Z
σ = 0.15 Unit
μ = 10.0000 Unit
LSL = 9.6500 Unit
LSL = -2.33 Z
USL = 10.4000 Unit
USL = 2.67 Z
=
NAME STO RCL PLOT FIND EXIT

```

Step 8:

Entering 1.1 into $\Delta\sigma$, and finding **Yld**. 83.3% is the long term yield. We see that, over time, the yield can be reduced by more than 15% to 83.3 %.

```

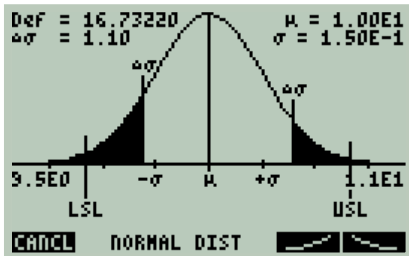
Def = 16.732203♦ %
Δσ = 1.10 Z
σ = 0.15 Unit
μ = 10.0000 Unit
LSL = 9.6500 Unit
LSL = -2.33 Z
USL = 10.4000 Unit
USL = 2.67 Z
=
NAME STO RCL PLOT FIND EXIT

```

Alternately, the percentage of defects can be displayed by pressing the right arrow key, (▶), twice.

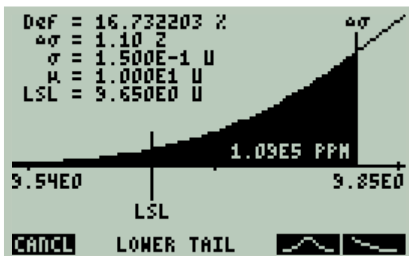
Plotting ($F4$) in the Main Menu)

Press F4 ($F4$) in the Main Menu) to plot the probability density curve specified by the parameters.



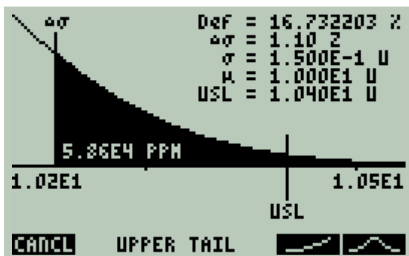
Step 1:

Using the parameter values from the previous example, press F4 ($F4$) in the Main Menu). The probability density is plotted. The shaded regions in the upper and lower tails are measurements that are out of specification, and therefore represent defects.



Step 2:

Press $F5$ (F5) to plot the defects in the lower tail region. The white number in the shaded region is the contribution of the lower tail region to the total defects (in PPM).



Step 3:

Press $F6$ (F6) to plot the defects in the upper tail region. The white number in the shaded region is the contribution of the upper tail region to the total defects (in PPM).

Press $F1$ (F1) to return to the parameter display.

This second example illustrates how to determine how much a specification would need to be relaxed in order to meet a given production yield.

The manufacturer of the sensor desires to improve the long term yield from 83.3% to 90.00%. One way to achieve this is to relax one or more of its specification limits. We will find how much **USL** or **LSL** would need to be reduced to achieve the yield. We continue to use the process specification, as before: mean (μ) is 10mA, standard deviation (σ) is 0.15mA, and a long term process shift ($\Delta\sigma$) of 1.1Z.

Start from the previous set of parameters,

```
Yld =83.267797%
Δσ = 1.10 Z
σ = 0.15 Unit
μ = 10.0000 Unit
LSL = 9.6500 Unit
LSL = -2.33 Z
USL = 10.4000 Unit
USL = 2.67 Z
=
NAME STO RCL PLOT FIND EXIT
```

```
Yld =90.000000%
Δσ = 1.10 Z
σ = 0.15 Unit
μ = 10.0000 Unit
LSL = 9.6500 Unit
LSL = -2.33 Z
USL = 10.4000 Unit
USL = 2.67 Z
≠
NAME STO RCL PLOT FIND EXIT
```

Step 1:

Enter a 90% yield.

```
Yld =90.000000 %
Δσ = 1.10 Z
σ = 0.15 Unit
μ = 10.0000 Unit
LSL = 9.6500 Unit
LSL = -2.33 Z
USL = 10.4000 Unit
USL = 2.67 Z
No Solution!
NAME STO RCL PLOT FIND EXIT
```

Step 2:

Select **USL** and press **F5** (**▢▢▢**). The calculator reports “No Solution!”. This means that there is not value of **USL** that will yield 90%. The reason for this can be seen from the Upper Tail plot on the previous page. The upper tail accounts for only 5.9% of the defects, so no increase in **USL** can produce the required 15% improvement. Next try changing **LSL**.

