designing for reliability

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published by COMPONENT NEWS
November, 1976

RELIABILITY – CONCEPTS AND CAUSES

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V. Reliability Estimation

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I. WHY WE CARE

A. To maintain a long-term customer base by offering a good return on the customer's investment.

B. To minimize the direct cost of reliability to Tektronix.

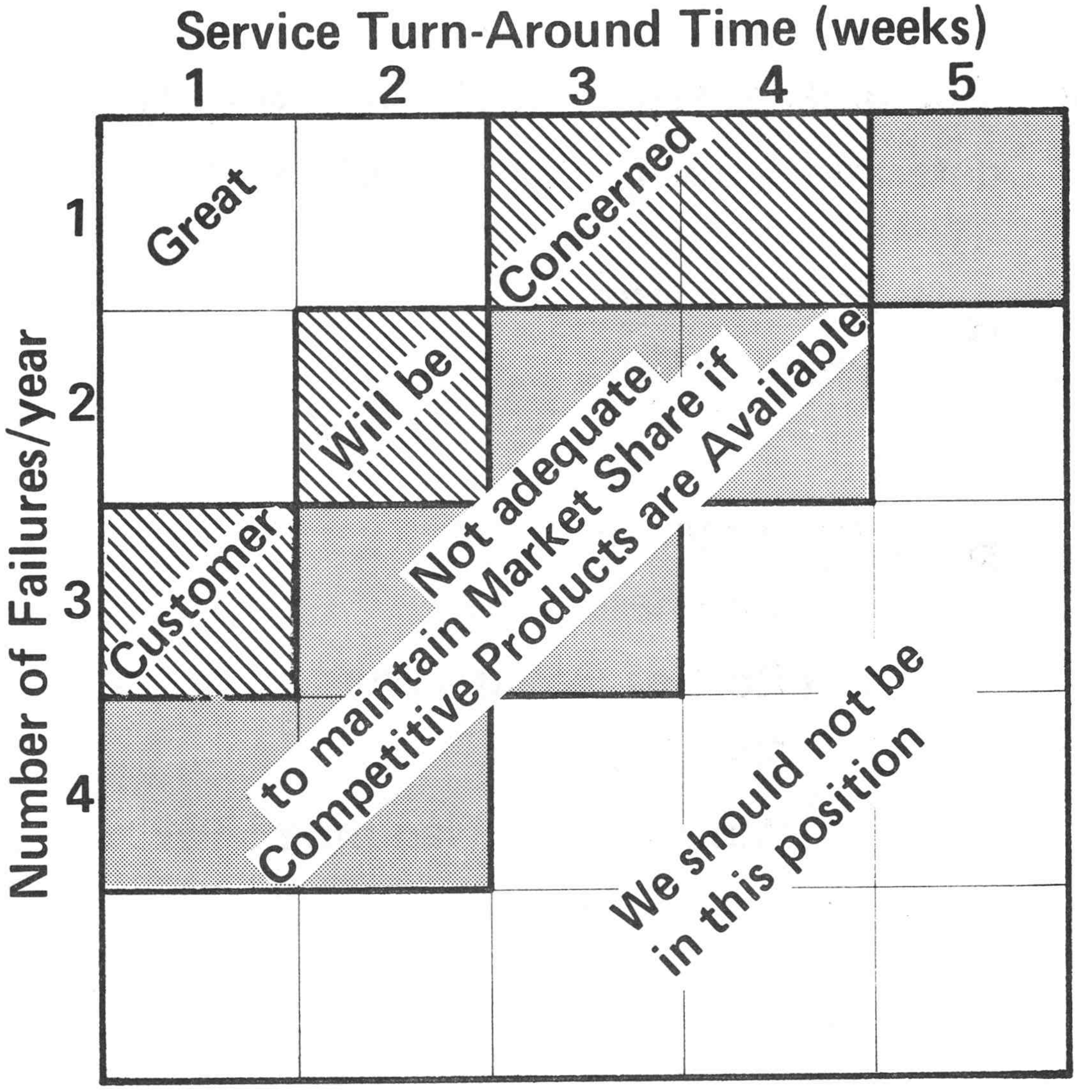
I. WHY WE CARE

A. Customer's Return On Investment (R_c) determines our future market share

$$R_c = \frac{\text{Product Use}}{\text{Product Cost}}$$

$$R_c = \frac{\text{Performance Value}}{\sum \left\{ \begin{array}{l} \text{Purchase Price} \\ \text{Cost of Down Time} \\ \text{Repair Cost} \\ \text{Paperwork \& Handling Cost} \end{array} \right.}$$

Customer Satisfaction is related to Failure Rate and speed of repair service



A possible relationship for one type of measurement system

I. WHY WE CARE

B. DIRECT COST OF RELIABILITY TO TEK

1. Cost of extra care in design (money & delay)
2. Cost of careful design evaluation
3. Cost of reliable components and materials
4. Cost of manufacturing tests, inspections and information monitoring
5. Cost of materials and labor for warranty repair
6. Cost for Marketing/Sales personnel to pacify irate customers
7. Cost of redesign for curing reliability problems

Example:

Service Cost for Lab Instrument Division

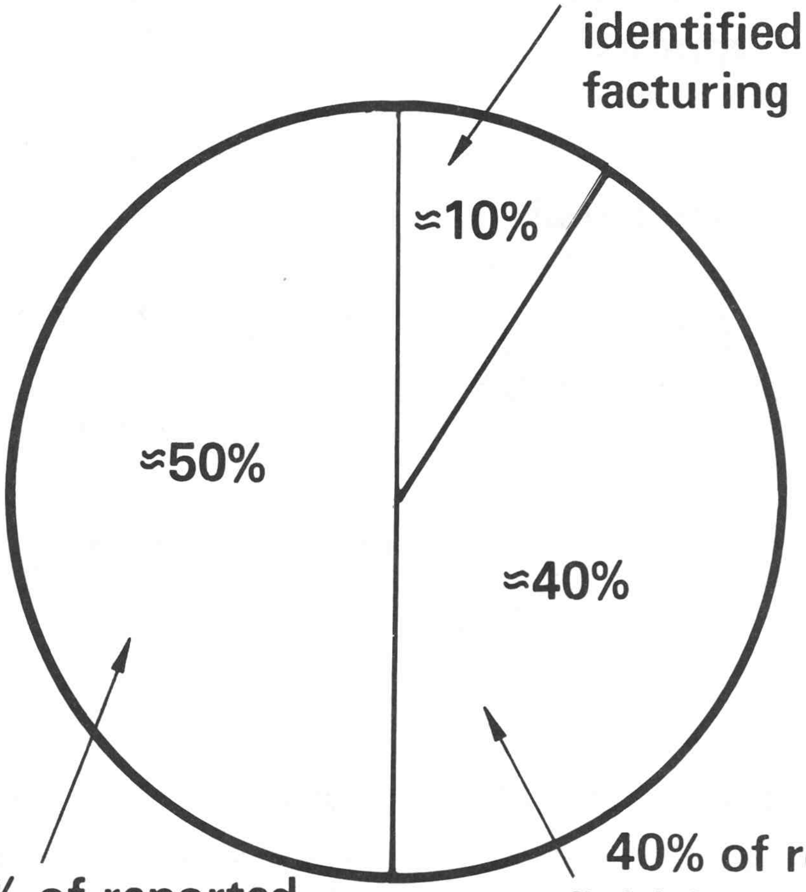
For Fiscal Year 600:

Identified Warranty Expense = $591,000
(≈1% of Sales)

Total Service Expense Charged— Including Overhead, paperwork, handling, demo repair, etc.
= $1,078,000
(≈2% of Sales)

II. DISTRIBUTION OF FAILURES

Distribution of Field Failures with respect to Reported Information



10% of reported field failures are identified as Manufacturing Related

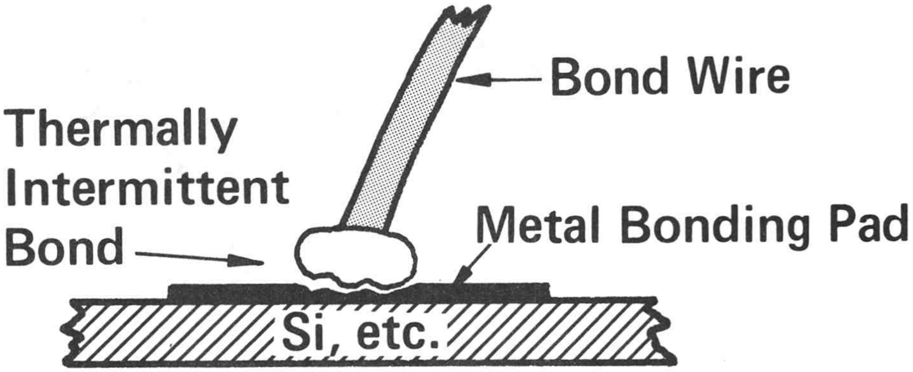
50% of reported field failures are related to certain common circuit locations.

40% of reported field failures are Randomly Located and not identified to cause.

