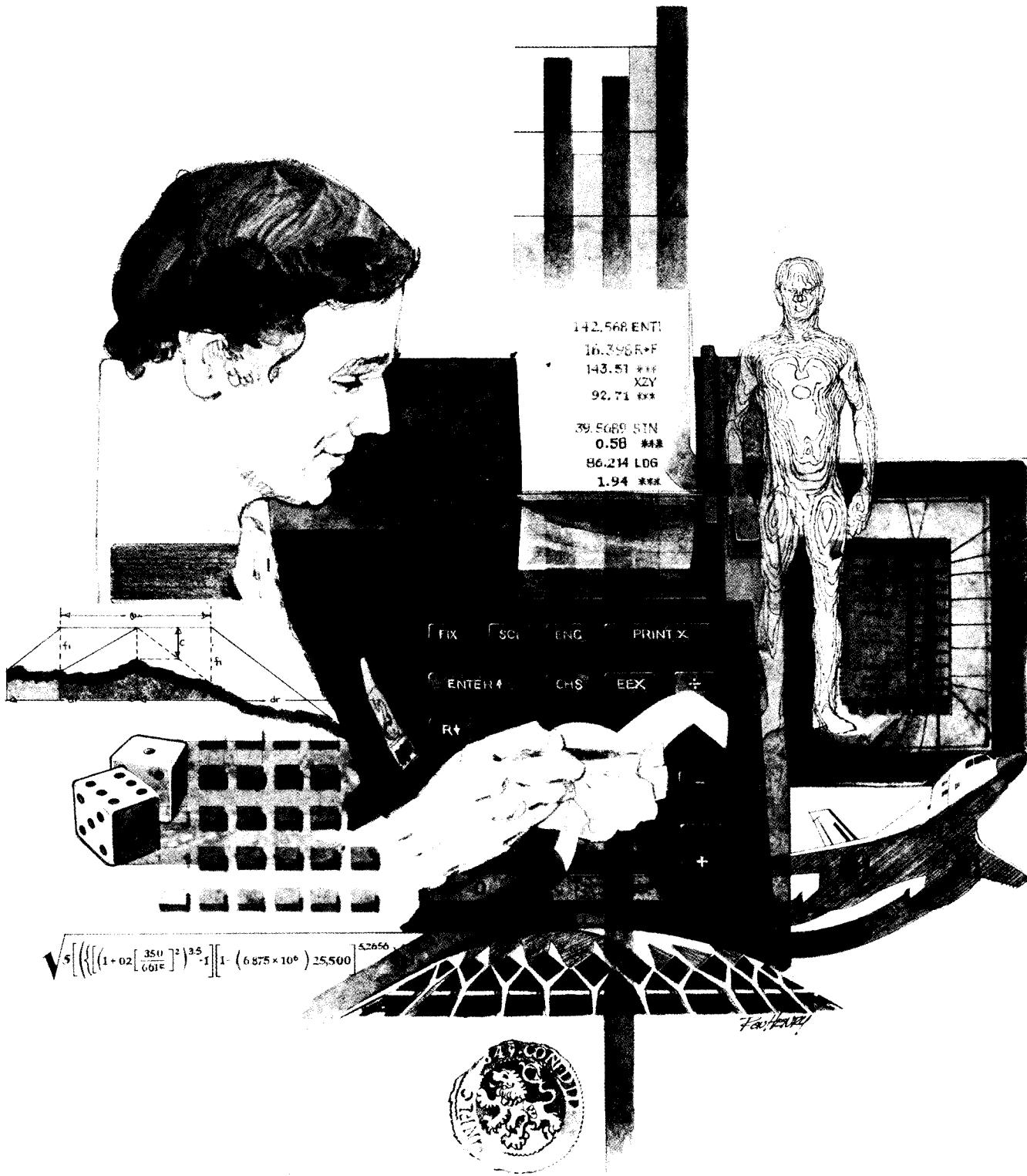


HEWLETT-PACKARD

# HP-67/HP-97

Users' Library Solutions

Reliability/QA



## INTRODUCTION

In an effort to provide continued value to its customers, Hewlett-Packard is introducing a unique service for the HP fully programmable calculator user. This service is designed to save you time and programming effort. As users are aware, Programmable Calculators are capable of delivering tremendous problem solving potential in terms of power and flexibility, but the real genie in the bottle is program solutions. HP's introduction of the first handheld programmable calculator in 1974 immediately led to a request for program **solutions** — hence the beginning of the HP-65 Users' Library. In order to save HP calculator customers time, users wrote their own programs and sent them to the Library for the benefit of other program users. In a short period of time over 5,000 programs were accepted and made available. This overwhelming response indicated the value of the program library and a Users' Library was then established for the HP-67/97 users.

To extend the value of the Users' Library, Hewlett-Packard is introducing a unique service—a service designed to save you time and money. The Users' Library has collected the best programs in the most popular categories from the HP-67/97 and HP-65 Libraries. These programs have been packaged into a series of low-cost books, resulting in substantial savings for our valued HP-67/97 users.

We feel this new software service will extend the capabilities of our programmable calculators and provide a great benefit to our HP-67/97 users.

## A WORD ABOUT PROGRAM USAGE

Each program contained herein is reproduced on the standard forms used by the Users' Library. Magnetic cards are not included. The Program Description I page gives a basic description of the program. The Program Description II page provides a sample problem and the keystrokes used to solve it. The User Instructions page contains a description of the keystrokes used to solve problems in general and the options which are available to the user. The Program Listing I and Program Listing II pages list the program steps necessary to operate the calculator. The comments, listed next to the steps, describe the reason for a step or group of steps. Other pertinent information about data register contents, uses of labels and flags and the initial calculator status mode is also found on these pages. Following the directions in your HP-67 or HP-97 **Owners' Handbook and Programming Guide**, "Loading a Program" (page 134, HP-67; page 119, HP-97), key in the program from the Program Listing I and Program Listing II pages. A number at the top of the Program Listing indicates on which calculator the program was written (HP-67 or HP-97). If the calculator indicated differs from the calculator you will be using, consult Appendix E of your **Owner's Handbook** for the corresponding keycodes and keystrokes converting HP-67 to HP-97 keycodes and vice versa. No program conversion is necessary. The HP-67 and HP-97 are totally compatible, but some differences do occur in the keycodes used to represent some of the functions.

A program loaded into the HP-67 or HP-97 is not permanent—once the calculator is turned off, the program will not be retained. You can, however, permanently save any program by recording it on a blank magnetic card, several of which were provided in the Standard Pac that was shipped with your calculator. Consult your **Owner's Handbook** for full instructions. A few points to remember:

The Set Status section indicates the status of flags, angular mode, and display setting. After keying in your program, review the status section and set the conditions as indicated before using or permanently recording the program.

**REMEMBER!** To save the program permanently, **clip** the corners of the magnetic card once you have recorded the program. This simple step will protect the magnetic card and keep the program from being inadvertently erased.

As a part of HP's continuing effort to provide value to our customers, we hope you will enjoy our newest concept.

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Using a one-way ANOVA layout, this program estimates the ratio of variance due to treatment (CF. true scores) to total or "Observed" variance. This is interpreted as a measure of the extent to which group membership is related to the magnitude of the observed score. In turn, this can be used to estimate the reliability of a measurement with the treatment levels being subjects.	
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# Program Description I

Program Title RELIABILITY: INTRA-CLASS CORRELATION

Contributor's Name Hewlett-Packard  
Address 1000 N.E. Circle Blvd.  
City Corvallis

State Oregon Zip Code 97330

Program Description, Equations, Variables, etc. Let the scores (measures)  $X_{ij}$  represent the  $j$ -th subject's score on the  $i$ -th test (measurement). In the ANOVA model  $X_{ij} = \mu + a_j + e_{ij}$ ,  $\mu$  the mean "true" measure over all subjects,  $a_j$  the deviation of the  $j$ -th subject from that mean, and  $e_{ij}$  the error in test  $i$  on the  $j$ -th subject, the reliability of the set of tests is the ratio  $\rho_I = \sigma_A^2 / \sigma_X^2$ , of true-difference variance to observed-score variance. This ratio is estimated by the formula

$$r_I = \frac{MS_{Bet} - MS_{With}}{MS_{Bet} + (c-1)MS_{With}},$$

where  $MS_{Bet}$  is the between mean squares,  $MS_{With}$  the within mean squares, and  $c$  is a factor dependent on sample size given by

$$c = \frac{1}{J-1} \left[ \sum n_j - \frac{\sum n_j^2}{\sum n_j} \right]$$

where  $J$  is the number of subjects,  $n_j$  the number of test scores for subject  $j$ . Standard formulas are used for the mean squares, and the ANOVA F-ratio is computed as a by-product of the main program.

Operating Limits and Warnings This estimate is based on the ANOVA random-effects model, and violations of its assumptions (e.g., normal distribution of the  $a_j$ , homogeneity of variances) should be held to a minimum for an accurate estimate. Winer (op. cit.) and other texts fully explain these assumptions and possible effects of departures. Most ill effects are minimized by use of equal  $n_j$ 's, for all  $j = 1, 2, \dots, J$ .

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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# Program Description II

Sketch(es)

**Sample Problem(s)** The following data represent the scores of three subjects on repeated measurements of the same attribute. Compute the intra-class correlation (reliability) estimate and the ANOVA F.

		1	2	3	4	5	6	
		1	10	8	5	12	14	11
		2	6	9	8	13		
		3	14	13	10	17	16	

**Solution(s)**  $r_I = 0.36$ ;  $F = 3.79$

Keystrokes:

[f][CLREG] 10 [A] 8 [A].... 11[A] [B]  
6 [A] 9 [A].... 13[A] [B]  
14 [A] 13 [A].... 16 [A] [B]

Outputs:

[C]  $\rightarrow$  0.36  
[R/S]  $\rightarrow$  3.79

**Reference(s)** Winer, B. J., Statistical principles in experimental design, pp. 165, 283-287, McGraw-Hill, 1971.

This program is a translation of the HP-65 Users' Library Program # 03102A submitted by James M. Price.