```
Yld =90.000000 %
Δσ = 1.10 Z
σ = 0.15 Unit
μ = 10.0000 Unit
LSL = 9.5748 Unit
LSL = -2.83 Z
USL = 10.4000 Unit
USL = 2.67 Z
=
NAME STO RCL PLOT FIND EXIT
```

Step 3:

Select **LSL** and press **F5** (**▢▢▢**). We find that if we relax **LSL** from 9.65 to 9.57mA the long term yield will increase to 90%.

Another approach is to keep the original specifications, and find out how to improve the process (μ , σ , or $\Delta\sigma$) to achieve the desired yield.

Let's find out how to improve the process. Return the Upper Specification Limit (**USL**) to 9.65mA.

How must the long term process shift ($\Delta\sigma$) be reduced to maintain the same yield?

```

Yld = 90.000000 %
Δσ = 0.83 Z
σ = 0.15 Unit
μ = 10.0000 Unit
LSL = 9.6500 Unit
LSL = -2.33 Z
USL = 10.4000 Unit
USL = 2.67 Z
=
NAME STO RCL PLOT FIND EXIT

```

Step 1:

Enter 9.65mA in **USL** and select $\Delta\sigma$ using the arrow keys. Press **F5** (**▢**). We find the Long Term Process Shift must be reduced to 0.86 Z to maintain a 90% yield.

Alternatively, you can find the reduction in Short Term Sigma (σ) needed to maintain the same yield *without* changing the Long Term Process Shift ($\Delta\sigma$).

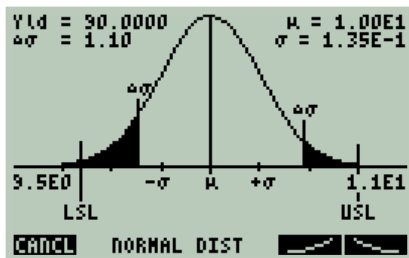
```