III. CAUSES OF POOR RELIABILITY

A. Component/Materials Problems

1. Components with premature failure modes.



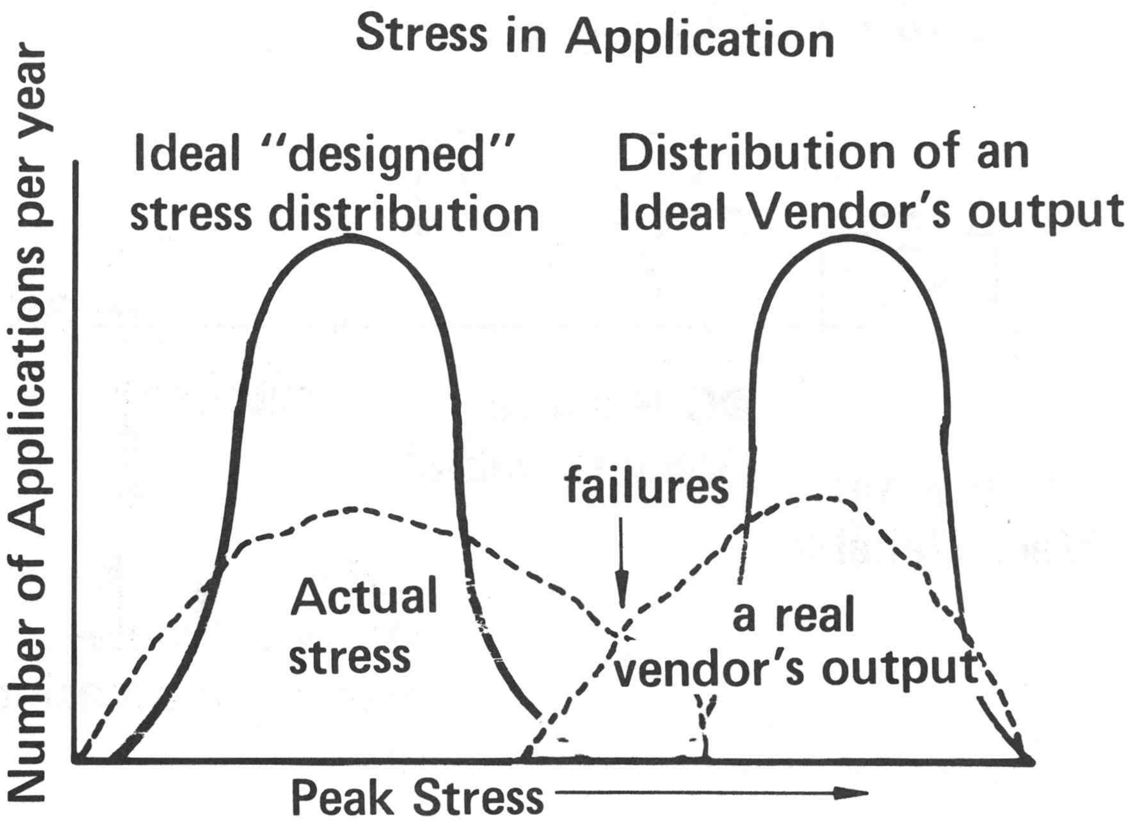
2. Out-of-spec or marginally adequate component performance.

These problems occur on a random basis, as batch problems, or on a relatively uniform basis, depending on the part number, application, vendor, and your ability to find and control the problems.

III. CAUSES OF POOR RELIABILITY

B. Design (Applications) Errors

1. Design Errors due to pressure in meeting proposed spec's or schedules.
2. A lack of adequate knowledge of component application stress levels vs component strength distribution.

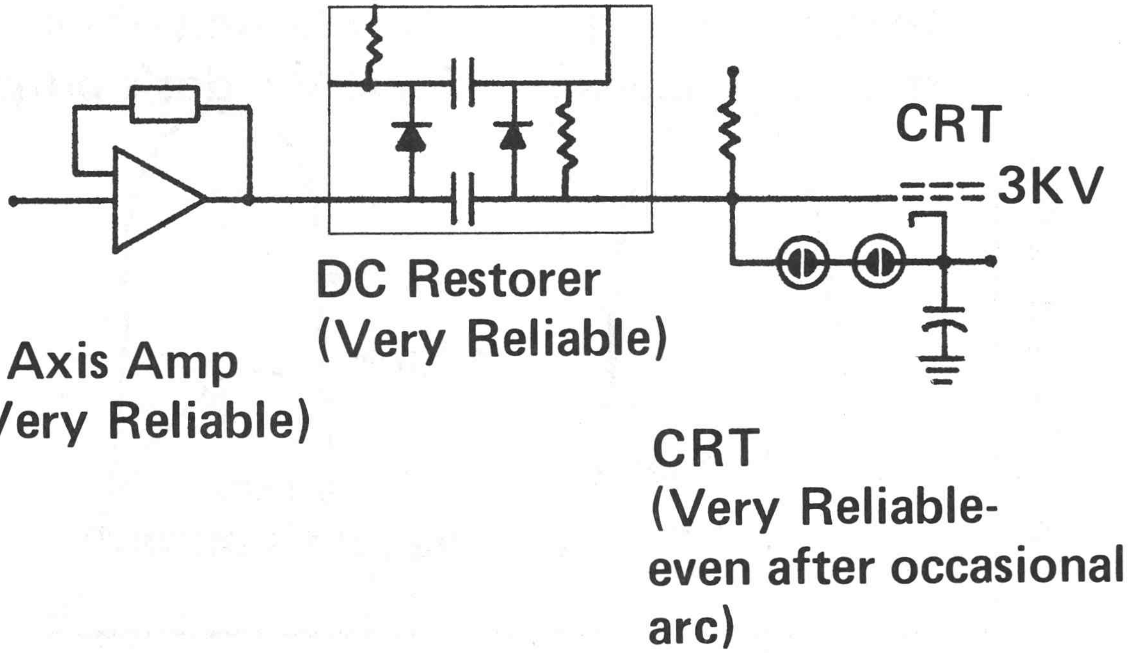


III. CAUSES OF POOR RELIABILITY

B. Design (Applications) Errors – Continued

3. Insufficient knowledge of non-obvious failure modes (as in tantalum slug capacitors)

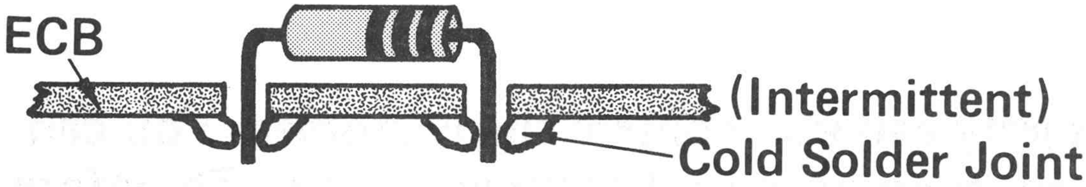
4. Un-anticipated "Negative Synergy" (The whole is worth less than the sum of the sub units)



III. CAUSES OF POOR RELIABILITY

C. Manufacturing Errors

1. <u>Poor Assembly</u> – loose hardware, bad soldering, wrong part, components touching, etc. (Often related to "buildability" of the design).
2. <u>Process Problems</u> – Bad plating, lack of part dimension control, poor flow soldering, cleaning, handling, etc.



Note: All of these problems exist due to the compromise of:

Inspection Efficiency vs Cost of Inspection vs Shortage and Scheduling Conflicts

III. CAUSES OF POOR RELIABILITY

D. Customer Abuse

1. What abuse will be normal?
2. What abuse will be abnormal, but will happen? (How often will these happen? How long will the customer loose use of his instrument? Will he seek another source for his next purchase?)

Rarely can you control the customer. You can only encourage or discourage abuse. Therefore one must either design to withstand abuses or plan to accommodate them.