# User Instructions



# 97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11		057	ST09	35 09	
002	ST+7	35-55 07		058	RCL7	36 07	c
003	X <sup>2</sup>	53		059	RCL8	36 08	
004	ST+2	35-55 02		060	-	-45	
005	RCL8	36 08		061	RCL7	36 07	
006	1	01		062	RCL9	36 09	
007	+	-55		063	1	01	
008	ST08	35 08		064	-	-45	
009	RTN	24		065	RCL8	36 08	
010	*LBLB	21 12		066	X	-35	
011	RCL7	36 07		067	+	-55	
012	ST+1	35-55 01		068	÷	-24	
013	X <sup>2</sup>	53		069	R/S	51	
014	RCL8	36 08		070	RCL7	36 07	
015	÷	-24		071	RCL8	36 08	
016	ST+3	35-55 03		072	÷	-24	
017	LSTX	16-63		073	R/S	51	F
018	ST+4	35-55 04					
019	X <sup>2</sup>	53					
020	ST+5	35-55 05					
021	1	01					
022	ST+6	35-55 06					
023	CLX	-51					
024	ST07	35 07					
025	ST08	35 08					
026	RTN	24					
027	*LBLC	21 13					
028	RCL3	36 03					
029	RCL1	36 01					
030	X <sup>2</sup>	53					
031	RCL4	36 04					
032	÷	-24					
033	-	-45					
034	RCL6	36 06					
035	1	01					
036	-	-45					
037	÷	-24					
038	ST07	35 07	df between MS between → R7				
039	RCL2	36 02					
040	RCL3	36 03					
041	-	-45					
042	RCL4	36 04					
043	RCL6	36 06					
044	-	-45					
045	÷	-24					
046	ST08	35 08	df within MS within → R8				
047	RCL6	36 06					
048	1	01					
049	-	-45					
050	1/X	52					
051	RCL4	36 04					
052	RCL5	36 05					
053	RCL4	36 04					
054	÷	-24					
055	-	-45					
056	X	-35					

## REGISTERS

0	1 $\Sigma \Sigma X_{1j}$	2 $\Sigma \Sigma X_{11}^2$	3 $\Sigma n_j X_{1j}^2$	4 $\Sigma n_j$	5 $\Sigma n_j^2$	6 J	7 used	8 used	9 c
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E				I	

# Program Description I

Program Title      SPECIFICATION COMPLIANCE from LIMITS and REGRESSION ANALYSIS

Contributor's Name      Hewlett-Packard Company

Address      1000 N.E. Circle Boulevard

City      Corvallis

State Oregon

Zip Code 97330

## Program Description, Equations, Variables

$$X_i = X_o + \Delta x$$

A = intercept value

B = slope

S = standard deviation

L = lower specification limit

U = Upper specification limit

Y = ordinate

X = abscissa

$\Delta x$  = change in X value

Z = standard normal deviate

subscripts:

o = original value

i = any other value

u = upper limit

L = lower limit

$$Z_L = \frac{Y_i - L}{S} ; P_L = f(Z_L) \text{ Note 1}$$

$$Z_u = \frac{U - Y_i}{S} ; P_u = f(Z_u) \text{ Note 1}$$

$$Y_u = U - ZS ; X_u = \frac{Y_u - A}{B}$$

$$Y_L = L + ZS ; X_L = \frac{Y_L - A}{B}$$

NOTE 1 :  $P_L$  and  $P_u$  are the probability of meeting the lower or upper specification limits respectively. They are found from a table of the normal probability distribution at the value of  $Z_L$  or  $Z_u$  in question.

## Operating Limits and Warnings

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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# Program Description II

Sketch(es)	i	X <sub>i</sub>	Y <sub>i</sub>	Z <sub>L</sub>	Z <sub>u</sub>	P <sub>L</sub>	P <sub>u</sub>	NOTE:
	0	15.00	42.50	-1.88	9.38	.030	1.000	obtain P <sub>L</sub> and
	1	20.00	50.00	0.00	7.50	.500	1.000	P <sub>u</sub> from table
	2	25.00	57.50	1.88	5.63	.970	1.000	of normal
	3	30.00	65.00	3.75	3.75	1.000	1.000	distribution
	4	35.00	72.50	5.63	1.88	1.000	.970	
	5	40.00	80.00	7.50	0.00	1.000	.500	
	6	45.00	87.70	9.38	-1.88	1.000	.030	

**Sample Problem(s)** The following information is obtained from a regression analysis for a linear equation: A = 20; B = 1.5; S = 4.0. What are the probabilities of meeting specification limits of L = 50 and U = 80 as X varies from 15.0 to 45.0 in steps of 5.0? What are the X values at the specification limits and the x and y values at the lower and upper 90% confidence limits?

**Solution(s)** Insert program: 20↑, 1.5↑, 4.0↑, 15.0, [f] [A] 50↑, 80↑, 5.0 [R/S] [A] y<sub>0</sub> = 42.50; [B] Z<sub>L</sub> = -1.88; [C] Z<sub>u</sub> = 9.38; [D] X<sub>1</sub> = 20.00; [A] y<sub>1</sub> = 50.00 [B] Z<sub>L</sub> = 0.00; [C] Z<sub>u</sub> = 7.50; [D] X<sub>L</sub> = 25.00 . . . etc. to complete the table shown under sketches.

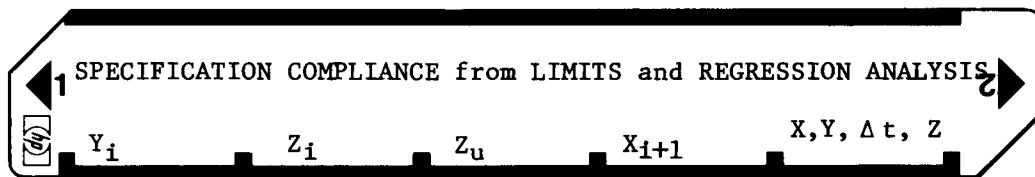
For the x values at the specification limits [CLX] [E] Y<sub>L</sub> = 50.00; [R/S] X<sub>L</sub> = 20.00; [f] [STF] [1] [CLX] [E] Y<sub>u</sub> = 80.00; [R/S] X<sub>u</sub> = 40.00

For 90% limits [f][CLF][1]

[GTO][1][R/S][E] Y<sub>L90</sub> = 55.13; [R/S] X<sub>L90</sub> = 23.42; [f] [STF] [1] [GTO] [1] [R/S] [E] Y<sub>u90</sub> = 74.87; [R/S] X<sub>u90</sub> = 36.58

**Reference(s)** This program is a translation of the HP - 65 Users' Library Program # 03202A submitted by George J. Sellers.

# User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter Program			
2	Enter A		↑	
3	B		↑	
4	S		↑	
5	X <sub>0</sub>		f	A
6	L		↑	
7	U		↑	
8	Δ x		R/S	
9			A	
10			B	
11			C	
12			D	
13	Repeat 9 through 11 for each new X			
14	for X <sub>L</sub> at L		CLX	E
15	for X <sub>u</sub> at U		R/S	
16			[f][STF][1][CLX]	
17			E	U
18	for 90% limits		R/S	X <sub>u</sub>
19			[f][CLF][1][GTO][1]	
20			R/S	E
21			R/S	Y <sub>L90</sub>
22			R/S	X <sub>L90</sub>
23			[f][STF][1][GTO][1]	
24	for 95% limits substitute GT02 for GT01 in steps 18 and 21		R/S	E
25	for 99% limits substitute GT03 for GT01 in steps 18 and 21		R/S	Y <sub>u90</sub>
26	for X <sub>L</sub> , Y <sub>L</sub> at a given Z, enter Z		[f][CLF][1][E]	X <sub>z</sub> at Z
27			R/S	X <sub>L</sub> at Z
28	for X <sub>u</sub> , Y <sub>u</sub> at a given Z, enter Z		[f][STF][1][E]	Y <sub>u</sub> at Z
29			R/S	X <sub>L</sub> at Z
	Note: when calculating X and Y at U flag 1 must be fSF1; at L flag 1 must be f <sup>-1</sup> SF1.			•

## 97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 16 11		057	RCL1	36 01	
002	ST08	35 08		058	-	-45	
003	R↓	-31		059	RCL2	36 02	
004	ST03	35 03		060	÷	-24	
005	R↓	-31		061	R/S	51	
006	ST02	35 02		062	*LBL4	21 04	
007	R↓	-31		063	CHS	-22	
008	ST01	35 01		064	RCL6	36 06	
009	R/S	51		065	GT05	22 05	
010	ST05	35 05		066	*LBL1	21 01	
011	R↓	-31		067	1	01	
012	ST06	35 06		068	.	-62	
013	R↓	-31		069	2	02	
014	ST04	35 04		070	8	08	
015	CLX	-51		071	1	01	
016	ENT↑	-21		072	7	07	
017	ENT↑	-21		073	R/S	51	
018	ENT↑	-21		074	*LBL2	21 02	
019	R/S	51		075	2	02	
020	*LBLA	21 11		076	1	01	
021	RCL8	36 08		077	.	-62	
022	RCL2	36 02		078	6	06	
023	X	-35		079	4	04	
024	RCL1	36 01		080	5	05	
025	+	-55		081	R/S	51	
026	ST07	35 07		082	*LBL3	21 03	
027	R/S	51		083	3	03	
028	*LBLB	21 12		084	2	02	
029	RCL4	36 04		085	.	-62	
030	-	-45		086	3	03	
031	RCL3	36 03		087	2	02	
032	÷	-24		088	3	03	
033	R/S	51		089	7	07	
034	*LBLC	21 13		090	R/S	51	
035	RCL6	36 06					
036	RCL7	36 07					
037	-	-45					
038	RCL3	36 03					
039	÷	-24					
040	R/S	51					
041	*LBLD	21 14					
042	RCL8	36 08					
043	RCL5	36 05					
044	+	-55		100			
045	ST08	35 08					
046	R/S	51					
047	*LBL E	21 15					
048	ST09	35 09					
049	RCL3	36 03					
050	X	-35					
051	F1?	16 23 01					
052	GT04	22 04					
053	RCL4	36 04					
054	*LBL5	21 05					
055	+	-55					
056	R/S	51					