Yld = 90.000000 %
Δσ = 1.10 Z
σ = 0.14 Unit
μ = 10.0000 Unit
LSL = 9.6500 Unit
LSL = -2.59 Z
USL = 10.4000 Unit
USL = 2.96 Z
=
NAME STO RCL PLOT FIND EXIT

```

Step 2:

Return $\Delta\sigma$ to 1.1, then select and find σ . We find the short term sigma must be reduced to 0.14mA to maintain a 90% yield.



Step 3:

Press **▢** (**F4** in the Main Menu) to plot the distribution.

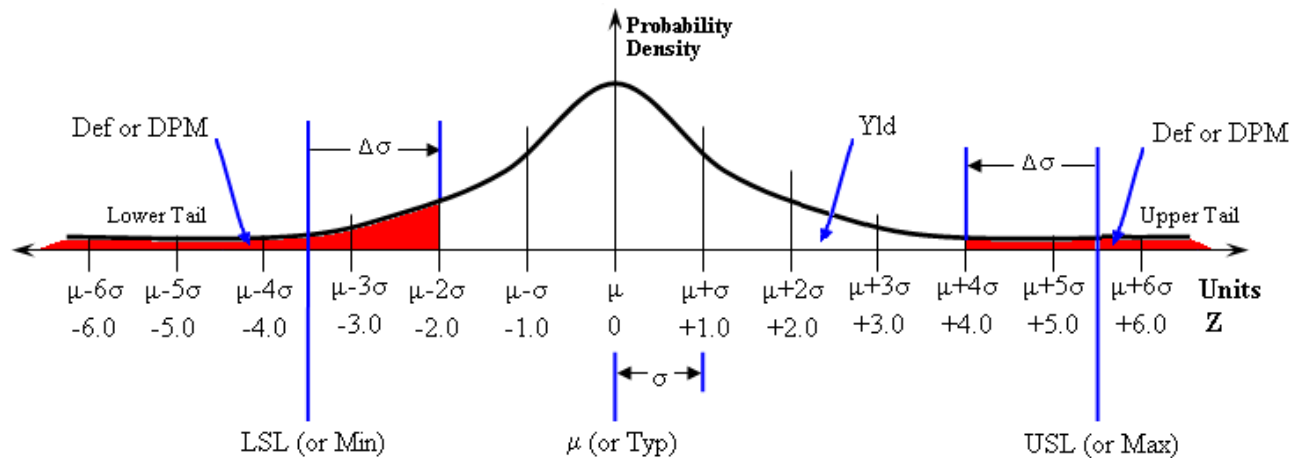
SECTION 7 - BACKGROUND

What is Statistical Process Control?

Statistical Process Control (SPC) is a structured methodology for continuous process improvement. The ultimate goal of SPC is to achieve six-sigma quality standards over the short term. The six-sigma quality standard over the short term are assumed to produce long-term defect levels below 3.4 defects per million (**DPM**). This is because it is assumed there is a 1.5σ long term process shift, $\Delta\sigma$.

Statistical Process Control Calculator (SPCC) is a program that aids in the prediction and analysis of process yield. SPCC can calculate long term production yield, and all related parameters. SPCC is based on the Normal (sometimes called 'Gaussian') distribution curve that results from the presence of random variables found in all processes and measurements. Normal distribution provides a simple model for complex phenomena such as measurements and production processes.

Normal Distribution Curve with SPCC Parameters



Parameter Classifications

Process		Product
Long Term	Defects Per Million, DPM Yield, Yld Defects, Def Process Shift, $\Delta\sigma$	Lower Specification Limit, LSL Upper Specification Limit, USL
Short Term	Standard Deviation, σ Mean, μ	

Definition of Parameters

Yield (Yld)

Yield is the percentage of a product, process, service that is free of defects, in the long term.

Defect (Def)

Defect is the percentage of a product, process, service that is defective, or fails to meet one of the acceptance criteria of your customers, in the long term.

Defects Per Million (DPM)

The number of defects found per million. A defect is any area within a product, process, or service that fails to meet one of the acceptance criteria of your customers, in the long term.

Long Term Process Shift ($\Delta\sigma$)

The Longer Term Process Shift ($\Delta\sigma$) is a fudge-factor used to account for changes in process over time. Experience has shown that in the long term, processes usually degrade, leaving fewer standard deviations between the mean and the specification limits, resulting in lower yield. $\Delta\sigma$ represents this reduction in sigmas between the mean (μ) and **USL** and **LSL**.

Standard Deviation (σ)

Standard Deviation is a measure of the variation in a distribution around the Mean. This is a short term measurement. It is the square root of the sum of the squared deviations of the mean of all samples, and is expressed in user units (Unit). Sigma is used as a scaling factor to convert upper and lower specification limits to Z.

Mean (μ)

The Mean is the most likely value to occur. It is the average value of a data set. Mean is a short term measurement and is expressed in user units (Unit). It is sometimes referred to as “Typical” (**Typ**), commonly used in the electrical characteristics table of integrated circuits and other electronic components.

Lower Specification Limit (LSL)

A Lower Specification Limit is a value above which performance of a product, process, service is acceptable. It is the minimum acceptable value of a parameter. It is expressed in user units (Unit) or in the number of sigmas (σ) from the mean (Z). An alternative name is “Minimum” (**Min**), commonly used in the electrical characteristics table of integrated circuits and other electronic components.

Upper Specification Limit (USL)

An Upper Specification Limit is a value below which performance of a product, process, service is acceptable. It is the maximum acceptable value of a parameter. It is expressed in user units (Unit) or in the number of sigmas (σ) from the mean (Z). An alternative name is “Maximum” (**Max**), commonly used in the electrical characteristics table of integrated circuits and other electronic components.

Equations Used

Normal Distribution

Normal Probability Density Function,

$$pd = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Probability

Probability that x is between LSL and USL over the long term,

$$P = \frac{1}{\sigma\sqrt{2\pi}} \int_{LSL+\Delta\sigma\cdot\sigma}^{USL-\Delta\sigma\cdot\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}} dx$$

Probability can be converted to yield (Yld) by multiplying P by 100%

$$Yld = \frac{100}{\sigma\sqrt{2\pi}} \int_{LSL+\Delta\sigma\cdot\sigma}^{USL-\Delta\sigma\cdot\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}} dx$$

Defects & Yield

Equivalent expressions of defects or yield,

$$DPM = 10,000 \cdot Def = 10,000 \cdot (100 - Yld) = 1,000,000 \cdot (1 - P)$$

Z-score

x value in units of sigma (σ) from the mean (μ),

$$LSL_z = \frac{LSL_u - \mu}{\sigma} \quad LSL_z = \frac{LSL_u - \mu}{\sigma}$$

SECTION 8 - TOOLS, MODELS, AND SOFTWARE NOTICE

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