HEWLETT-PACKARD

Using the HP-71 for Production Process Monitoring

Introduction

This application note provides information on how the HP-71 Handheld Computer can be used for monitoring your production processes. An example of a "continuous updating" technique for production process monitoring is included, and "moving window" process monitoring is illustrated by an annotated program which keeps track of good and defective units as they are entered into the HP-71 by your production workers (or by digital sensors connected to the HP-71 through an HP-IL or an HP-IB interface).

A production process begins with the flow of the various parts and materials that are used to build a product; the process ends when the packaged product is shipped to the customer. Between these points are all of the procedures, techniques, testing, and work that make up the process of converting those parts and materials into your product. When the process is operating properly and product statistics are as expected, the product will be of consistent (expected) quality. If something goes wrong – if the product build-time or rework increases, or if too many completed units (or subassemblies) fail their qualification tests – your process is said to be "out of control."

Statistical Process Control

Statistical process control is the use of numbers and data to analyze production processes. Statistical procedures are used to set the statistical *limits* for your process, that is, to determine how much your process can vary from the expected norm and still be in control.*

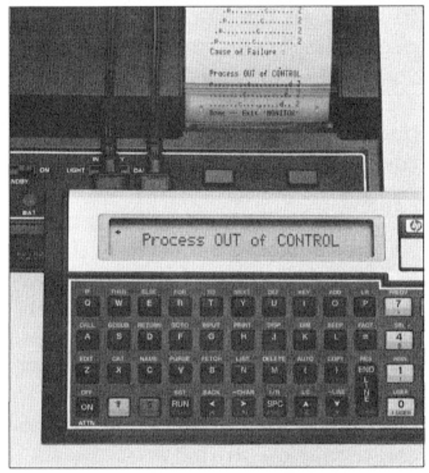
The HP-71's role in statistical process control is to *compare* your process data with these calculated or historical statistical limits. This comparison is then used by the HP-71 to monitor your process to assure that it is delivering the desired level of product quality.

Statistical methods are used to distinguish normal variation from emerging problems in your process. The "continuous updating" and "moving window" techniques explained below are powerful statistical tools for keeping your product at a high level of quality. These techniques involve gathering data obtained from tests or measurements on each unit of your product, taken at selected points in the manufacturing cycle, and periodically updating the appropriate statistics on that data. The HP-71 is ideally suited for calculating and storing such information.

*For information on how to determine the statistical limits for your production process, consult AT&T's Statistical Quality Control Handbook, referenced at the end of this application note.

Production Process Monitoring

The objective of production process monitoring is to gather data (from the products on your production lines) that can be used to help you determine whether your process is in or out of control. If your process *is* out of control, this information will also help you to determine what corrective action is needed to adjust your process, so that it will produce the expected level of product quality. An additional benefit of gathering product data is a better understanding of your process, enabling you to exert tighter controls on your system, and increasing the efficiency and quality of your manufacturing operations.



The first step in establishing a production process monitoring system is to determine the *normal* deviations in the process and *which* deviations indicate that the process is (going) out of control. The techniques described in AT&T's Statistical Quality Control Handbook* tell you how to make these determinations.

Next, you determine where in your process deviations are most likely to occur, for example, in assembly, test, incoming and outgoing inspection, and repair stations. You then place the HP-71 in these locations to monitor the process.

Using the HP-71 for Production Process Monitoring

Using an HP-71 system to monitor your production process allows you to:

- Set the number and causes of defects (including purchased parts)
- Monitor product parameters such as size and weight (when connected to appropriate digital instrumentation)
- Determine the time needed to perform an operation
- Monitor repairs and reworks

The HP-71 can be programmed to allow an operator to record production data for a process station with one or two keystrokes. The HP-71 can then compare that data with the statistical limits for the process to ensure that the process at the station is in control. If too many failures, or too many failures of *one type*, occur, or if too much time is taken for a particular operation, the HP-71 can indicate that the process is out of control. Patterns in the product data that the HP-71 gathers can then be analyzed to determine the cause of the deviation in the process, so you can take corrective action.

When a new unit is entered in the HP-71, the computer's real-time clock can log the time of data entry and the elapsed time since the previous unit was entered. Thus, the HP-71 can automatically track the time taken for completing a procedure. If the procedure time changes from the statistically expected time, such change becomes a change in the normal process, and the process may be considered to be out of control. Evaluation of the *cause* for the time change (for example, production tool wear or a delay in material delivery) helps you to correct the cause and restore the process to your statistically expected norm.