IV. RELIABILITY TESTING & NOTATION

WHY: To know what is likely to happen in the field

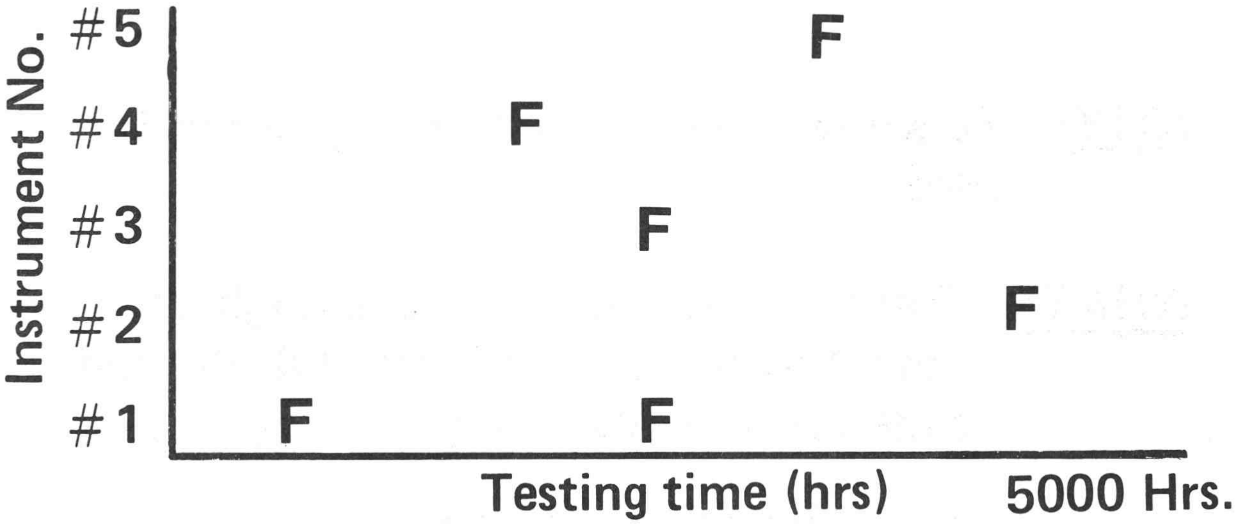
WHAT: Testing Instruments long enough to obtain instrument failures and running time for demonstrating:

1. Likely failure modes
2. The effects of the failures
3. The running time between failures

IV. RELIABILITY TESTING AND NOTATION

MTBF

The Mean of the Times (of operation) Between Failures



Total Instrument hrs = (5 ea) x (5000 hrs)
= 25000 Instrument hours

Total failures = 6

Exhibited MTBF = $\frac{(25000 \text{ Instrument hours})}{(6 \text{ Instrument failures})}$

MTBF Exhibited = <u>4167 hours</u>

IV. RELIABILITY TESTING AND NOTATION

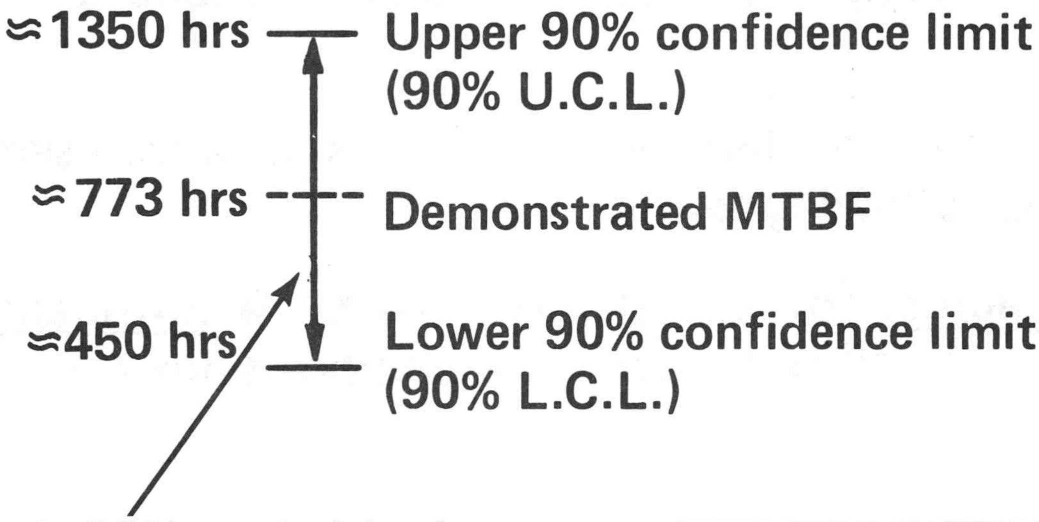
The Value of Exhibited MTBF

From a demonstrated or exhibited MTBF, it is possible to make statistical predictions of future failure rates. Certain assumptions must be made about the uniformity of manufacturing output vs the sample tested and the long-term failure rate.

The results of these estimations can be expressed in the following terms:

Probability (often expressed as a %) A confidence level defined as a set of limits (upper & lower).

example: 10 units, tested for 541 hours/ instrument, having a total of 7 failures might yield a 90% probability that future MTBF will be between 450 hours and 1350 hours.



It is <u>90% probable</u> that the average future MTBF will be in this band

10 units 541 hrs/ unit — 7 failures

IV. RELIABILITY TESTING AND NOTATION

ACCELERATION FACTORS

The adjustment factors which allow translation of data between environmental situations or stress levels.

example: An acceleration factor of 2.3 may be appropriate for translating failure rate in a 25°C ambient to failure rate in a 50°C ambient

$$\begin{array}{ll} \text{Component F.R. in 25°C ambient} = & 0.0032\%/1000 \text{ hr.} \\ & \underline{\quad \times 2.3 \quad} \\ \text{Component F.R. in 50°C ambient} = & .00736\%/1000 \text{ hr.} \end{array}$$

Some accelerating functions:

- Temperature
- Humidity
- Voltage (DC & AC)
- Current (DC & AC)
- Mechanical Force
- Humidity
- Particulate or Gaseous Contaminants

V. RELIABILITY ESTIMATIONS

The component failure rates can be adjusted via acceleration factors to compensate for the level of stress within the application, and then summed to obtain the overall system failure rate.

Currently, there are three commonly used sets of component failure rates at Tek:

1. MIL-HDBK-217B & MIL-R-26474 combined
2. MIL-R-26474
3. Tek/MIL-217B/RADC, Vol II

#1 and #2 can easily be performed with a canned program on the Cyber computer. #3 can be done manually in a few minutes, using forms available from Reliability Test Department.

Ranges of Commonly Used Component Failure Rates

Component Category	Approx. Failure Rate/ 1000 hr.
Digital IC's Purchased Digital IC's Tekmade Linear IC's Purchased Linear IC's Tekmade	.00084 to .0028
Bi-polar transistors	.00039 to .002
FET's	to .002
Diodes (incl. Zeners)	.0002 to .002
Multilayer ECB's	to .0003
2-layer ECB's	to .00001
Variable Resistors	.0006 to .0015
Resistors	.00002 to .0005
Capacitors	.0001 to .0005
Relay	.0007 to .015
Transformers/ Inductors	.0002 to .0005
Connectors/Sockets	.000324 to .0005
Switches	.000310 to .0045
CRT/tubes	.0065 to .03
Fan Motor	.015 to .063
"Misc Parts"	.0005 to .002

Failure Rate and MTBF estimation for the T-912 Oscilloscope *

ITEM	Total Number	Average Failure Rate/k-hr.	Total # times F.R.	Total # times F.R. (General)
IC's Linear Tek.		0.003500		-------
IC's Digital Tek.		0.001000		-------
IC's Linear Non-Tek.		0.002520		-------
IC's Digital Non-Tek.	6	0.000840	0.0151	-------
** (IC's General)	-------	(0.000975)	-------	
Transistors Si. Analog	66	0.001280	0.0845	-------
Transistors Si. Digital		0.000390		-------
** (Transistors- General)		(0.001000)	------	
Diodes Power	19	0.001100	0.0209	-------
Diodes Logic		0.000230		-------
** (Diodes - General)	63	(0.000500)	------	
Relays		0.000720		
Resistors - General	355	0.000020	0.0071	
Capacitors - General	136	0.000100	0.0136	
Transformers or Inductors	6	0.000200	0.0012	
Connectors / Sockets	10	0.000324	0.0032	
Switches	15	0.000310	0.0049	
CRT / Tubes	1	0.006500	0.0065	
Motors / Fans	1 .	0.063000	0.063	
Adjustments ---Internal-- Var.	38	0.001500	0.057	
Batteries		0.007000		
Hybrid Circuits (Res. networks, et		0.000050		
All Other / Misc. Parts	5	0.000100	0.005	
Potentiometers	26	0.000600	0.0156	
	TOTALS	**0.3246/1000 hrs.**		

