MR16IN
MTBF Report

by

Percept Technology Labs

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1.0	1/6/2025	Initial draft	MB

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Project Manager: Marty Best	2/14/2025

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1 Introduction

1.1 Overview

Failure rates were determined for the components in the Bill of Materials provided by HID Global. The BOM was PCA-00961 MR16IN-S3B. A Mean Time Between Failure (MTBF) calculation was then performed using Telcordia SR332, Issue 4, ARPP Version 12.1a, 2017.

1.2 Scope

This report, prepared by Percept Technology Labs LLC, documents the failure rate analysis and the results of the calculation.

1.3 Definitions

BOM = Bill of Materials

FR = Failure Rate - units are failures/million hours

FIT = Failures in Time - units are failures/billion hours

MTBF = Mean Time Between Failure – units are hours

The predicted elapsed time between inherent failures of a system during operation is called the mean time between failures (MTBF). This is calculated as the arithmetic mean (average) time between failures of a system. The MTBF is typically part of a model that assumes the failed system is immediately repaired (zero elapsed time), as a part of a renewal process. In contrast, the mean time to failure (MTTF), measures average time between failures with the modeling assumption that the failed system is not repaired.

The definition of MTBF depends on the definition of what is considered a system failure. For complex, repairable systems, failures are considered to be those out of design conditions which place the system out of service and into a state for repair. Failures which occur that can be left or maintained in an unrepaired condition, and do not place the system out of service, are not considered failures under this definition. In addition, units that are taken down for routine scheduled maintenance or inventory control are not considered within the definition of failure.

For the purposes of this report, we are using the first definition of failure: that which places the system out of service and in need of repair.

1.4 Company Restricted Information

This document contains confidential and restricted information. Reproduction of this document outside of HID Global or Percept Technology Labs LLC is prohibited.

1.5 Reference Documents

Reference documents for this evaluation included the HID Global PCA-00961 MR16IN-S3B Bill of Materials and component specifications.

1.6 Client Information

HID GLOBAL
Unit 3, Cae Gwyrdd
Green Meadow Springs Business Park
CF15 7AB Cardiff
United Kingdom

1.7 Test Entrance Criteria

- All necessary product-related materials and support documentation required for Percept Technology Labs LLC to execute this project.
- Access to a technical resource (person) for operational questions.

1.8 Test Exit Criteria

- All data collected for specified test cases.
- Completed Test Report (This document).

2 Analysis

2.1 General Reliability Prediction Assumptions

- An electronic component can only fail when current is applied.
- The probability of failure for any electronic component is constant throughout its "useful life". The probability of failure is the same from the first it is turned on until the end of its useful life is reached (usually millions of hours of run time).
- MTBF = 1/failure rate. If the failure rate number is obtained from the Telcordia database or the supplier's datasheets it has assumed 100% duty cycle. The failure rate to be used in the MTBF prediction calculation is equal to the base failure rate times the duty cycle.
- Mechanical and electrical wearout are not part of the reliability prediction calculations.

2.2 Environmental Stress Factors

- Ambient temperature = 25°C.
- Electrical Stress is assumed to be 50% for all components.
- Component Quality Level 1 is used for the prediction.
- The Environment is assumed to be Ground, Fixed, Uncontrolled for all components
- The assumed Duty Cycle is 100% for all components.

3 Results:

Table 1: MR16IN Reliability Prediction

P/N	Quantity	Description	FIT
	1	MR16IN	391.894
		Failures per Billion Hours	391.894
		MTBF	2,551.707

Assumptions:

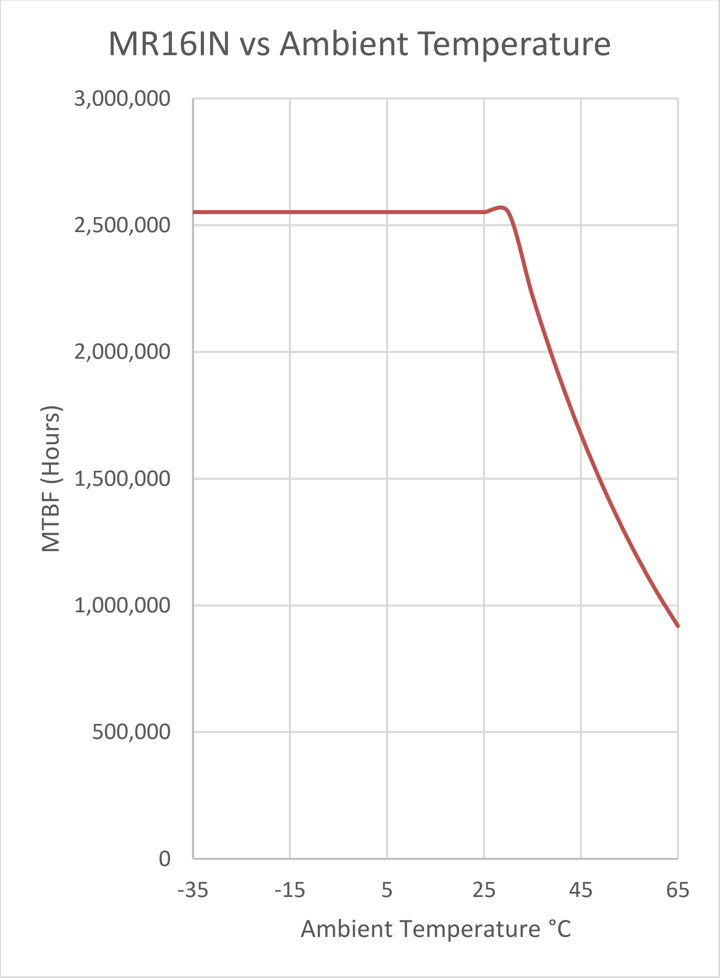
Part Stress Level = 50%

Ambient Temperature = 25ºC

Environment = "Ground Fixed, Uncontrolled"