The HP-71 can also monitor the number and types of repairs that are being done. Too many repairs or too many repairs of one type may indicate a marginal assembly or test procedure. You can then correct the procedure, so that only good units are produced.

Continuous Updating Example

The first example illustrates a continuous updating statistical technique for production process monitoring.

The XYZ Company sells breakfast cereal foods. The FDA requires that the food *weight* be printed on each box in which the cereal is packaged and specifies two limits:

- The amount by which the food weight can be less than the figure printed on the box
- The maximum number of boxes per 100 that can be less than the printed weight

The XYZ Company must satisfy the limits set by the FDA and, to avoid losing money, stay within the upper weight limit it sets for itself.

To accomplish this, the production line is set up to randomly divert 10 boxes out of every 100 to an automatic digital scale connected to an HP-71 through an HP-IL or an HP-IB interface.

The HP-71 updates the product data after each box of cereal is weighed; if too many boxes exceed the required limits, the HP-71 signals that the production line requires adjustment to restore process quality.

The process data are then archived daily for presentation to the FDA. (The day's product data can be downloaded from an HP-71 to the XYZ Company's data bank via an HP-IL link.)

Moving Window Example

The second example illustrates the moving window concept of statistical quality control in production process monitoring.

In this example the HP-71 is being used primarily for *monitoring* the production process – not for calculating statistics. (The process limits have already been calculated statistically and should be rechecked periodically by the production engineers to verify that they are still valid. Consult the reference for more information.)

For illustration purposes, here is a simplified example with only three possible failure modes:

- The new unit doesn't turn on
- The unit draws excessive battery current
- The unit doesn't pass its internal diagnostic test

The program listed below stores test results in the computer from the last 20 units produced. As every new unit is tested, the test data are entered into the HP-71, replacing the data on the oldest (20th) unit. Thus, *the statistics are always on the last 20 units produced,* which comprise the moving window.

The historical data we have suggest that, when our process is in control, we will see **two failures or less per 20 units** (a 10% maximum reject rate). Thus, if the process is going out of control, the HP-71 can catch it quickly.

The program for this example (written in HP-71 Enhanced BASIC) establishes a "window" that is 20 units in length and presents the contents of the window in the HP-71 display, along with the number of defective units from the last 20 entered. In this example, the manufacturing process is out of control if more than two defective units appear in the window (i.e., a 10% maximum reject rate).

Units move from right to left in the display as they are entered into the HP-71. As the test results for the latest unit appear on the right, the results for the 20th unit "fall off" the left end of the display – hence the name "moving window."

A good unit is represented by a **"."** and defective units are identified by failure code letters: **"p"** for power-on failure, **"c"** for excessive battery-current drain, and **"d"** if the new unit fails the internal diagnostic test. The numeral on the right end of the display is the number of defective units in the last 20. These "rejects" are visible in the displayed "window."

To try out this example on the HP-71, set the computer in the PROGRAM mode (cursor should be at the *left* end of the display) and type in the program listed below. To start the program, enter "RUN MONITOR" into the HP-71, and then press [ENTER]. The following table lists all four possible test results and the required HP-71 keystroke responses.

IF	PRESS HP-71 KEY	DISPLAY
Unit **passed all** 3 tests – **GOOD**	[+]	Adds a **DOT**
Unit **failed any** of 3 tests – **BAD**	[−]	**Cause of Failure:**
If the **fail** ([−]) key is pressed, the HP-71 prompts you for the failure mode. Press one of the following keys:		
Unit failed Power-on test	[P]	Adds **p** to window
Unit failed Excess Current test	[C]	Adds **c** to window
Unit failed Diagnostic test	[D]	Adds **d** to window

The following figure is an example of an out-of-control-process display window showing 17 GOOD units (.), a "Power-on" failure (**p**), an "Excess Current" failure (**c**) and a "Diagnostic" failure (**d**). The numeral **3** on the right is the number of failures appearing in the 20-unit window:

p . . . . c . . . d 3

Pressing the [Q] key ends the program.