$$\text{MTBF} = \frac{1000\ \text{hrs}}{0.3246} = 3080\ \text{hrs MTBF}$$

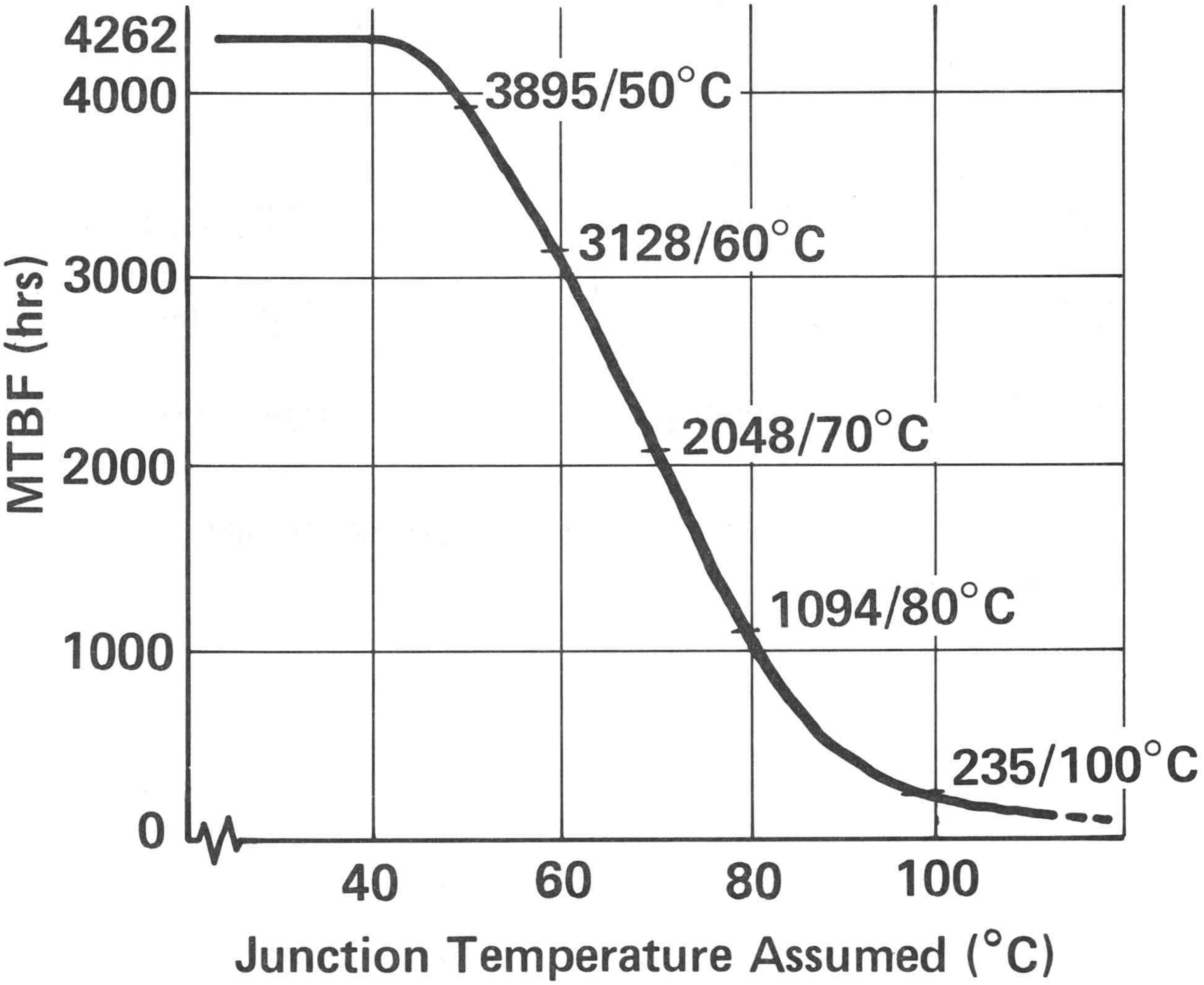
* Tek/MIL-217B/RADC, Vol II

Comparison of T-912 estimated MTBF, using three common methods

1.	MIL-HDBK-217B/ MIL-R-26474 Comb (60°C)*	3128 hrs.
2.	MIL-R-26474	1591 hrs.
3.	Tek/MIL-2173/RADC, Vol II	3080 hrs.

*Assuming 60°C junction temperature on all semiconductors

Predicted Variation of T-912 MTBF with Assumed Semiconductor Junction Temperature



MTBF, as per MIL-HDBK-217B and MIL-R-26474 Combined

Assuring reliability of new products

This section contains guidelines, checklists and other information to assist design engineers in a systematic method to meet product reliability goals. More specifically, this information pertains to the problems of designing and planning for reliability during the Design Phase, A Phase and B Phase of the New Product Introduction Cycle.

There are several reasons why a systematic approach in designing a product to meet its reliability goals is needed. These are:

1. We don't normally know how reliable a product line is until many of the products have been in use by customers for some time.
2. Because of the above reason, many of our good intentions regarding reliability get squeezed out when trying to meet other goals, such as development schedule, instrument cost, performance, or manufacturing convenience.
3. To achieve the desired level of product reliability requires attention to many little details in every aspect of product design. There is no simple or all encompassing thing to do, that, by itself, will achieve the desired level of product reliability.

This section includes:

I. Key Reliability Activities Chart
II. Buildability Considerations for New Product Design
III. Reliability Prediction Form
IV. Reliability Prediction Program (—RELY)
V. Failure Analysis Request Form

Some of these materials may only have a limited use within Tektronix at this time. Any feedback on the effectiveness or value of this information would be appreciated and will help in making our future products provide greater customer satisfaction and corporate profits.

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ext. 5710 (50-435)

Key Reliability Activities During Engineering Development

A. Use guidelines to avoid applications problems and previous mistakes of other projects

B. Evaluate the design

C. Predict if product will meet the Reliability Goal

D. Perform Failure Mode and Effect Analysis

E. Perform Environmental Tests

F. Set Reliability/Quality Subgoals on Components and Processes

G. Control Risk of Critical Areas and factors

H. Measure Reliability to see if you are making the goal

I. Develop manufacturing plan (to ensure Reliability/Quality)

J. Develop field support and failure feedback plan

	When				Who Does It				Who Sees It Gets Done			Who Reviews & Critiques			
	Concept φ	Design φ	Eval. Aφ	Proto. Bφ	Elect. Des. Engr.	Mech. Des. Engr.	Project Leader	Prod. Eval. Engr.	Project Leader	Mfg. Mgr.		Project Leader	Product Eval.	Div. Rel. Engr.	
I. Engineering Development Activities															
A. Guidelines for Design & Component Application															
1. List all components for which specs & application information are desirable (over and above Tek catalog specs) Examples: ECL, TTL & CMOS IC's OP Amp IC's Power transistors Filter capacitors Reed relays LED readout Switches (Purchased & Tekmade) Batteries	←	—	—	→	★	★	★	★	★			★	★	★	
2. Use the following guidelines and application notes and others as appropriate.	←	—	—	→	★	★		★	★				★	★	
a. Device Deratings for Tektronix Design, (revised June, 1976) (call ext. 6867.)					★										
b. Tektronix Design Parts Catalogs					★	★									
c. Tektronix specs on components Purchased & Tekmade					★	★									
d. Instrument Buildability Guidelines					★	★									
e. Circuit board design standards					★	★									
f. Mechanical Design Standards						★									
g. Specific Technologies (e.g. Fairchild, TTL Applications Handbook, GE Sub-Miniature Lamp Catalog.)					★	★									
B. Evaluation															
1. Contact following and request evaluation or technical assistance.							★						★	★	
a. Product Evaluation for your division - electrical	←	→			★	★									
- mechanical	←	→			★	★									
b. Reliability Engineer for your division	★				★	★									
c. Component Applications Eng. (and Comp. Eval. Eng.)	←	★ →			★	★									
d. Tekmade Component Engineers (Good part? Proper application?)	←	→			★	★									
e. Manufacturing liason for Tekmade Parts. (e.g. Circuit boards, Metal Parts, Plastics)		←	→		★	★									

	When				Who Does It				Who Sees It Gets Done			Who Reviews & Critiques			
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f. Assembly Line Manager (buildability).	★				★	★									
g. Manufacturing Staff Engineer (overall evaluation including buildability, test, past problems.)		★			★	★									
h. Service Support (Servicibility, support plan, past reliabilty/ service problems)		★					★								
i. Environmental Test (Humidity, EMI, etc.)		★			★	★		★							
j. Reliability Test (Instrument Reliability Test Plan)		★					★	★							
2. Provide briefing(s) on the instrument to people involved in Evaluation and Support.	←	→			★	★			★						
3. Plan specific evaluation activities and forecast requirements for instrument, materials, manpower. Provide to project leader so that resources will be available when needed. Note: Component Application Engineer needs: a. Schematics, copies in each phase b. Parts list (same) c. EIS, 1 copy in each phase d. Aφ instrument 3 days to 1 week e. Bφ instrument 2 days	←	→			Groups Evaluating				★			★	★	★	
4. Evaluate product and provide comments to project leader.	←			→	Groups Evaluating				★			★	★	★	
C. <u>Predict Product Reliabiltiy</u>					★			★	★				★	★	
1. By transistor/IC count.	★														
2. By parts count.	←			→											
3. By stress level	←			→											
D. <u>Failure Mode and Effect Analysis and Testing</u> Examples: Shorts on or between power supplies Excessive input voltage causing breakdown Power line voltage surges or wrong voltage applied Power supply failure — going high	←			→	★	★		★	★			★	★	★	
E. <u>Perform Environmental Tests</u> Measure internal temperatures Performance vs. temperature		←		→	★	★		★				★	★	★	

Humidity, Altitude
Vibration, shock, bench handling
Transportation Package

	When				Who Does It				Who Sees It Gets Done			Who Reviews & Critiques			
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F. Set reliability/quality subgoals on subassemblies, components and processes, considering product reliability goal and predictions. Convey to suppliers and others involved.	←	→			★	★	★		★				★	★	
G. Control risk of critical areas 1. Identify and list critical areas (components, designs and manufacturing processes whose impact on reliability is adverse or unknown). Groups doing evaluation (Part B above) should contribute to list.	←	→	- -	- -	★	★		★	★			★	★	★	
2. Assign responsibility for each critical area.	←	→	- -	- -			★								
3. For each complex critical area, a. Develop a plan to: assess reliability meet reliability goal assess cost of meeting goal monitor progress in development (performance, reliability, cost, schedule) b. Get approval c. Implement Plan	←	→	- -	- -	Designated Persons				★				★	★	
4. Control costs and schedule a. The cost or schedule delays in meeting a particular reliability sub goal may be out of proportion to to the benefit received. It may be desirable to relax a particular sub goal and tighten up on others.	←	—	—	→			★							★	
H. Measure Reliability Performance 1. Plan reliability test parameters for each group of instruments being tested.		←	→				★	★	★					★	
2. Identify required peripheral equipment. Provide if necessary.		←	→	- -			★	★	★						
3. Conduct tests. Report failures, write and distribute summary report (except #10).			←	→	Reliab. Test Group				★				★	★	
4. Assist in initial data recording if requested.			←	→	★			★	★						