## REGISTERS

0	1 A	2 B	3 S	4 L	5 Δx	6 U	7 Y <sub>1</sub>	8 X <sub>1</sub>	9 A
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C		D	E		I		

## SET STATUS

FLAGS		TRIG	DISP
ON	OFF		
0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	DEG <input checked="" type="checkbox"/>
1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	GRAD <input type="checkbox"/>
2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	RAD <input type="checkbox"/>
3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	SCI <input type="checkbox"/>
			ENG <input type="checkbox"/>
			n2 <input type="checkbox"/>

# Program Description I

Program Title    PARAMETER ESTIMATION (EXPONENTIAL DISTRIBUTION)

Contributor's Name    Hewlett - Packard Company

Address    1000 N.E. Circle Boulevard

City    Corvallis

State    Oregon

Zip Code    97330

## Program Description, Equations, Variables

### Case 1

Let  $X$  be the sample mean of a random sample of size  $n$  from a truncated exponential distribution with pdf.

$$f(x) = \sigma^{-1} e^{-x/\sigma} / (1 - e^{-x_0/\sigma}) \quad 0 \leq x \leq x_0$$

The maximum likelihood estimator  $\hat{\sigma}$  for  $\sigma$  is the solution of

$$\bar{X} - \hat{\sigma} + x_0 (e^{x_0/\hat{\sigma}} - 1)^{-1} = 0$$

### Case 2

Let  $x_{(1)} \leq x_{(2)} \dots \leq x_{(r)}$  denote the first  $r$  order statistics from a random sample of size  $n$  from a distribution with pdf.

$$f(x) = \sigma^{-1} \exp(-(x-\theta)/\sigma) \quad \theta \leq x \leq \infty$$

The minimum variance unbiased estimators for  $\sigma$  and  $\theta$  are

$$\sigma^* = (r-1)^{-1} \sum_{j=2}^r (n-j) (x_{(j+1)} - x_{(j)})$$

$$\theta^* = x_{(1)} - \sigma^*/n$$

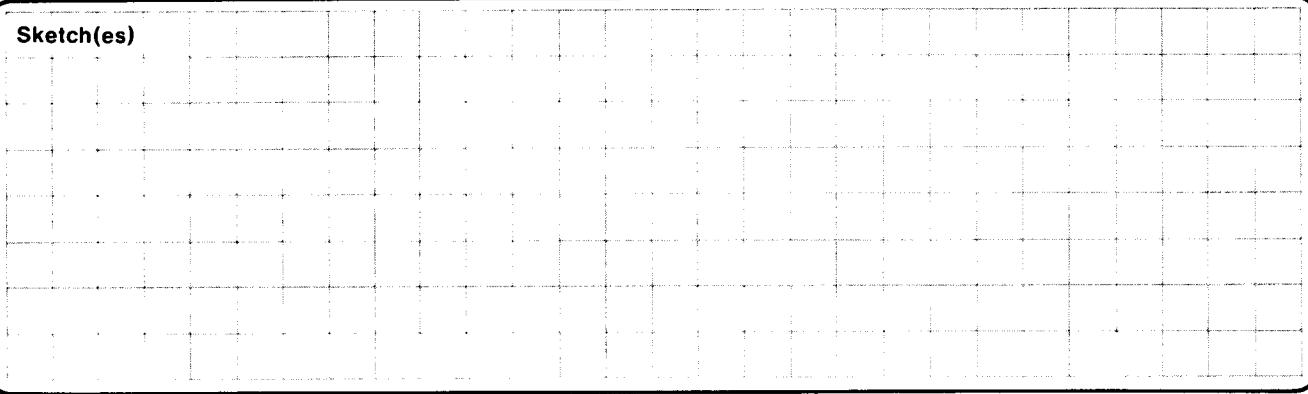
**Operating Limits and Warnings** In case 1,  $\sigma$  is finite only if  $X < x_0/2$ . If  $X > x_0/2$ , then  $\hat{\sigma}$  is infinite - this means that the truncated exponential distribution is not a good model for the observations. Program may not work when  $\bar{X}$  is very close to  $x_0/2$ .

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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# Program Description II

## Sketch(es)



## Sample Problem(s)

CASE 1  $X^o = 5, X = 2$

CASE 2  $n = 5, r = 4, X(j), j = 1, \dots, 4 = 11.12, 12.55, 13.47, 14.58$

## Solution(s)

CASE 1  $\hat{\sigma} = 4.065$

CASE 2  $\sigma^* = 3.567, \theta^* = 10.407$

### Keystrokes:

5 [ENT<sup>↑</sup>] 2 [A] → 4.065

5 [ENT<sup>↑</sup>] 4 [ENT<sup>↑</sup>] 11.12 [B] 12.55 [C] 13.47 [C]

14.58 [C] [D] → 3.567

[E] → 10.407

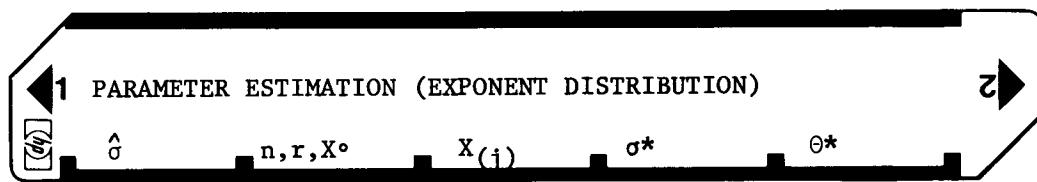
### Outputs:

## Reference(s)

Johnson and Kotz, "Continuous Univariate Distributions - 1",  
Houghton Mifflin Co., 1970.

This program is a translation of the HP - 65 Users' Library Program  
# 03652A submitted by Richard Freedman.

## User Instructions



# 97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11		057	R↓	-31	
002	ST01	35 01		058	ST03	35 03	
003	ST03	35 03		059	8	00	
004	R↓	-31		060	ST06	35 06	
005	ST04	35 04	$\sigma \leftarrow \sigma - \Delta \sigma$	061	RTN	24	
006	*LBL1	21 01		062	*LBL0	21 13	
007	RCL1	36 01		063	RCL5	36 05	
008	GSBE	23 15		064	X $\leftrightarrow$ Y	-41	
009	ST02	35 02		065	ST05	35 05	
010	RCL1	36 01		066	-	-45	
011	+	-55		067	RCL3	36 03	
012	GSBE	23 15		068	RCL4	36 04	
013	RCL2	36 02		069	-	-45	
014	-	-45		070	X	-35	$S \leftarrow S + (n-j)$
015	LSTX	16-63		071	ST-6	35-45 06	
016	ENT↑	-21		072	RCL4	36 04	$(X(j) - \text{Last})$
017	X	-35		073	1	01	
018	X $\leftrightarrow$ Y	-41		074	+	-55	
019	÷	-24		075	ST04	35 04	
020	RCL1	36 01		076	RTN	24	
021	X $\leftrightarrow$ Y	-41		077	*LBL0	21 14	
022	-	-45		078	RCL6	36 06	
023	ST01	35 01		079	RCL2	36 02	
024	LSTX	16-63		080	÷	-24	
025	ABS	16 31		081	ST06	35 06	
026	EEX	-23		082	RTN	24	
027	3	03		083	*LBL0	21 15	
028	CHS	-22		084	RCL1	36 01	
029	X $\leq$ Y?	16-35		085	RCL6	36 06	
030	GT01	22 01		086	RCL3	36 03	
031	RCL1	36 01		087	÷	-24	
032	RTN	24		088	-	-45	
033	*LBL0	21 15		089	RTN	24	
034	ENT↑	-21		090			
035	ENT↑	-21					
036	RCL4	36 04					
037	X $\leftrightarrow$ Y	-41					
038	÷	-24					
039	e <sup>X</sup>	33					
040	1	01					
041	-	-45					
042	1/X	52					
043	RCL4	36 04					
044	X	-35					
045	-	-45					
046	RCL3	36 03					
047	-	-45					
048	RTN	24					
049	*LBL0	21 12					
050	ST01	35 01					
051	ST05	35 05					
052	R↓	-31					
053	1	01					
054	ST04	35 04					
055	-	-45					
056	ST02	35 02					
X <sub>(1)</sub>							
last + X <sub>(1)</sub>							
SET STATUS							
FLAGS							
ON OFF				TRIG			
0 <input type="checkbox"/> <input checked="" type="checkbox"/>				1 <input type="checkbox"/> <input checked="" type="checkbox"/>			
2 <input type="checkbox"/> <input checked="" type="checkbox"/>				3 <input type="checkbox"/> <input checked="" type="checkbox"/>			
DEG <input checked="" type="checkbox"/>				RAD <input type="checkbox"/>			
SCI <input type="checkbox"/>				ENG <input type="checkbox"/>			
n <sup>2</sup> <input type="checkbox"/>				I <input type="checkbox"/>			

## REGISTERS

0	1 $\sigma$ , X <sub>(1)</sub>	2 Temp, r-1	3 $\bar{X}$ , n	4 j	5 Last	6 S	7	8	9 Used
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	F	G	H	I	J

# Program Description I

Program Title LOWER LIMIT OF RELIABILITY - BINOMIAL DISTRIBUTION

Contributor's Name Hewlett - Packard Company

Address 1000 N.E. Circle Boulevard

City Corvallis

State Oregon

Zip Code 97330

## Program Description, Equations, Variables

$$(1 - \gamma) = \sum_{j=0}^x \left[ \frac{N!}{j!(N-j)!} \right] p^j (1-p)^{N-j}$$

where N = total number of items tested

j = number of items failed

$\gamma$  = confidence level (in decimal form .XX)

P = probability of failure

$(1-P)$  = reliability =  $R_{L,X}$

$$\alpha = \frac{(1-\gamma) - (1-\gamma)_{\text{calculated}}}{(1 - \gamma)} \quad \text{allowable error}$$