This simple example of statistical process control can be expanded to accommodate your production needs. For instance, the numerical quantities of failure modes can be stored in arrays, p( ), c( ), d( ), and so on, for later retrieval and analysis; the number of failures "N" per lot W$[ ] can be changed to suit the process; and the number of failures of *one type* can be calculated to assist you in determining what corrective action is needed to improve your production process. If digital sensors are used for input to the HP-71, the program will need slight modification to allow the program to assign the ASCII key code values (for selected keys) to the input variable **K$**.

Summary

The following program illustrates the potential of the HP-71. This handheld computer can deal with complex situations and perform sophisticated statistical analyses. Its computing power can help to solve your most difficult production problems. The HP-71 can perform as a stand-alone computer at individual work stations or, with the addition of an HP 82401A HP-IL Interface Module, can communicate with other devices such as printers and digital voltmeters.

An excellent source of information for using the HP-71 with digital instruments is a booklet entitled "HP-71 Instrument Control Systems" (5954-1241). This publication contains information about converters from HP-IL to other interfaces such as HP-IB, RS-232C, or 80-column video. It also gives brief descriptions of several HP-IL instruments and peripherals for the HP-71.

Sophisticated HP-IL networks (HP-71 product application note 5954-1312) can be configured with a master loop connecting several HP-71 nodes to a host computer. Each node consists of an HP-71 with **two** HP-IL loops – one loop for control of local measuring devices and the other loop for communication with a host computer. Each node can use its own program(s) to interact with the instruments, so that an operator can determine the state of a process at that point. Communications with the host computer may include status reports on individual work stations and alarm messages to tell the operator that a process is going out of control.

Line #	Program Statement	Comment
	EDIT MONITOR [ENDLINE]	Creates a file named "MONITOR"
10	DELAY 0,0	Speeds up program execution.
20	DISP "Production MONITOR" @ WAIT 2	Displays program title.
30	DIM W$[20],K$[1]	Defines number of elements in "Window" and "KEY" arrays.
40	REAL N	Declares "N" a precision numeric variable.
50	W$=" " @ W$[20]=" "	Clears the HP-71 Display.
60	IMAGE 20ax,d	Formats display for "Window" and "number of Failures".
70	DISP USING 60;W$,N	Displays latest "Window" and number of failures.
80	!	
90	'TOP':	Beginning of data entry routine.
100	K$=KEY$ @ on pos("+ – Q",K$)+1 GOTO 100,'good','bad','quit'	Select routine based on operator input: GOOD, BAD, or QUIT.
110	!	
120	'GOOD':	GOOD unit routine.
130	IF NOT POS(" .",W$[1,1]) THEN N=N–1	Decrement number of "Failures". (Note SPACE before the ".")
140	W$=W$[2]&"." @ GOTO 'TEST'	Add a GOOD unit (dot) to the "Window".
150	!	
160	'BAD':	BAD unit routine.
170	IF NOT POS(" .",W$[1,1]) THEN N=N–1	Decrement # of "Failures". (Note SPACE before the ".")
180	DISP "Cause of Failure :"; CHR$(13);	
190	K$=KEY$ @ IF NOT POS("PDC",K$) THEN 190	Input "cause of failure" code.
200	K$=CHR$(NUM(K$)+32)	Change failure code letter to **lower case.**
210	W$=W$[2]&K$ @ N=N+1	Add a BAD unit (failure-code letter) to "Window" and increase number of failures in last 20 units.
220	!	
230	'TEST'	Start "failed unit" test.
240	If N>2 THEN DISP @ WAIT .5 @ BEEP @ DISP "Process OUT of CONTROL" @ WAIT 2	If # of failures in "Window" >2, display "Out of Control" message & give audible warning.
250	GOTO 70	Displays latest "Window" and number of Failures.
260	!	
270	'QUIT'	
280	W$=" "	Clear the "Window" array.
290	DISP "Done — Exit 'MONITOR'" @ WAIT 2 @ OFF	Turns the HP-71 off after 2-second "Exit" message.
	[RUN]	Runs the "MONITOR" program.

***Reference: Statistical Quality Control Handbook**
Western Electric Company
Indianapolis, IN 46226
2nd Edition, October, 1983

For additional information about Hewlett-Packard's handheld computers in manufacturing solutions, call the HP office nearest you and ask for your technical computer or instrument representative. Local HP sales offices are listed in the white pages of your telephone book.

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