	When				Who Does It				Who Sees It Gets Done			Who Reviews & Critiques			
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5. React to failures reported a. Assist in troubleshooting b. Analyze failures for cause and request component failure analysis. c. Interpret results and take corrective action.					★	★		★	★					★	
Interpret results regarding meeting product reliability goal and take corrective action.					★	★		★	★					★	
6. Provide two Aφ instruments fully calibrated.			★		★			★	★					★	
7. Provide five Bφ instruments fully calibrated.				★	★			★	★					★	
8. Provide 10 late pilot instruments fully calibrated for Quality Audit and Reliability Audit Test (500 hrs resaleable).		Pilot			Supplied by Mfg. Test by Reliab. Test					★		★	★	★	
9. Continue running 3 to 5 of above instruments for long term test (non-saleable optional depending on extent of changes from Bφ to pilot and results of previous tests.		Pilot								★		★	★	★	
10. 200 hrs. test of first 10 pilot instruments in manufacturing cycle chamber — before any instruments are shipped.												★	★	★	
a. Plan test, data recording.				★	Mfg. & Engr.					★		★		★	
b. Conduct tests, report failures, write and distribute summary report.		1st Pilot			Mfg.					★		★	★	★	
c. Plan 200 hr. test into product availability schedule.	←→	- - -	- - -	- - -	Mfg. Mgr.					★		★	★	★	
I. <u>Develop the Manufacturing Plan to control Quality and Reliability</u>. consider:	←→	- - -	- - -	- - -	Mfg. Mgr.					★		★	★	★	
1. Assembly, Test and Inspection Processes.															
2. Quality Control and screening for incoming components (Purchased and Tekmade).															
3. Instrument Burn-In.															
4. Outgoing Quality Monitoring.															
5. Special control over processes new to the assembly line.															

	When				Who Does It				Who Sees It Gets Done			Who Reviews & Critiques			
	Concept φ	Design φ	Eval. Aφ	Proto. Bφ	Elect. Des. Engr.	Mech. Des. Engr.	Project Leader	Prod. Eval. Engr.	Project Leader	Mfg. Mgr.		Project Leader	Product Eval.	Div. Rel. Engr.	
J. <u>Develop the Field Support Plan.</u> Plan for: Service locations Test equipment required Spare parts in service center available Information package to service centers Review manual for adequacy for: Service information User information to prevent abuse Plan for special failure feedback from selected locations if necessary.	←	→	- - -	- - -	Service Support				★			★	★	★	

Notes

BUILDABILITY CONSIDERATIONS
FOR NEW PRODUCT DESIGN

The following suggested guidelines for new product design were developed by Tim Ruvo, TM500 Manufacturing, and George Kolibaba, 200 Series Oscilloscope Manufacturing. These suggestions cover four areas:

A. Etched Circuit Boards
B. Assembly (Mechanical)
C. Electrical Test and Calibration
D. Costs

These suggestions may not be directly applicable to all product lines. However, if followed as much as possible, the buildability of an instrument will be better, resulting in lower manufacturing cost and fewer quality problems facing the proud owner of a Tektronix product.

PART A: ETCHED CIRCUIT BOARDS

1. **Use Machine Insertion** — The more machine-insertable components used, the better. The cost of Kit Prep and hand insertion is high, especially if there are stand-up components.
2. **Complete and Washable** — Completed boards should be able to go through Freon or detergent wash.
3. **One Operation Cycle** — One stage build saves processes and time. Good example: A machine inserted board may first go to solder flow, then to the builder for hand adds and clipping, then final wash. Bad example: Board goes to builder for hand insertion, then to flow solder, back to builder for hand adds and clipping, then back to wash. This later method creates additional in-process steps, labor and inventory.
4. **Spacing** — Allow enough space to provide clearance between the crimped ends of machine-inserted parts and the runs on the circuit board.
5. **No Backside Components** — Flow solder can be utilized if we keep parts off the back of boards.
6. **Component Size Variance** — Component sizes vary with different manufacturers and lot dates. This causes problems with available space on the circuit board. Beware of designing circuit boards around the parts found in Engineering Stock. Consult the component specification for worst-case physical dimensions.
7. **Wires With or Without Connectors** — Wires with crimped-on connectors tend to be intermittent, (reason is builder quality out of the prep area). The problem runs in cycles; wires tend to break off near the connection because the wires are knicked in striping. Again a cable area quality problem that runs in cycles. The best solution is to eliminate both types of connections.
8. **Berg System** — Present Berg system is intermittent and expensive. Also difficult to use, sometimes you don't mate the connectors and don't realize it. We use a lot of gold in our connector systems. Gold is costly, and we have high insertion force systems without gold that may be as good in many applications.
9. **Direction of Components** — If parts (resistor groups) and especially IC's are lined up correctly, solder flow bridging problems will be reduced. Also, with our new solder flow machines, the board dimensions are a factor. The two longest sides should be straight with no or very little routed outer edge. This is to provide the belt fingers a surface to grab.
10. **UL** — UL consideration on board spacings are a must and also aid the general buildability and production quality.
11. **Test Points** — Test points are a good convenience for troubleshooting, providing there is good electrical clearance around them.
12. **Mylar Here and There** — Mylar slapped on the instrument to prevent shorting problems is not cheap to do, and it cheapens the appearance of the scope.

13. **Multi Layers are a Mess** — Inner layer boards have always been a problem; either the design layout has errors or the ECB manufacturing area makes errors. This has been true on every instrument with multilayer boards that we have been associated with.
14. **Garbage Compacting** — The large numbers of parts with no clearance is a problem on TM500 and 200 Series boards. We have solder bridging, broken parts, missing parts and other problems. These cause additional cost and impacts reliability.
15. **Stay Away from Edges** — Parts on edge of the board that the solder machine engages should have their body .125" from the edge of the board.
16. **Smaller Pads and Holes** — Size of pads should be decreased when possible so as to avoid bridging.
17. **Board layout will make or break you — in production.**

PART B: ASSEMBLY (MECHANICAL)

1. **Don't Disassemble to Complete** — You should not have to partially disassemble a scope that is calibrated to put on a case or cabinet.
2. **Cabling is not a Chassis** — Cabling is not something that holds the instrument together. Either a strong connector system should be used or a chassis device.
3. **Connectors should be Quick and Accurate** — Interboard connecting pins should all be located in the same area to make it easier to align all the pins and sockets simultaneously. Connectors for cables should be arranged and marked to prevent reversed or interchanged connectors.
4. **CRT Alignment** — CRT alignment with the face of the scope should be adjustable.
5. **Tolerance Build-Up** — Tolerance build-up from one part to three parts or more should be avoided so there is zero chance of interference fit.
6. **Lettering on Round or Drum Knobs** — Lettering printed on the round surface of knobs is expensive, difficult, and results in very poor quality.
7. **Printing Recessed Areas** — Printing on recessed areas is difficult (e.g. 200 Series side panel). A flat, insertable printed panel would be better.
8. **Printing on Top of Knobs** — Marking the function on top (or front) of a knob is expensive in operation and also in maintaining so many part numbers.
9. **Do Not Create a Garbage Compactor** — Too much in one package creates field reliability problems, particularly when a customer puts the instrument back together. Even our own field service centers have problems in repairing a scope they have never seen. A scope should fall back together.
10. **Flip Top Box** — A case design for easy removal of one portion to allow calibration while the scope is still in one chunk is desirable.
11. **Shake and Make** — A Field Engineer should be able to case an instrument the first time without a shoe horn, and have it work when he turns it on.There should be no problems with connectors coming loose or parts being knocked loose during installation of the cabinet.
12. **Material Strength** — Sometimes the plastic selected for a particular application may not be resistant enough to impact, particularly at cold temperatures, or may have some other unknown problem. Complete evaluation of parts and materials is necessary.
13. **Latches are going to be used** — Latching mechanisms are going to be cycled many times. That is the purpose for using them. Thorough evaluation needs to be done on any latching system. Expect abuse by the customer to be routine.
14. **Shaft Extension can rub you wrong** — Extending a control to the front panel can be very tricky. The mounting of the control that is to be extended is very critical. Extending a shaft often makes component and board alignment more critical.
15. **"Why Use Something Old"** — The more times an existing part or assembly can be used in new designs, the better the profit and quality of the product. New designed parts result in additional cost from tooling, setting up a new part number, and re-design because it doesn't quite work the first time. An established part has established a known quality level and cost.