Operating Limits and Warnings  $N \leq 69$

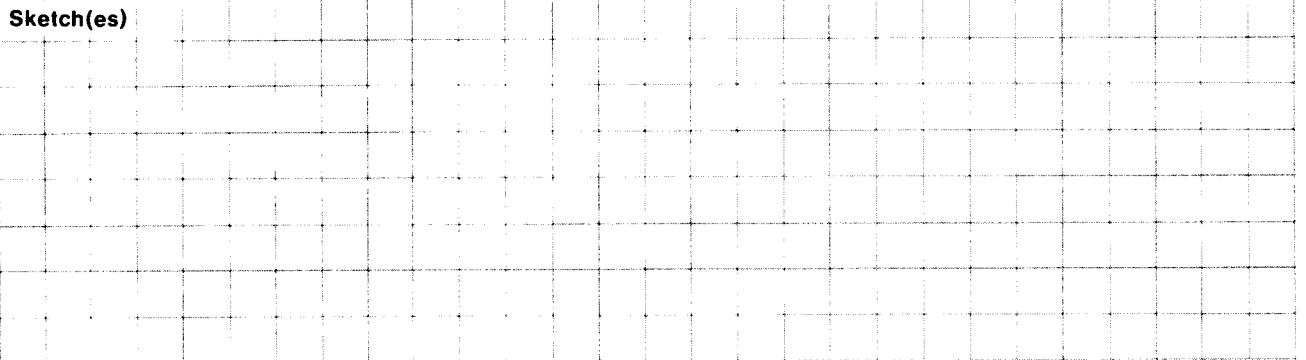
$.50 < \gamma < .99$  for most cases  $\gamma$  will not work if outside this range.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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# Program Description II

Sketch(es)



**Sample Problem(s)** A) Twenty rocket motors are fired with one failure; what is the demonstrated reliability at the lower 90% confidence level?

B) Fifty components are tested at 1 1/2 times their normal rated loading; what is the maximum number of failures that can be obtained and still demonstrate a .87 reliability at a 95% confidence level?

C) What is the reliability of 1 failure out of 15 tests of the 90% confidence level calculated to four decimal places ( $\alpha \leq .001$ ).

**Solution(s)** A) 20 [↑], 1 [A] [B]  $\rightarrow$  0.82

B) 50 [↑], 1 [A], .95 [C] 0.91

50 [↑], 2 [A], .95 [C] 0.88

50 [↑], 3 [A], .95 [C] 0.85

only 2 failures can be obtained

C) 15 [↑], 1 [A], .001 [STO] [7] [B]  $\rightarrow$  0.7645

**Reference(s)** This program is a translation of the HP - 65 Users' Library  
Program # 03820A submitted by George J. Sellers.

## User Instructions

## 1 LOWER LIMITS of RELIABILITY - BINOMIAL DISTRIBUTION

10

Enter  
N↑, j

R<sub>L,90</sub>

R<sub>LX</sub>

# 97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11		057	CHS	-22	
002	CLRG	16-53		058	X#Y?	16-32	
003	STO1	35 46		059	GT01	22 01	
004	STO2	35 02		060	RCL7	36 07	
005	R↓	-31		061	RCL6	36 06	
006	STO1	35 01		062	RCL5	36 05	
007	.	-62		063	-	-45	
008	1	01		064	RCL5	36 05	
009	STO7	35 07		065	÷	-24	
010	CF1	16 22 01		066	ABS	16 31	
011	STO5	35 05		067	X≤Y?	16-35	
012	STO3	35 03		068	GT02	22 02	
013	CLX	-51		069	RCL6	36 06	
014	ENT↑	-21		070	RCL5	36 05	
015	ENT↑	-21		071	+	-55	
016	ENT↑	-21		072	2	02	
017	R/S	51		073	÷	-24	
018	*LBLC	21 13		074	RCL5	36 05	
019	1	01		075	÷	-24	
020	-	-45		076	1	01	
021	CHS	-22		077	+	-55	
022	STO5	35 05		078	RCL3	36 03	
023	*LBLB	21 12		079	×	-35	
024	1	01		080	2	02	
025	RCL3	36 03		081	÷	-24	
026	-	-45		082	STO3	35 03	
027	STO4	35 04		083	0	00	
028	RCL2	36 02		084	STO6	35 06	
029	STO1	35 46		085	GT0B	22 12	
030	*LBL1	21 01		086	*LBL2	21 02	
031	1	01		087	RCL4	36 04	
032	RCL1	36 01		088	R/S	51	
033	N!	16 52					
034	RCLI	36 46					
035	N!	16 52					
036	÷	-24					
037	RCLI	36 01					
038	RCLI	36 46					
039	-	-45					
040	N!	16 52					
041	÷	-24					
042	RCL3	36 03					
043	RCLI	36 46					
044	Y <sup>x</sup>	31					
045	X	-35					
046	RCL4	36 04					
047	RCL1	36 01					
048	RCLI	36 46					
049	-	-45					
050	Y <sup>x</sup>	31					
051	X	-35					
052	ST+6	35-55 06					
053	DSZI	16 25 46					
054	SF1	16 21 01					
055	RCLI	36 46					
056	1	01					

## REGISTERS

0	1 N	2 j	3 P	4 $(1 - P)$ = $\bar{R}_{LX}$	5 $(1 - \gamma)$ calculated	6 $(1 - \gamma)$ calculated	7 Y	8 i	9 Logic
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E			I		

## SET STATUS

FLAGS	TRIG		DISP	
	ON	OFF	DEG	SCI
0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

FIX   
SCI   
ENG   
n<sub>2</sub>

# Program Description I

Program Title      Reliability and Probability of Failure of Series and Parallel Systems

Contributor's Name      Hewlett-Packard

Address      1000 N.E. Circle Blvd.

City      Corvallis

State      Oregon

Zip Code      97330

**Program Description, Equations, Variables**

Given the mission time  $t$ , number of parallel

components  $n_i$ , failure rates  $\lambda_{ij}$  and reliability block diagram of a parallel, series or combination parallel/series system, the program calculates the following values:

$$\text{Probability of Failure } Q_S(t) = 1 - R_S(t)$$

$$\text{Reliability } R_S(t) = \prod_{i=1}^k R_i(t)$$

where  $k$  = number of parallel groupings in series

$$R_i = R_i(j-1) + (1 - R_i(j-1))R_{ij} \quad 1 \geq j \geq n_i$$

$$R_{ij} = \exp(-\lambda_{ij}t)$$

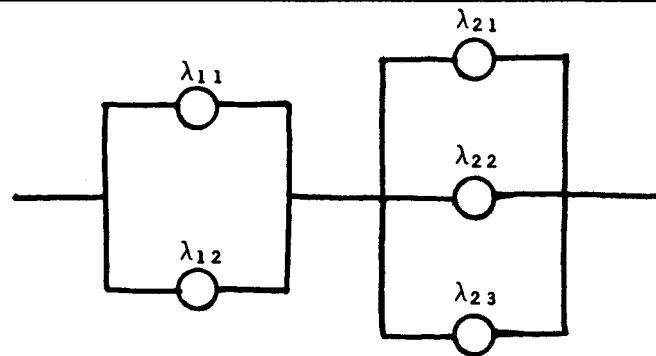
**Operating Limits and Warnings**       $n$  is a positive integer and  $\lambda \geq 0$ .

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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# Program Description II

## Sketch(es)



## Sample Problem(s)

Find the system reliability and probability of failure of the system represented on the line above, given the following failure rates and mission time:

$$\lambda_{11} = 2 \times 10^{-4} \text{ failures/hour}$$

$$\lambda_{12} = 1.5 \times 10^{-2} \text{ "}$$

$$\lambda_{21} = 3.4 \times 10^{-3} \text{ "}$$

$$\lambda_{22} = 1.2 \times 10^{-2} \text{ "}$$

$$\lambda_{23} = 2.5 \times 10^{-2} \text{ "}$$

$$t = 10 \text{ hours}$$

## Solution(s)

DSP 8

f A 10 A 2 B .0002 C .015 C  
 3 B .0034 C .025 C .012 C

→ .99888578 (  $R_s(t)$  )

→ .00111422 (  $Q_s(t)$  )

## Reference(s)

Bazovsky, Igor, Reliability Theory and Practice, pgs. 17, 89, 98  
 Prentice Hall, 1961

This program is a translation of the HP-65 Users' Library program #03869A  
 submitted by James E. Wells.

# User Instructions

RELIABILITY AND PROBABILITY OF FAILURE OF SERIES AND PARALLEL SYSTEMS				
$t$	$n_i$	$\lambda_{ij}$	$Q_s(t)$	$R_s(t)$

# 97 Program Listing I

20

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBL <sub>a</sub>	21 16 11	Initialize	057	RCL <sub>6</sub>	36 06	
002	P <sub>1</sub> S	16-51		058	CHS	-22	
003	ST04	35 04		059	ENT $\uparrow$	-21	
004	ST05	35 05		060	1	01	
005	ST08	35 08		061	+	-55	
006	1	01		062	GT02	22 02	
007	ST06	35 06					
008	RTN	24					
009	*LBLA	21 11					
010	ST05	35 05	Store 1 in R <sub>6</sub>				
011	RTN	24	Display 1 in R <sub>6</sub>				
012	*LBL1	21 01	Enter t				
013	0	00					
014	ST01	35 01	Initialize	070			
015	ST03	35 03	Store 0 in R <sub>1</sub> , R <sub>3</sub>				
016	RCL <sub>6</sub>	36 06					
017	RTN	24					
018	*LBL2	21 02					
019	RTN	24					
020	*LBLB	21 12					
021	ST08	35 08					
022	RTN	24					
023	*LBL3	21 03					
024	RCL1	36 01		080			
025	RTN	24					
026	*LBLC	21 13	Display counter				
027	ENT $\uparrow$	-21	Calculate R <sub>1</sub>				
028	RCL5	36 05					
029	x	-35					
030	CHS	-22					
031	e <sup>x</sup>	33					
032	ST04	35 04					
033	RCL3	36 03					
034	CHS	-22		090			
035	ENT $\uparrow$	-21					
036	1	01					
037	+	-55					
038	RCL4	36 04	(1 - R <sub>i</sub> (j-1)) R <sub>ij</sub>				
039	x	-35					
040	RCL3	36 03					
041	+	-55					
042	ST03	35 03					
043	RCL1	36 01					
044	1	01	Update counter	100			
045	+	-55					
046	ST01	35 01					
047	RCL8	36 08					
048	X $\neq$ Y?	16-32	Test counter				
049	GT03	22 03					
050	RCL3	36 03					
051	ENT $\uparrow$	-21					
052	RCL6	36 06	R <sub>s</sub> (t)				
053	x	-35	Store R <sub>s</sub> (t)				
054	ST06	35 06		110			
055	GT01	22 01					
056	*LBLD	21 14	Calculate Q <sub>s</sub> (t)				
REGISTERS							
0	1 Counter	2	3 R <sub>i</sub> (j-1)	4 R <sub>ij</sub>	5 t	6 R <sub>s</sub> (t)	7
S0	S1	S2	S3	S4	S5	S6	S7
A	B	C	D	E	F	G	I

## SET STATUS

FLAGS	TRIG	DISP	ON	OFF
			0	1
		DEG	<input checked="" type="checkbox"/>	<input type="checkbox"/>
		GRAD	<input type="checkbox"/>	<input checked="" type="checkbox"/>
		RAD	<input type="checkbox"/>	<input checked="" type="checkbox"/>
		SCI	<input type="checkbox"/>	<input checked="" type="checkbox"/>
		ENG	<input type="checkbox"/>	<input checked="" type="checkbox"/>
		n	8	

# Program Description I

Program Title MIL-STD-883 CALCULATED LEAK RATE

Contributor's Name Hewlett-Packard  
 Address 1000 N.E. Circle Blvd.  
 City Corvallis

State Oregon Zip Code 97330

## Program Description, Equations, Variables

MIL-STD-883A Method 1014.1 Condition A<sub>2</sub> requires a calculated leak rate using the equation

$$R = L \frac{P_E}{P_0} \sqrt{\frac{M_a}{M}} \left\{ 1 - \exp \left[ -L \frac{t_1}{VP_0} \sqrt{\frac{M_a}{M}} \right] \right\} \exp \left[ -L \frac{t_2}{VP_0} \sqrt{\frac{M_a}{M}} \right]$$

To calculate L given the value for R. This equation must be solved iteratively for L. Solution is done using the Newton procedure for refining the trial values for L.

The user is referred to MIL-STD-883 for the meaning and complete description of variables and test techniques.

R = Measured leak rate

L = Calculated leak rate cc/sec

P<sub>E</sub> = Bomb pressure (usually 5 atm)

t<sub>1</sub> = Pressurization time sec.

P<sub>0</sub> = Atmospheric pressure (1 atm)

t<sub>2</sub> = Time from end of pressure to measurement sec.

$\frac{M_a}{M}$  = Ratio of molecular wts of air to tracer gas (assumed He)

## Operating Limits and Warnings

Mathematically there is no limit, but calculation time is less for 1% than for .01%. 1% is adequate for most experimental setups.

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# Program Description II

## Sketch(es)

### Sample Problem(s)

For the inputs

$$R = 7.2 \times 10^{-8}$$

$$t_1 = 3600 \text{ sec}$$

$$t_2 = 300 \text{ sec}$$

$$v = 1.1684 \text{ cc}$$

$$\text{ERROR} = .01$$

The program should return the value 8.058 -07. Keying RCL 3 will tell you that it took 6 iterations to obtain the answer.

### Solution(s)

#### Keystrokes:

#### Outputs:

7.2 [EEX][CHS][8][STO][8], 3600 [STO][1], 300 [STO][2],  
1.1684 [STO][3], 2.678 [STO][4], .01 [STO][5]

[SCI][DSP][3][A]  
[RCL][3]

→ 8.058 -07  
→ 6.000 00

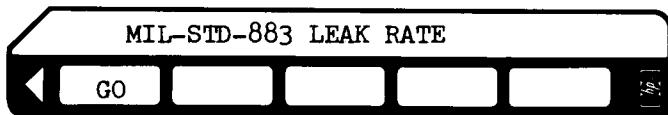
### Reference(s)

MIL-STD-883A "Military Standard Test Methods and Procedures for Microelectronics"

#### Method 1014.1 Seal

This program is a translation of the HP-65 Users' Library Program #04109A  
submitted by Richard T. Lamoureux.

# User Instructions



# 97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11		057	ST07	35 07	
002	RCL8	36 08		058		1	01
003	CHS	-22		059	ST+3	35-55 03	
004	ST07	35 07		060	GTOE	22 12	L <sub>i+1</sub>
005	RCL4	36 04		061	RTN	24	
006	RCL3	36 03		062	*LBLC	21 13	
007	÷	-24		063	RCL7	36 07	Display final L
008	STX1	35-35 01		064	CHS	-22	
009	STX2	35-35 02		065	R/S	51	
010	0	00		066	RTN	24	
011	ST03	35 03		070			
012	*LBLB	21 12		080			
013	RCL7	36 07		090			
014	RCL2	36 02		100			
015	x	-35		110			
016	e <sup>x</sup>	33					
017	RCL7	36 07					
018	RCL1	36 01					
019	x	-35					
020	e <sup>x</sup>	33					
021	1	01					
022	-	-45					
023	x	-35					
024	RCL4	36 04					
025	x	-35					
026	5	05					
027	x	-35					
028	RCL7	36 07					
029	x	-35					
030	RCL8	36 08					
031	-	-45					
032	ST06	35 06					
033	RCL8	36 08					
034	÷	-24					
035	ABS	16 31					
036	RCL5	36 05					
037	X>Y?	16-34					
038	GTOC	22 13					
039	RCL7	36 07					
040	RCL6	36 06					
041	RCL2	36 02					
042	4	04					
043	0	00					
044	x	-35					
045	RCL7	36 07					
046	x	-35					
047	2	02					
048	7	07					
049	-	-45					
050	RCL1	36 01					
051	x	-35					
052	RCL7	36 07					
053	x	-35					
054	÷	-24					
055	+	-55					
056	CHS	-22					

## REGISTERS

0	1 $t_b$ $b$	2 $t_c$ $c$	3 $v_n$	4 2.6785	5 $10^{-2}$	6 $R^1-R$	7 L	8 R	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	F	G	H	I	J

FLAGS		TRIG	DISP
ON	OFF		
0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	DEG <input checked="" type="checkbox"/>
1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	GRAD <input type="checkbox"/>
2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	RAD <input type="checkbox"/>
3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	SCI <input type="checkbox"/>
			ENG <input type="checkbox"/>
			n 3

# Program Description I

Program Title MLE:  $\hat{\theta}$  FROM HAZARD RATE

Contributor's Name Hewlett-Packard Company

Address 1000 N.E. Circle Boulevard

City Corvallis

State Oregon Zip Code 97330

**Program Description, Equations, Variables** Given the test failure data of the sample, the program computes differential failure times ( $\Delta t_i$ ); mean time to failure (MTTF); failure rate  $Z(t_i)$ ; parameter  $\lambda$  (constant hazard rate) and  $\hat{\theta}$  from this hazard rate.

Following formulas and variables are used:

- 1)  $\Delta t_i = t_i - t_{i-1}$  ; where  $i = 0, 1, 2, 3, \dots, n$  failures
- 2)  $MTTF = \hat{\theta} = \sum t_i / N_0$  ; where  $t_i$  = time to failures  
 $N_0$  = total # of failures
- 3)  $Z(t_i) = \frac{n(t_i) - n(t_i + \Delta t_i)}{\Delta t_i} \cdot \frac{1}{N_s(t_i)}$  ; where  $[n(t_i) - n(t_i + \Delta t_i)]$   
 $N_s(t_i)$  is # of failures in that time difference.  
 $N_s(t_i)$  = # survived at  $t_i$ .
- 4)  $\lambda = \frac{\sum Z(t_i)}{N_0} = \bar{Z}(t_i)$  ;  $\lambda$  = parameter (hazard rate)  
i.e. mean of total  $Z(t_i)$ 's.
- 5)  $\hat{\theta}_Z(t) = \frac{1}{\lambda}$  ; [MLE from hazard rate]  
hazard  
rate

## Operating Limits and Warnings

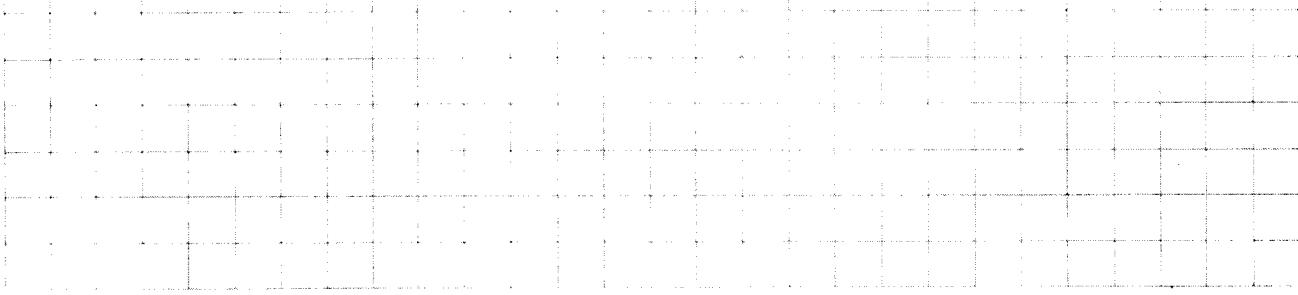
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# Program Description II

Sketch(es)

PLEASE SEE ATTACHED GRAPH



Sample Problem(s) Ten tires were put on testing machines with a known load and rpm: results were as follows.