PART C: ELECTRICAL TEST & CALIBRATION

1. **Tweek it like it will be shipped** — Calibration of the instrument is more accurate if all shields and parts can be left in place during calibration.
2. **All Non-Related Tweeks** — Interacting tweeks cause confusion and take costly time.
3. **No Tweeks** — Tweeking is costly, just set up and turn the pot.
4. **Manufacturing is Not a Component Selection Group** — Playing games to find a part that will work in each scope is very time consuming and costly.
5. **No Marginal Specs** — Marginal specs will eventually always go to the wrong side of the margin. We need "room" to assure speed in manufacturing accuracy in calibration and reliability.
6. **Reduce Special Test Equipment** — Special test equipment means cost to purchase or build additional training and probably special steps in calibration.
7. **Optimum Range on Tweeks** — Tweeks that run out of range or that are too touchy (too much range) are difficult to use.
8. **A Pre-Test Method** — An effective pre-testing method for boards and assemblies can save much time. However, the machines we have used so far have problems in connecting reliably to the board under test.
9. **Circuit Numbers** — Circuit numbers on the board speed-up trouble shooting.
10. **Isolation of Bad Circuits** — If one part, strap or connector could be lifted to isolate a circuit, trouble shooting could proceed more quickly.
11. **Test Points** — Test points give specific check points to refer to in calibration and checkout procedures. However, make sure there is plenty of clearance around the test point to prevent shorting to transistor metal cans, etc. when connecting probes.
12. **Access** — The instrument must leave critical points easily accessible for tweeking or testing.

PART D: COSTS

1. **IC's are Quick** — You can insert one IC in the time it takes to insert two transistors.
2. **So are Substrates** — You can insert one substrate in the time it takes to insert one resistor.
3. **Cheap Parts Cost More** — Some of the hand add, inexpensive pots that we use take a special hand cleaning process — a cost of 50¢ per pot. The in-plant and field failure rate is so high we are spending an equivalent of 20¢ more per pot installed in replacement. This inexpensive part is costing us a total of 70¢ extra per pot. A more expensive, sealed, and electrically better pot would certainly be an improvement.
4. **KISS (Keep it super simple)** — Labor rate is affected by the type of labor needed to perform a job, i.e.: Range 8 technicians can exchange parts in sockets, but Range 10 technicians would be used to narrow down to the exact part to unsolder and replace parts not in sockets.
5. **It Costs to Touch** — A single large board will be less expensive than two or three small boards. Each additional board creates another part number, additional tooling, and a whole series of handling steps. There is a basic amount of time for each board just for handling that is not affected by board size.

RELIABILITY PREDICTION

Used by Reliability Test Group

Inst. Type ____________ **Date** ____________ **Effective--** June 16,1976

By parts population and failure rates according to Tek., MIL-217B, and R.A.D.C. Vol. II data.

ITEM	Total Number	Average Failure Rate/k-hr.	Total # times F.R.	Total # times F.R. (General)
IC's Linear Tek.		0.003500		-------
IC's Digital Tek.		0.001000		-------
IC's Linear Non-Tek.		0.002520		-------
IC's Digital Non-Tek.		0.000840		-------
** (IC's General)		(0.000975)	-------	
Transistors Si. Analog		0.001280		-------
Transistors Si. Digital		0.000390		-------
** (Transistors- General)		(0.001000)	------	
Diodes Power		0.001100		-------
Diodes Logic		0.000230		-------
** (Diodes - General)		(0.000500)	------	
Relays		0.000720		
Resistors - General		0.000020		
Capacitors - General		0.000100		
Transformers or Inductors		0.000200		
Connectors / Sockets		0.000324		
Switches		0.000310		
CRT / Tubes		0.006500		
Motors / Fans		0.063000		
Adjustments ---Internal-- Var.		0.001500		
Batteries		0.007000		
Hybrid Circuits (Res. networks, etc		0.000050		
All Other / Misc. Parts		0.000100		
Potentiometers		0.000600		
		TOTALS		

ITEM	Number
Resistors - Variable	
Capacitors- Variable	
Inductors - Variable	

Summary

MTBF	
LAMBDA	

** Use this listing only when it is not possible to differentiate linear from digital components.

Prepared By ______________________________

RELIABILITY PREDICTION PROGRAM

COMPONENT NEWS Reprints

These reprints describe the function and use of the reliability prediction program (-RELY) available on the CYBER system. Though some information in the earliest article is no longer timely, it describes the original development of this program.

Articles reprinted are:		
	"Failure Rate Model Added To 'RELY' Program"	May 21, 1976
	"Reliability Prediction Program Updated"	April 27, 1976
	"High Parts Count Affects Reliability"	September 9, 1975

Failure rate model added to 'RELY' program

The previous issue of **Component News** (No. 231) described the updating of a computer program for MTBF prediction by parts count. Additional changes have been made to the program (RELY) as follows:

★The category for connections, hand soldered has been replaced by variable resistors. This is due to the differences in relative significance of contribution to the total failure rate.

★The option which lists components by category and quantity now also lists total failure rate (λ) by part category so that the relative contributions may be observed.

★A feature for calculating the failure rates of bipolar transistors as a function of junction temperature and voltage stress level has been included and is described below.

Part of the RELY program provides parts count MTBF prediction based on MIL-HDBK-217B. Since 217B does not provide base failure rates for plastic-encapsulated semiconductors (which comprise the bulk of Tek usage), base failure rates used by the 217B part of the program were derived from average Tek field experience data. These derived rates were compared to failure rates developed in extensive reliability tests of plastic semiconductors by several other users and were found to be in general agreement.

basis of failure rate model

The basis of the failure rate dependence model is not rigorously mathematical, but rather heuristic. The failure rate of bipolar transistors is assumed to be:

$$F = \lambda_b (F_{VCE} \times F_{TJ})$$

where F = failure rate under high stress conditions
λ_b = base failure rate
F_{VCE} = modifying factor for voltage stress
F_{TJ} = modifying factor for junction temp.

The voltage stress ratio is defined as the percentage ratio of operating collector-emitter voltage to rated collector-emitter voltage. The model for dependence of failure rate on voltage stress is based on MIL-HDBK-217B.

The failure rate dependence on junction temperature is based on the Arrhenius Model. This model assumes:

★That performance degradation is a linear function of time and that the degradation rate depends on stress level only.

★The log of the degradation ratio yields a linear function of the reciprocal of absolute temperature.

In a thermally accelerated physical process, the process rate is dependent on temperature according to the Arrhenius equation:

$$R = R_o \exp\left(- \frac{E_A}{kT_K}\right)$$

where R = reaction rate
R_o = a constant
E_A = activation energy in eV
k = Bultzman's constant (8.6×10^{-5} eV/K)
T_K = absolute temp. in Kelvin

continued

Thus, the acceleration factor (AF) for the failure rate is:

$$AF = \exp \frac{E_A}{k}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Where T_1 is the test temperature (or reference temperature) and T_2 is the desired temperature in degrees in Kelvin.

Figure 1 at right shows this factor normalized to a failure rate of 1 at 60°C junction temperature. Also shown is the effect of voltage stress. The activation energy used for this plot was 1.0 eV, a factor widely accepted for bipolar transistor time-temperature degradation.

validity of Arrhenius model

The validity of this model is widely accepted for hermetically-sealed transistors. Field experience of over 10^9 device-hours accumulated by the Bell System under known field conditions confirmed the model's applicability.

However, application of this model to plastic transistors is not so widely accepted. This is due to the addition of another variable, humidity. As yet there is no generally agreed upon model to relate high stress conditions of temperature and humidity (e.g. 85°C, 85% R.H.) to lower stress conditions. However, several researchers claim the Arrhenius model does apply when high humidity is not a factor.

A series of accelerated high temperature tests is now being conducted by Component Reliability Engineering on plastic and metal can transistors (same chip inside both) to verify these relationships.

other factors affecting transistor failure rates

Transistor failure rates are dependent on many factors other than voltage stress level and junction temperature. It may well be that these other factors more strongly affect the part failure rate than the voltage or temperature stress. Some of these factors are:

★Circuit designs which depend on typical or unspecified parameters for proper operation, also circuit designs which did not anticipate component parameter distributions.

★Effects of thermomechanical cycling stress, such as in a sweep circuit.

★Inadequate circuit characterization at high and low temperature.

★Safe operation area/second breakdown phenomena

★Susceptibility to burn-out by transients.

★User-induced failure.