FAILURE # OPERATING TIME

1	6
2	22
3	30
4	45
5	62
6	88
7	114
8	140
9	190
10	251

Find the following:

- 1)  $\Delta t_i$  : differential time failures
- 2) MTTF: mean time to failure
- 3)  $Z(t_i)$  ; failure rate parameter
- 4)  $\lambda$  : constant hazard rate
- 5) MLE:  $\hat{\theta}$  from hazard rate

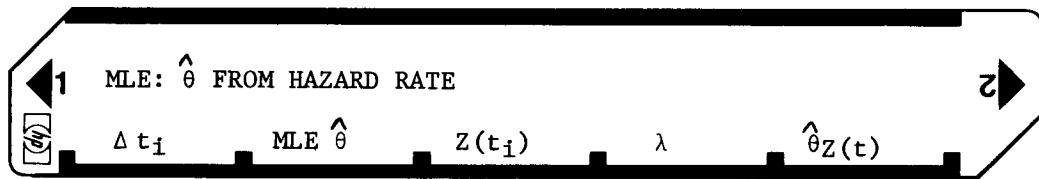
Solution(s)	Failure #	Operating Time	$\Delta t_i$	$Z(t_i)$	
	1	6	6	0.0167	$\lambda = \frac{\sum Z(t_i)}{No} = \frac{0.1151}{10}$
	2	22	16	0.0069	
	3	30	8	0.0156	
	4	45	15	0.0095	$\lambda = .01151$
	5	62	17	0.0098	
	6	88	26	0.0077	$\hat{\theta} = \frac{1}{\lambda} = 86.8919$
	7	114	26	0.0096	
	8	140	26	0.0128	
	9	190	50	0.0100	
	10	251	61	0.0164	
	$\sum t_i = 948$		$\sum Z(t_i) = 0.1151$		

Reference(s) This program is a translation of the HP-65 Users' Library Program #05105A submitted by Ashok H. Doshi.

## COMPLETE KEYSTROKES FOR THE EXAMPLE

	[f] [REG]	0.00	(Clear registers)
251	[A]	251.00	( $t_{10}$ )
190	[R/S]	61.00	( $\Delta t_{10}$ )
	[R/S]	190.00	[Recall last input]
140	[R/S]	50.00	( $\Delta t_9$ )
	[R/S]	140.00	[Recall last input]
114	[R/S]	26.00	( $\Delta t_8$ )
	[R/S]	114.00	[Recall last input]
88	[R/S]	26.00	( $\Delta t_7$ )
	[R/S]	88.00	[Recall last input]
62	[R/S]	26.00	( $\Delta t_6$ )
	[R/S]	62.00	[Recall last input]
45	[R/S]	17.00	( $\Delta t_5$ )
	[R/S]	45.00	[Recall last input]
30	[R/S]	15.00	( $\Delta t_4$ )
	[R/S]	30.00	[Recall last input]
22	[R/S]	8.00	( $\Delta t_3$ )
	[R/S]	22.00	[Recall last input]
6	[R/S]	16.00	( $\Delta t_2$ )
	[R/S]	6.00	[Recall last input]
0	[R/S]	6.00	( $\Delta t_1$ )
	[R/S]	0.00	[Recall last input]
	[B]	94.80	( $\hat{\theta}$ )
6	[C]	0.0167	[ $Z(t_1)$ ]
16	[R/S]	0.0069	[ $Z(t_2)$ ]
8	[R/S]	0.0156	[ $Z(t_3)$ ]
15	[R/S]	0.0095	[ $Z(t_4)$ ]
17	[R/S]	0.0098	[ $Z(t_5)$ ]
26	[R/S]	0.0077	[ $Z(t_6)$ ]
26	[R/S]	0.0096	[ $Z(t_7)$ ]
26	[R/S]	0.0128	[ $Z(t_8)$ ]
50	[R/S]	0.0100	[ $Z(t_9)$ ]
61	[R/S]	0.0164	[ $Z(t_{10})$ ]

## User Instructions



# 97 Program Listing I

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STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11					
002	*LBL3	21 03					
003	ST+1	35-55 01	Calculate the operating time differences				
004	R/S	51		060			
005	-	-45					
006	DS2I	16 25 46					
007	GT04	22 04					
008	GT03	22 03					
009	*LBL4	21 04					
010	R/S	51					
011	LSTX	16-63					
012	GT03	22 03					
013	*LBLB	21 12					
014	RCLI	36 01	Calculate MTTF: $\hat{\theta}$	070			
015	RCLI	36 46					
016	CHS	-22					
017	=	-24					
018	RTN	24					
019	*LBLC	21 13					
020	1/X	52	Calculate $Z(t_i)$				
021	RCLI	36 46	(failure rate)				
022	CHS	-22					
023	=	-24					
024	ST+2	35-55 02		080			
025	RCL2	36 02					
026	DSP4	-63 04					
027	*LBL1	21 01					
028	R/S	51					
029	1/X	52					
030	RCLI	36 46					
031	1	01					
032	ST+5	35-55 05					
033	RCL5	36 05					
034	X $\neq$ Y	-41		090			
035	R↓	-31					
036	+	-55					
037	=	-24					
038	CHS	-22					
039	ST+2	35-55 02					
040	GT01	22 01					
041	*LBLD	21 14	Calculate the parameter $\lambda$				
042	RCL2	36 02	(constant hazard rate)				
043	RCLI	36 46		100			
044	CHS	-22					
045	=	-24					
046	DSP4	-63 04					
047	RTN	24					
048	*LBLE	21 15	Calculate MLE: $\hat{\theta} Z(t)$				
049	GSBD	23 14					
050	1/X	52					
051	DSP4	-63 04					
052	RTN	24					
SET STATUS							
FLAGS							
ON				OFF		DEG	
0	<input type="checkbox"/>	<input checked="" type="checkbox"/>		1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
1	<input type="checkbox"/>	<input checked="" type="checkbox"/>		2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2	<input type="checkbox"/>	<input checked="" type="checkbox"/>		3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
GRAD							
RAD							
SCI							
ENG							
n <u>2</u>							
REGISTERS							
0	1 USED	2 USED	3	4	5 USED	6	7
S0	S1	S2	S3	S4	S5	S6	S7
A	B	C		D	E		I

# Program Description I

Program Title MLE:  $\hat{\theta}$  BY LEAST SQUARE METHOD

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Boulevard

City Corvallis

State Oregon

Zip Code 97330

## Program Description, Equations, Variables

The program uses least square technique to compute maximum likelihood estimator. By using the probability of survival  $R(t_i)$

where:

$$R(t_i) = \frac{N_s}{N_o} ;$$

$N_s$  = numbers survived at time  $t_i$

$N_o$  = total number failed

least square parameter  $\lambda = - \frac{\sum_{i=1}^n t_i \ln R(t_i)}{\sum_{i=1}^n t_i^2} ;$

for detail see page 4 of 7

and  $\hat{\theta} = \frac{1}{\lambda} ;$

maximum likelihood estimator

## Operating Limits and Warnings

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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DEVELOPING  $\theta$  BY GENERATING THE PARAMETER  $\lambda$  USING RELIABILITY FOR LEAST SQUARE METHOD

Using Least Square Estimate

To Find value of parameter  $\lambda$

$$R(t_i) = e^{-\lambda t_i}$$

$$\ln R(t_i) = -\lambda t_i$$

$$s(\lambda) = \sum [\ln R(t_i) - (-\lambda t_i)]^2$$

Now taking derivative w.r.t.  $\lambda$  on both sides and equating to zero for maximum we get:

$$\frac{d s(\lambda)}{d \lambda} = \sum [ \ln R(t_i) + \lambda t_i ] (t_i) = 0$$

$$\sum [ \ln R(t_i) + \lambda t_i ] (t_i) = 0$$

$$\sum [t_i \ln R(t_i) + \lambda t_i^2] = 0$$

$$2\sum [t_i \ln R(t_i) + \lambda t_i^2] = 0$$

$$\sum_{i=1}^n t_i \ln R(t_i) + \lambda \sum_{i=1}^n t_i^2 = 0$$

$$\lambda = \frac{\sum_{i=1}^n t_i \ln R(t_i)}{\sum_{i=1}^n t_i^2}$$

## Program Description II

### Sketch(es)

**Sample Problem(s)** Ten tires were put on testing machines with a known load and rpm.

The test results of failures were as follows:

FAILURE #      OPERATING TIME

1	6
2	22
3	30
4	45
5	62
6	88
7	114
8	140
9	190
10	251

**FIND THE FOLLOWING:**

- 1) probability of survival  $R(t_i)$
- 2) MLE:  $\theta$  by using least square method

**Solution(s)** For solution please see pages attached next 4 of 7 and 5 of 7.

**Reference(s)** Authors Own Notes On "Quality Assurance and Reliability".

This program is a translation of the HP-65 Users' Library Program  
#05106A submitted by Ashok Doshi.

## COMPLETE KEYSTROKES FOR THE EXAMPLE

Press	Display
[f] [REG]	0.00 [Clear Registers]
6 [A]	36.00 [ $t_1^2$ ]
22 [A]	484.00 [ $t_2^2$ ]
30 [A]	900.00 [ $t_3^2$ ]
45 [A]	2025.00 [ $t_4^2$ ]
62 [A]	3844.00 [ $t_5^2$ ]
88 [A]	7744.00 [ $t_6^2$ ]
114 [A]	12996.00 [ $t_7^2$ ]
140 [A]	19600.00 [ $t_8^2$ ]
190 [A]	36100.00 [ $t_9^2$ ]
251 [A]	63001.00 [ $t_{10}^2$ ]
[B]	0.9000 [ $R(t_1)$ ]
[B]	0.8000 [ $R(t_2)$ ]
[B]	0.7000 [ $R(t_3)$ ]
[B]	0.6000 [ $R(t_4)$ ]
[B]	0.5000 [ $R(t_5)$ ]
[B]	0.4000 [ $R(t_6)$ ]
[B]	0.3000 [ $R(t_7)$ ]
[B]	0.2000 [ $R(t_8)$ ]
[B]	0.1000 [ $R(t_9)$ ]
[B]	0.0000 [ $R(t_{10})$ ]

PRESS		DISPLAY	
.9	[C]	-0.1054	$[\ln R(t_1)]$
.8	[C]	-0.2231	$[\ln R(t_2)]$
.7	[C]	-0.3567	$[\ln R(t_3)]$
.6	[C]	-0.5108	$[\ln R(t_4)]$
.5	[C]	-0.6931	$[\ln R(t_5)]$
.4	[C]	-0.9163	$[\ln R(t_6)]$
.3	[C]	-1.2040	$[\ln R(t_7)]$
.2	[C]	-1.6094	$[\ln R(t_8)]$
.1	[C]	-2.3026	$[\ln R(t_9)]$
.0	→ (not possible)	--	$\leftarrow [\ln R(t_{10})]$
6	[D]	6.00	$[t_1]$
.1054	[CHS] [R/S]	- 0.6324	$[t_1 \cdot \ln R(t_1)]$
22	[D]	22.0000	$[t_2]$
.2231	[CHS] [R/S]	- 4.9082	$[t_2 \cdot \ln R(t_2)]$
30	[D]	30.0000	$[t_3]$
.3567	[CHS] [R/S]	- 10.7010	$[t_3 \cdot \ln R(t_3)]$
45	[D]	45.0000	$[t_4]$
.5108	[CHS] [R/S]	- 22.9860	$[t_4 \cdot \ln R(t_4)]$
62	[D]	62.0000	$[t_5]$
.6931	[CHS] [R/S]	- 42.9722	$[t_5 \cdot \ln R(t_5)]$
88	[D]	88.0000	$[t_6]$
.9163	[CHS] [R/S]	- 80.6344	$[t_6 \cdot \ln R(t_6)]$
114	[D]	114.0000	$[t_7]$
1.2040	[CHS] [R/S]	- 137.2560	$[t_7 \cdot \ln R(t_7)]$
140	[D]	140.0000	$[t_8]$
1.6094	[CHS] [R/S]	- 225.3160	$[t_8 \cdot \ln R(t_8)]$
190	[D]	190.0000	$[t_9]$
2.3026	[CHS] [R/S]	- 437.4940	$[t_9 \cdot \ln R(t_9)]$
[Delete]→251	[D]	251.0000	$[t_{10}]$
this one only	[R/S]	--	$[t_{10} \cdot \ln R(t_{10})]$
	[E]	152.3834	$[\hat{\theta}]$

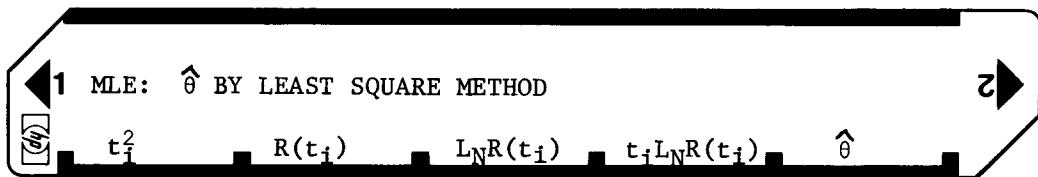
BY LEAST SQUARE ESTIMATE METHOD USING  $R(t)$ 

$$\text{ie } \lambda = - \frac{\sum_{i=1}^{10} t_i \ln R(t_i)}{\sum_{i=1}^{10} t_i^2} \quad (\text{as formed previously})$$

	$t_i$	$R(t_i)$	$\ln R(t_i)$	$t_i \ln R(t_i)$	$t_i^2$
1	6	0.90	- 0.1054	- 0.6324	36
2	22	0.80	- 0.2231	- 4.9082	484
3	30	0.70	- 0.3567	- 10.7010	900
4	45	0.60	- 0.5108	- 22.9860	2025
5	62	0.50	- 0.6931	- 42.9722	3844
6	88	0.40	- 0.9163	- 80.6344	7744
7	114	0.30	- 1.2040	- 137.2560	12996
8	140	0.20	- 1.6094	- 225.3160	19600
9	190	0.10	- 2.3026	- 437.4940	36100
10	251	0.00	--	--	<u>63001</u>
			$\lambda = - 962.90$		146730

$$\therefore \lambda = - \frac{-962.90}{146730} = 0.0066 \quad \therefore \tilde{\theta} = \frac{1}{\lambda} = 152.3834$$

# User Instructions



## 97 Program Listing I

# Program Description I

Program Title	SYSTEMS RELIABILITY - SERIES AND PARALLEL WITH SAME FAILURE RATE $\lambda$		
Contributor's Name	Hewlett-Packard Company		
Address	1000 N.E. Circle Boulevard		
City	Corvallis	State	Oregon
		Zip Code	97330

**Program Description, Equations, Variables** Program calculates total systems reliability when units (composed of differential components) are placed in series or parallel, by using the concept of unreliability to calculate systems reliability in parallel, avoiding very lengthy and tedious calculations. Saves considerable amount of time. Equations used are as follows:

$j_i$  is number of components of corresponding  $\lambda_i$

$\lambda_i$  is failure rate/hr of differential components (say  $r$  types)  
(where  $i = 1, 2, 3, \dots, r$ )

$\sum_{i=1}^r j_i \lambda_i$  ; total failure rate/hr of a unit

$$-\sum_{i=1}^r \lambda_i j_i \cdot t$$

Unit  $R_s(t) = e^{-\sum_{i=1}^r \lambda_i j_i \cdot t}$  ; Unit reliability for  $t$  hours.

Unit  $Q_s(t) = 1 - R_s(t)$  ; Unit unreliability for  $t$  hours.

$$\text{Series } R_{sys} = \prod_{m=1}^n R_m = \prod_{m=1}^n e^{-\sum_{i=1}^r \lambda_i j_i \cdot t_m} = [e^{-\sum_{i=1}^r \lambda_i j_i \cdot t}]^n$$

$$\text{Series } Q_{sys} = 1 - R_{sys}$$

$$\text{Parallel } R'_{sys} = 1 - \prod_{m=1}^n Q'_m = [1 - [1 - \prod_{m=1}^n [R_s(t)]_m]]$$

## Operating Limits and Warnings

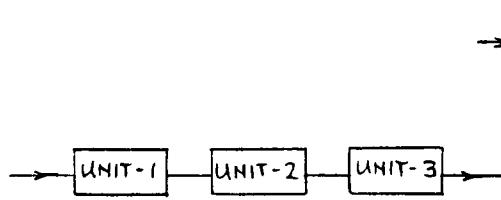
All units placed in series or parallel must have same  $\lambda$  failure rate per hour.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

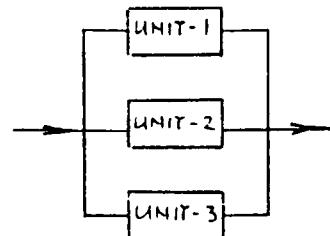
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# Program Description II

## Sketch(es)



SERIES CONFIGURATION



PARALLEL CONFIGURATION

**Sample Problem(s)** The given electrical unit has following components with corresponding failure rates:

chronological order i	# of components j	$\epsilon$ failure rate/hr/comp. $\lambda$	$\lambda_{ij_i}$
1	2-diodes	$2.0 \times 10^{-6}/hr$	$4.0 \times 10^{-6}/hr$
2	3-transistors	$10.0 \times 10^{-6}/hr$	$30.0 \times 10^{-6}/hr$
3	1-capacitor	$1.0 \times 10^{-6}/hr$	$1.0 \times 10^{-6}/hr$
4	2-resistors	$2.0 \times 10^{-6}/hr$	$4.0 \times 10^{-6}/hr$

Find for  $t = 1000$  hours; following:

- 1) Reliability, unreliability of a unit:  $R_s(t)$  &  $Q_s(t)$
- 2) Series reliability  $R_{sys}$ ; unreliability for 3 units ( $n=3$ )
- 3) Parallel unreliability  $Q'_{sys}$ ; reliability for 3 units ( $n=3$ )
- 4) Total failure rate/hour of an unit:  $(\sum \lambda_{ij_i})$

**Solution(s)**  $\sum_{i=1}^4 \lambda_{ij_i} = 3.9000000 - 05$

Unit:  $R_s(1000) = 0.961751$  ;  $Q_s(1000) = 0.038249$

Series System:  $R_{sys}^{(1000)} = 0.889585$  ;  $Q_s(1000) = 0.110415$   
for  $n=3$

Parallel System:  $Q'_{sys}(1000) = 0.000056$  ;  $R'_{sys}(1000) = 0.999944$   
for  $n=3$

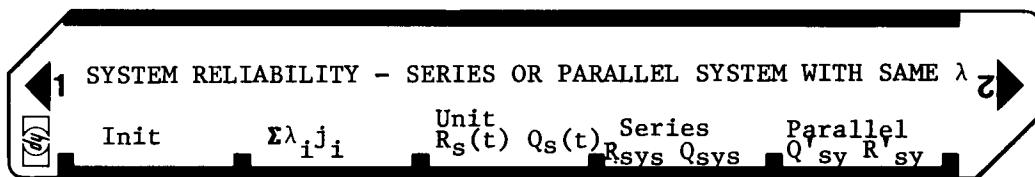
**Reference(s)** Authors Own Notes on "Quality Assurance And Reliability".

This program is a translation of the HP-65 Users' Library Program  
#05108A submitted by Ashok Doshi.