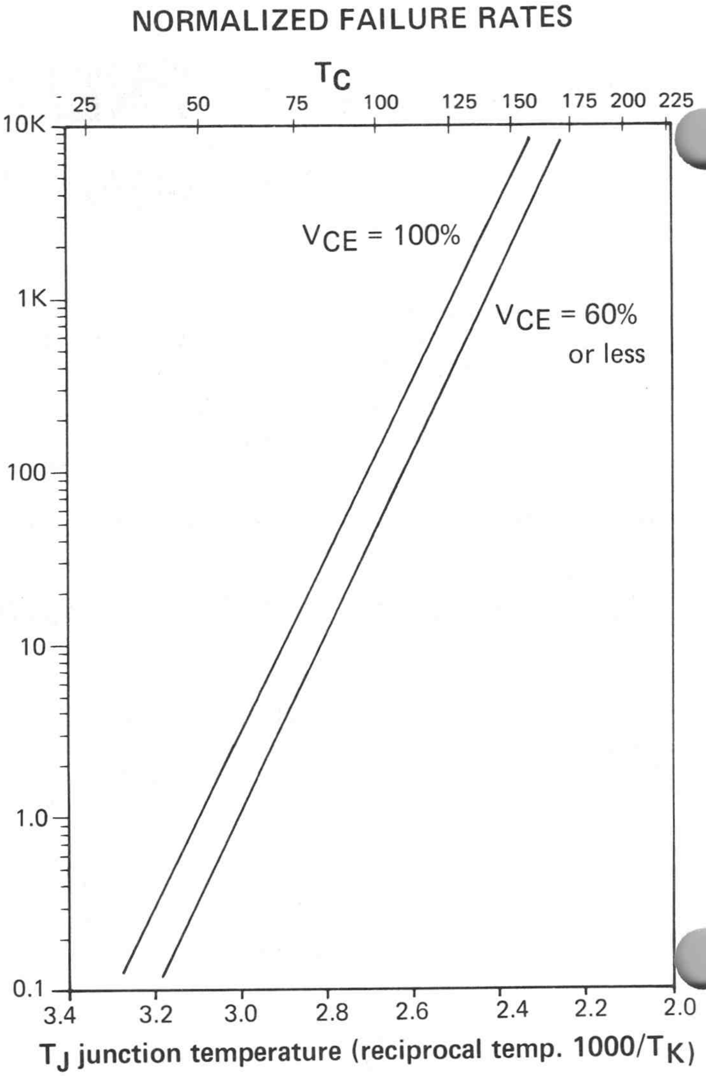

Figure 1 — Failure rate acceleration factors normalized to a failure rate of 1 at 60°C junction temperature. Effects of transistor voltage stress are indicated by the two lines for 100% and 60% voltage stress levels. For microcircuit acceleration factors, use the 60% line.

program use

The RELY program will now calculate failure rates of bipolar transistors under high stress conditions by entering the number of high stress transistors and the junction temperature and voltage stress ratio applicable to each or all of them. The program may be accessed on the CYBER system by logging on and typing:

```
OLD,RELY/UN=ACA0RAS
–RELY
```

Arrhenius model for IC's

The same Arrhenius relationship described above is also applicable to integrated circuits with the same assumptions as previously stated. A program capability for IC failure rate dependence (on temperature only) is now in preparation and will be included in the program soon.

RELIABILITY PREDICTION PROGRAM UPDATED

A computer program for instrument reliability prediction by parts count was described in Issue 221 of **Component News** by Tom Clark. This program has now been updated and effective April 26, 1976 will be available on the CYBER System by entering the following commands:

```
OLD,RELY/UN=ACA0RAS
-RELY
```

Note that the user number has been changed; after the above date, the program cannot be accessed using the previous (ACE0TRC) user number.

Several changes have been made to update the program. The old "RADC" failure rates (which were taken from the RADC Reliability Notebook, 1968) have been replaced by MIL-HDBK-217B generic failure rates (Sept 1974). Also, the categorization of parts has been modified to include all applicable categories listed in 217B.

New categories and a description of their use are shown below.

These changes have been made to reflect a more accurate distribution of failure contributions by category than was available using the old "RADC" or MIL-R-26474 failure rates.

While the MIL-R-26474 failure rates have often yielded a reliability prediction which approximates demonstrated reliability, the distribution of failure contribution by category is not accurate. For example, for a typical instrument, the MIL-R-26474 method predicts over 24% of the failure contribution attributable to diodes, while the 217B (or Tek field experience) would show less than 2%.

The reliability prediction figure (MTBF) arising from 217B will generally be 25 to 50% higher than the MTBF calculated using MIL-R-26474. Since some Tek instruments have demonstrated a much higher reliability than that predicted by 26474, it could be postulated that the MIL-R-26474 may be accurate for early production instruments while the 217B may represent the ultimate MTBF for mature instruments.

New categories for instrument reliability prediction program

MOS/LSI/Memory	Includes MOS RAM's, ROM's, and LSI Logic
Multi-Layer Boards	Each separate board should be counted
Two-Sided Boards	Each separate board should be counted
Connections, hand solder	Estimate number of hand soldered connections external to PC board

High parts count affects reliability

One of the greatest detriments to instrument reliability is a high parts count. Regardless of steps taken to ensure high product reliability, such as conservative stress levels on all components, a high parts count can set an upper bound on reliability that can't be changed significantly by other good design practices.

Moreover, a high parts count directly affects both heat and workmanship problems.

In order to enable designers and evaluators to get a handle on parts population effects early in the design phase of an instrument, a program was written for the CDC computer to make quick and easy reliability predictions. These predictions are made on the "parts population" technique.

The "parts population" technique produces a failure rate for an instrument by multiplying the quantity of each component (example: the number of digital IC's) by an average failure rate for that component, and summing the results to get a failure rate per thousand hours. MTBF (mean-time-between-failure) of the instrument, then, is simply 1000/failure rate.

The component failure rates are "average" rates, assuming a 50% stress level, and approximately 25°C ambient. The feasibility of using varying stress levels (such as MIL-217B pi factors) is being studied.

The MTBF figures obtained by this method should not be considered an exact prediction, but rather a "ballpark" indication. In the past, however, this technique has proven to be a fairly accurate indicator of the reliability (or unreliability!) of an instrument.

Note that an instrument's reliability can be predicted in segments by using this method. In this case,

$$\text{MTBF}_{\text{system}} = \frac{1}{\frac{1}{\text{MTBF}_1} + \frac{1}{\text{MTBF}_2} + \ldots} = \frac{1000}{\text{failure rate}_1 + \ldots}$$

continued

This program is simple to use, requiring about five minutes to run. After logging on the CDC system, two commands are required to execute the program:

```
OLD, RELY/UN=ACE0TRC
-RELY
```

After this, the computer provides a description of the program, along with instructions. The program asks questions such as,

```
HOW MANY POWER DIODES
? (and the user responds) 8 (return)
```

Once the quantities of the various components are entered, the program calculates and displays the predicted failure rates and MTBF figures.

At this point, the user can modify the quantities of any components and rerun the calculation, to see how changing quantities affects the predicted MTBF value. Another option of the program is a listing of the component failure rates used in the reliability prediction.

For user suggestions or more information concerning this program, contact Tom Clark, Component Applications, ext. 6511. For more information on reliability predictions, contact Jack Stoll in Reliability Engineering, ext. 5298.

FAILURE ANALYSIS Request & Report No.________

Date Submitted________________________

Date Needed
or Priority ("Normal" or "Quick")________________________

Request Sent to (Name, Org., Phone & Del. Sta.)

____

Qty Parts:________

Forwarded for additional analysis to:

____

Qty Parts:________

Tek Part No.________________________

Manufacturer________________________

Date Code(s)________________________

Other Nomenclature________________________

or Ratings________________________

Failed in Instr. yes no

Circuit Symbol________________________

Instr. Type____________S/N____________

Module Type____________S/N____________

Requested by (Return report to):
(Name, Org., Phone & Del. Sta.)

____

____

Resp. No.__________ - _____

Project No.________________________

Conditions of Use at time of Failure

User ____________

Customer use________	Demo________
Plant Test________	Plant Cycle Rm________
QC or Audit________	Reliability Test____
Engineering________	Environmental Test__

Other (specify)________________

Component____________

Incoming QC________	Preconditioning____

Other (specify)________________

Will this part be reworked for later use?	yes no
If no, can destructive test be done?	yes no

Date of Failure____________

DOA?_____yes _____no

Final Report Distribution

Name	Del. Sta.

Part History: (Operating Stress Levels)

Reason for Analysis and Extent of Analysis Required:

Suspected Failure Mode: (out of spec, open, etc.)

to be filled out by originator

to be filled out by person performing failure analysis

Work Done By ________________ ________ ________ ____________

Name Ext. Del. Sta. Date Completed

Failure Analysis Conclusions: (List analysis methods & results. What caused failure?)
Use reverse side if necessary.

Glossary of reliability terms

This glossary is not intended to have universal applicability but rather is intended to define the terms used in the preceding articles. Definitions were compiled from various sources, some paraphrased to eliminate unnecessary military jargon.

Accelerated test — A test in which the applied stress level is chosen to exceed that stated in the reference conditions in order to shorten the time required to observe the stress response of the item, or magnify the response in a given time. To be valid, must not alter the basic modes and mechanisms of failure and their relative prevalence in a use situation. (IEC 271)

Burn-in screen — Performed for the purpose of eliminating marginal devices, those with inherent defects or defects resulting from manufacturing aberrations which are evidenced as time and stress dependent failures. Burn-in is usually performed by applying maximum rated, operating conditions for a specified time period. (MIL-STD-883A, method 1015)

Electrical tests at elevated temperature — Usually a DC electrical and full functional test performed at a temperature above ambient (Typically 70°C or maximum rated operating temperature for IC's, and 125°C for transistors tested at Tektronix on the hot track.)