## COMPLETE KEYSTROKES FOR THE EXAMPLE

[A]	0.00		
2 [EEX]	2.	00	
6	2.	06	
[CHS]	2.	-06	$[\lambda_i]$
[↑]			
[2]			[# of components]
[X]	0.00		
[B]	4.000000000	-06	$[\Sigma \lambda_i j_i]$
10 [EEX]	10.	00	
6	10.	06	
[CHS]	10.	-06	
[↑]	10.000000000	-06	
3	3.		
[X]			
[B]	3.400000000	-05	
[EEX]	1.	00	
6	1.	06	
[CHS] [↑]	1.000000000	-06	
1	1.		
[X]	1.000000000	-06	
[B]	3.500000000	-05	
2 [EEX]	2.	00	
6	2.	06	
[CHS]	2.	-06	
[↑]	2.000000000	-06	
2	2.		
[X]			
[B]	3.900000000	-05	
1000 [C]	0.961751		$[R_s(1000)]$
[R/S]	0.038249		$[Q_s(1000)]$
3 [D]	0.889585		$[R_{sys}^{(1000)}]$ when we input $n=3$ units in series
[R/S]	0.110415		$[Q_{sys}^{(1000)}]$ of 3 units in series
3 [E]	0.000056		$[Q's(1000)]$ of 3 units in parallel
[R/S]	0.999944		$[R's(1000)]$ of 3 units in parallel

## User Instructions



## 97 Program Listing I

# Program Description I

Program Title SYSTEMS RELIABILITY - SERIES AND PARALLEL WITH DIFFERENT FAILURE RATE  $\lambda$

Contributor's Name Hewlett-Packard Company

Address 1000 N.E. Circle Boulevard

City Corvallis

State Oregon

Zip Code 97330

## Program Description, Equations, Variables

For series system, program uses  $R_{ss} = \prod_{i=1}^n R_i$  (where  $R_i$  = reliability of each component or unit) and for parallel system it uses unreliability concept to find reliability of the system.  $R_{sp} = 1 - Q_{sp}$  (where  $Q_{sp} = \prod_{i=1}^n (1 - e^{-\lambda_i t})$ ).  $\lambda$  is failure rate/hour.

The program is very useful to check out any dependent failures, repairs, sand by operation and redundancy of the system.

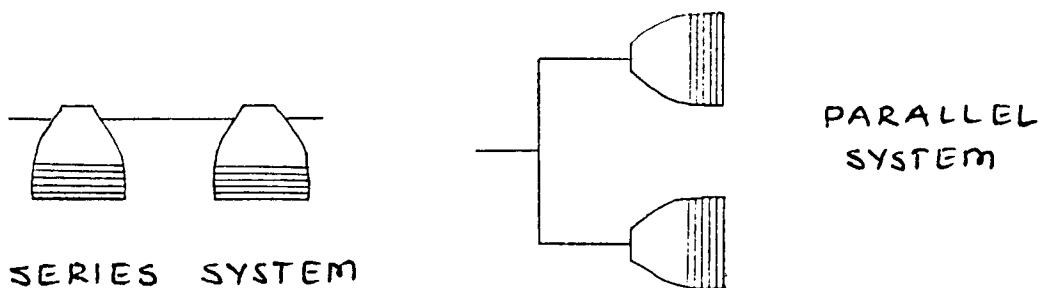
## Operating Limits and Warnings

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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# Program Description II

## Sketch(es)



**Sample Problem(s)** Two retro rockets of different capacities with failure rates

$6 \times 10^{-6}$  F/Hr and  $23 \times 10^{-6}$  F/Hr respectively of a command module of a spacecraft are to be mounted for maximum possible systems reliability for re-entry. Find out systems reliability for 1000 hours. If they are mounted in series or parallel. (Please refer to sketch above).

ie GIVEN:  $t = 1000$

$\lambda_1 = 6 \times 10^{-6}$  Failures/hour

$\lambda_2 = 23 \times 10^{-6}$  Failures/hour

## Solution(s)

$$R_{ss}(1000) = \prod_{i=1}^n R_i = e^{-\lambda_1 t} \cdot e^{-\lambda_2 t} = e^{-6 \times 10^{-6} \times 1000} \cdot e^{-23 \times 10^{-6} \times 1000} = 0.971416$$

$$Q_{ss}(1000) = 0.028584$$

$$R_{sp}(1000) = 1 - Q_{sp} = [1 - (1-R_1)(1-R_2)] = 0.999864$$

$$Q_{sp}(1000) = (1-R_1)(1-R_2) = (1-e^{-\lambda_1 t})(1-e^{-\lambda_2 t}) = 0.000136$$

**Reference(s)** 1) "Probabilistic Reliability: An Engineering Approach"  
Martin Shooman, McGraw-Hill.

2) HP-65 Owners Handbook

This program is a translation of the HP-65 Users' Library  
Program #05109A submitted by Ashok Doshi.

## COMPLETE KEYSTROKES FOR THE EXAMPLE

[f] [REG]	0.00	[Clear Registers]
[DSP] [6]		
1000 .	1000	[Input Time $t$ ]
[A]	1.00	
6 [EEX]	6. 00	
6	6. 06	
[CHS]	6. -06	[Input $\lambda_i$ ]
[B]	0.994018	[Intermediate $R_{ss}$ ]
23 [EEX]	23. 00	
6	23. 06	
[CHS]	23. -06	[Input $\lambda_i$ ]
[B]	0.971416	$[R_{ss} - \text{Reliability in series}]$
[C]	0.028584	$[Q_{ss} - \text{Unreliability in series}]$
6 [EEX]	6. 00	
6	6. 06	
[CHS]	6. -06	[Input $\lambda_i$ ]
[D]	0.005982	$[Q_{sp} - \text{Intermediate Unreliability in parallel}]$
23 [EEX]	23 00	
6	23 06	
[CHS]	23 -06	[Input $\lambda_i$ ]
[D]	0.000136	$[Q_{sp} - \text{Unreliability in parallel}]$
[E]	0.999864	$[R_{sp} - \text{Reliability in parallel}]$

# User Instructions

◀ 1 SYSTEMS RELIABILITY IN SERIES AND PARALLEL DIFFERENT λ

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R<sub>ss</sub>

988

$Q_{ST}$

R<sub>app</sub>

## 97 Program Listing I

## NOTES

## NOTES

## **NOTES**

## **Hewlett-Packard Software**

In terms of power and flexibility, the problem-solving potential of the Hewlett-Packard line of fully programmable calculators is nearly limitless. And in order to see the practical side of this potential, we have several different types of software to help save you time and programming effort. Every one of our software solutions has been carefully selected to effectively increase your problem-solving potential. Chances are, we already have the solutions you're looking for.

### **Application Pacs**

To increase the versatility of your fully programmable Hewlett-Packard calculator, HP has an extensive library of "Application Pacs". These programs transform your HP-67 and HP-97 into specialized calculators in seconds. Each program in a pac is fully documented with commented program listing, allowing the adoption of programming techniques useful to each application area. The pacs contain 20 or more programs in the form of prerecorded cards, a detailed manual, and a program card holder. Every Application Pac has been designed to extend the capabilities of our fully programmable models to increase your problem-solving potential.

You can choose from:

**Statistics**  
**Mathematics**  
**Electrical Engineering**  
**Business Decisions**  
**Clinical Lab and Nuclear Medicine**

**Mechanical Engineering**  
**Surveying**  
**Civil Engineering**  
**Navigation**  
**Games**

### **Users' Library**

The main objective of our Users' Library is dedicated to making selected program solutions contributed by our HP-67 and HP-97 users available to you. By subscribing to our Users' Library, you'll have at your fingertips, literally hundreds of different programs. No longer will you have to: research the application; program the solution; debug the program; or complete the documentation. Simply key your program to obtain your solution. In addition, programs from the library may be used as a source of programming techniques in your application area.

A one-year subscription to the Library costs \$9.00. You receive: a catalog of contributed programs; catalog updates; and coupons for three programs of your choice (a \$9.00 value).

### **Users' Library Solutions Books**

Hewlett-Packard recently added a unique problem-solving contribution to its existing software line. The new series of software solutions are a collection of programs provided by our programmable calculator users. Hewlett-Packard has currently accepted over 6,000 programs for our Users' Libraries. The best of these programs have been compiled into 40 Library Solutions Books covering 39 application areas (including two game books).

Each of the Books, containing up to 15 programs without cards, is priced at \$10.00, a savings of up to \$35.00 over single copy cost.

The Users' Library Solutions Books will compliment our other applications of software and provide you with a valuable new tool for program solutions.

**Options/Technical Stock Analysis**  
**Portfolio Management/Bonds & Notes**  
**Real Estate Investment**  
**Taxes**  
**Home Construction Estimating**  
**Marketing/Sales**  
**Home Management**  
**Small Business**  
**Antennas**  
**Butterworth and Chebyshev Filters**  
**Thermal and Transport Sciences**  
**EE (Lab)**  
**Industrial Engineering**  
**Aeronautical Engineering**  
**Control Systems**  
**Beams and Columns**  
**High-Level Math**  
**Test Statistics**  
**Geometry**  
**Reliability/QA**

**Medical Practitioner**  
**Anesthesia**  
**Cardiac**  
**Pulmonary**  
**Chemistry**  
**Optics**  
**Physics**  
**Earth Sciences**  
**Energy Conservation**  
**Space Science**  
**Biology**  
**Games**  
**Games of Chance**  
**Aircraft Operation**  
**Avigation**  
**Calendars**  
**Photo Dark Room**  
**COGO-Surveying**  
**Astrology**  
**Forestry**

## **RELIABILITY/QUALITY ASSURANCE**

Calculations related to reliability/quality assurance are included in this book, e.g., intra-class correlation, specific compliance, parameter estimation, lower limit and bounds of reliability, failure of serves, leak rate, maximum likelihood estimator, system reliability, distribution function, comparison of hazard models, etc.

**RELIABILITY: INTRA-CLASS CORRELATION**

**SPECIFICATION COMPLIANCE FROM LIMITS AND REGRESSION ANALYSIS**

**PARAMETER ESTIMATION (EXPONENTIAL DISTRIBUTION)**

**LOWER LIMIT OR RELIABILITY — BINOMIAL DISTRIBUTION**

**RELIABILITY AND PROBABILITY OF FAILURE OF SERIES AND PARALLEL SYSTEMS**

**MIL - STD - 883 CALCULATED LEAK RATE**

**MLE:  $\hat{\theta}$  FROM HAZARD RATE**

**MLE:  $\hat{\theta}$  BY LEAST SQUARE METHOD**

**SYSTEMS RELIABILITY-SERIES AND PARALLEL WITH SAME FAILURE RATE  $\lambda$**

**SYSTEMS RELIABILITY-SERIES AND PARALLEL WITH DIFFERENT FAILURE RATE  $\lambda$**

**HEWLETT  PACKARD**

**1000 N.E. Circle Blvd., Corvallis, OR 97330**

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