Failure — The inability of an item to perform within previously specified limits. (MIL-STD-790C)

CLASSIFICATION OF FAILURE AS TO DEGREE — (MIL-STD-790C)

partial failure — failure resulting from deviations in characteristic(s) beyond specified limits but not such as to cause complete lack of required function.

complete failure — failure resulting from deviations in characteristic(s) beyond specified limits such as to cause complete lack of the required function.

intermittent failure — failure of an item for a limited period of time, following which the item recovers its ability to perform its required function without being subjected to any external corrective action.

Failure activating cause — The stresses/forces, such as shock or vibration, which induce or activate a failure mechanism. (MIL-STD-790C)

Failure analysis — The process of examining parts to determine the cause of variations of performance characteristics outside of previously established limits with the end result that failure modes, failure mechanisms and failure activating causes will be identified. (MIL-STD-790C)

Failure mechanism — The physical process by which the degradation proceeded to the point of failure, identifying quality defects (including the original defect which initiated the device failure), internal, structural, or electrical weaknesses and, where applicable, the nature of externally applied stresses which led to failure. (MIL-STD-883A)

Failure mode — The cause for rejection of any failed device as defined in terms of the specific electrical/ physical requirement which it failed to meet. (MIL-STD-883A)

Failure Rate — The number of items replaced per unit of time due to failure of that item, normally expressed in % failures per 1000 hours of operation, or in number of failures per million hours of operation.

Functional tests — Defined as go, no-go tests which sequentially exercise a function (truth) table or in which the device is operated as a part of an external circuit and circuit operation is tested. (MIL-STD-883A)

High temperature reverse bias — (HTRB) - A reverse bias, less than breakdown voltage, is applied to one or both transistor junctions at elevated temperature to promote infant failures.

High temperature storage (stabilization bake) — The purpose of this test is to determine the effect on micro-electronic devices of storage at elevated temperature. This test is primarily used for device stabilization and the detection of parameter drift. It also is useful in accelerating temperature dependent failure mechanisms such as those resulting from chemical reaction or diffusion. (MIL-STD-883A, method 1008)

Intermittent life (or power cycling) — Performed for the purpose of determining a representative failure rate for micro-electronic devices or demonstrating quality or reliability of devices subjected to the specified conditions. It is intended for applications where the devices are exposed to cyclic variations in electrical stresses and power consumption between the "on" and "off" condition and resultant cyclic variations in device and case temperature. The test can be performed under various conditions ranging from DC reverse bias to operation under high power conditions. (MIL-STD-883A, method 1006)

MTBF (Mean Time Between Failures) — The average time of operation between failures of an item, expressed in hours. MTBF is the reciprocal of the failure rate.

Observed failure rate — For a stated period in the life of an item, the ratio of the total number of failures in a sample to the cumulative observed time on that sample...to be associated with particular and stated time intervals and with stated conditions (IEC 271)

Power cycling — see intermittent life

Preconditioning — The application of stress to a group of components which is done prior to screening (100% testing). This treatment is intended to promote the failure of intrinsically weak devices so they can be detected by screening.

Quality — The degree of conformance to applicable specifications and workmanship standards at the time of the quality inspection, OR The percentage of defective units (either dead-on-arrival or out-of-spec) furnished by the supplier to the user.

Reliability — The probability of a device performing its purpose adequately for the period of time intended under the specified operating conditions.

Reliability assurance — The management and technical integration of the reliability activities essential in maintaining reliability achievements, including design, production and product assurance. (MIL-STD-790C)

Sample — A random selection of units from a lot for the purpose of evaluating the characteristics or acceptability of the lot.

Screening — A test, or combination of tests, (performed on 100% of a group of parts) intended to remove unsatisfactory items or those likely to exhibit early failures. (IEC 271)

Stabilization bake — see high temperature storage

Stress — Voltage, power, temperature, or thermal environmental conditions during component testing or usage which affect the failure rate, and hence the reliability of the parts.

Temperature cycling — This test is conducted to determine the resistance of the part to exposures at extremes of high and low temperatures. Permanent changes in operating characteristics and physical damage result from variations in the physical properties and dimensions during test. This test is often used to screen for devices with weak mechanical properties. (MIL-STD-883A, method 1010)

Thermal shock — The purpose of this test is to determine the resistance of the device to sudden, extreme changes in temperature. It is useful for evaluating mismatches in thermal time constants and expansion coefficient between various device materials. (MIL-STD-883A, method 1011)

RELIABILITY REFERENCE MATERIALS

DEFINITION: The probability that a component part, equipment or system will satisfactorily perform its intended function under given circumstances, such as environmental conditions, limitations as to operating time, and frequency and throughness of maintenance for a specified period of time.

BOOKS on this subject may be found in the Tektronix Library by the following call numbers:

TA168 TK7870 TS156 QA273

Or, look in the card catalog **subject** file under:

RELIABILITY (ENGINEERING)
ELECTRONIC APPARATUS AND APPLIANCES – RELIABILITY
QUALITY CONTROL

INTRODUCTIONS to this subject include:

J. C. Cluley, ELECTRONIC EQUIPMENT RELIABILITY. New York, Wiley, 1974. TK7870 C5 1974.

C. Gordon Beattie, et al., "Elements of Semiconductor Device Reliability," IEEE PROCEDINGS, 62(2) pp 149-168 (1974).

COMPREHENSIVE HANDBOOKS:

R. T. Anderson, RELIABILITY DESIGN HANDBOOK. ITT Research Institute, Chicago, Illinois. March, 1976 Catalog No. RDH-376.

J. M. Juran, QUALITY CONTROL HANDBOOK. 3rd Edition. New York, McGraw-Hill, 1974. TS156 Q3 J8 1974.

W. G. Ireson, RELIABILITY HANDBOOK. New York, McGraw-Hill, 1966. TA168 I7.

SOURCES for finding TECHNICAL REPORTS and JOURNAL ARTICLES on various aspects of reliability:

Government Reports Announcements
Scientific and Technical Aerospace Reports
Electrical and Electronics Abstracts
Engineering Index
Applied Science and Technology Index

Also ask about the library's computerized literature searching service.

JOURNALS devoted to this subject include:

Evaluation Engineering
Journal of Quality Technology
IEEE Transactions on Reliability
Microelectronics and Reliability
Quality (formerly Quality Management and Engineering)

CONFERENCE PROCEEDINGS Available:

Annual Reliability and Maintainability Symposium (TA168 S855)
International Reliability Physics Symposium (TK7870 S95)

OTHER INFORMATION SOURCES:

TECHNICAL STANDARDS on this subject available at Tektronix:

MIL-HDBK 217B	Reliability Stress and Failure Rate Data for Electronic Equipment
MIL-STD-721B	Definitions of Effectiveness Terms for Reliability, Maintainability, Human Factors and Safety
MIL-STD-756A	Reliability Prediction
MIL-STD-757	Reliability Evaluation from Demonstration Data
MIL-STD-781B	Reliability Tests Exponential Distribution
MIL-STD-785A	Reliability Program for Systems and Equipment Development and Production
MIL-STD-790C	Reliability Assurance Program for Electronic Parts Specifications
MIL-STD-883A	Test Methods and Procedures for Microelectronics
MIL-STD-1304A	Reliability Report

EIA Reliability Bulletins:

Category 7 No. 1	A General Guide for Technical Reporting of Electronic Systems Reliability Measurement
Category 7 No. 2	The Reliability Program Guide for the Management of Firms Contracting for Electronic Products in the Armed Services
Category 7 No. 4	Reliability Quantification
IEC Pub. 271	List of Basic Terms, Definitions and Related Mathematics for Reliability (1974)

For information on Tektronix Technical Standards, contact Carol Schober (58-187) ext. 7976.

SPECIFIC ARTICLES dealing with Reliability:

"Elements of Semiconductor-Device Reliability" (Texas Instruments) IEEE Procedings, Vol. 62 No 2. February 1974, pp. 149-168.

"The Reliability of Semiconductor Devices in the Bell System" (Bell Labs) IEEE Procedings, Vol. 62 No 2, February 1974, pp. 185-211.

OTHER INFORMATION SOURCES:

Tektronix Reliability Committee (RESCU) — Bill Snell, Chairman

GIDEP (Government-Industry Data Exchange Program) service. Provides test and usage information between military and industry participants. Contact Keith Sessions (58-134) ext. 7690.

Device Derating Guidelines for Tektronix Design-Second Edition, (Publication R-01) August, 1976. Published by **Component News.**

RELIABILITY REPRINTS from Component News

Issue #	**Title**
239	"When is screening beneficial?"
236	"Accelerated life test run on 741 op amps"
235	"A look at IC testing economics"
232	"Failure rate model added to 'RELY' program"
231	"Thermomechanical test methods for IC's"
	"Reliability prediction program updated"
229	"IC's tested at high temperature"
227	"Component Preconditioning"