Table 2: MR16IN Prediction vs. Temperature

MR16IN		
Ambient	**FIT**	**MTBF**
-35	391.900	2,551,671
-30	391.900	2,551,671
-25	391.900	2,551,671
-20	391.900	2,551,671
-15	391.900	2,551,671
-10	391.900	2,551,671
-5	391.900	2,551,671
0	391.900	2,551,671
5	391.900	2,551,671
10	391.900	2,551,671
15	391.900	2,551,671
20	391.900	2,551,671
25	391.900	2,551,671
30	391.900	2,551,671
35	450.200	2,221,235
40	517.900	1,930,875
45	597.100	1,674,761
50	690.100	1,449,065
55	800.200	1,249,688
60	931.400	1,073,653
65	1088.700	918,527



4 Appendix A — Component Detail Tables

4.1 MR16IN

Table 3: MR16IN System Reliability @ Ambient Temp = 25˚C

Description	Qty	Ref Design	Device Fit	System Fit
CAP CER 0.01UF 10% 50V X7R 0805	2	C79,C1208	0.28	0.56
CAP CER 0.1UF 10% 16V X7R 0603	19	C11,C12,C13,C14,C15,C16,C17,C18,C19,C20,C21,C22,C30,C32,C33,C37,C38,C301,C302	0.28	5.36
CAP CER 1000PF 10% 100V X7R 0805	1	C54	0.28	0.28
CAP CER 10UF 10% 25V X5R 1206	9	C43,C44,C45,C46,C1205,C1206,C1207,C1302,C1303	0.28	2.54
CAP CER 12PF 50V 1% COG 0402	2	C5,C6	0.28	0.56
CAP CER 18PF 10% 50V C0G 0603	2	C1,C2	0.28	0.56
CAP CER 1UF 10% 50V X5R 1206	2	C80,C1204	0.28	0.56
CAP X5R 10UF 50V 10% 1206 LF	3	C85,C1209,C1210	0.28	0.85
CAP X7R 1UF 16V 10% 0603	18	C55,C56,C57,C58,C59,C60,C61,C62,C65,C66,C67,C68,C69,C70,C71,C72,C81,C1202	0.28	5.08
CAP X7R 220PF 50V 5% 0603	1	C1203	0.28	0.28
CONN HEADER STRAIGHT THRU HOLE 2.54MM 2-WAY	1	J3	0.15	0.15
CRY, 32.768K ±20PPM, 12.5PF, 3.2X1.5MM, SMT	1	Y2	3.03	3.03
CRYSTAL 12.000MHZ, 18-20PF LOAD, <30PPM FTOL, <30PPM STAB, -10 TO +70 DEG, 3.2X2.5MM (X4 PAD) SMD	1	Y1	5.70	5.70
DIO SIL 100V 150MA 2-PIN MLL34 SOD80	3	D44,D45,D91	0.76	2.27
DIO TVS 12.0V SM712 SOT-23-3 LEAD FREE	1	D1001	0.06	0.06
DIO TVS UNIDIRECTIONAL 28V DO-214AA(SMB)	33	D46,D47,D48,D49,D50,D51,D52,D53,D54,D55,D56,D57,D58,D59,D60,D61,D62,D63,D64,D65,D66,D67,D68,D69,D70,D71,D72,D73,D74,D75,D76,D77,D78	3.21	105.90
DIO TZB SMT 5V SMBJ5.0A LF	3	D79,D80,D82	0.13	0.38
DIODE DUAL SERIES SMALL SWITCHING 75V 0.15A SOT-23	18	D26,D27,D28,D29,D30,D31,D32,D33,D34,D35,D36,D37,D38,D39,D40,D41,D42,D43	0.06	1.13

Description	Qty	Ref Design	Device Fit	System Fit
DIODE SCHOTTKY 40V 3.0A SMA	2	D1201,D1202	2.64	5.27
DIODE TVS 3.3V SMB UNIDIRECTIONAL DO-214AA LEAD FREE	1	D81	0.09	0.09
DIODE, LED CLEAR RED, 0805	22	D1,D2,D3,D4,D5,D6,D7,D8,D9,D10,D11,D12,D13,D14,D15,D16,D17,D18,D19,D20,D22,D23	0.32	7.01
FILTER FERRITE BEAD 600OHM @ 100MHZ 1A 1206	2	L2,L13	0.25	0.50
FLTR, FERRITE BEAD, 600OHM 0603 1A, LEAD FREE	2	R1013,R1014	0.25	0.50
IC DUAL OP-AMP 0.7MHZ 26V 8SOIC	1	U4	0.14	0.14
IC HALF DUPLEX RS485, TX/RX, +3.3V, SO8	1	U5	0.01	0.01
IC LINEAR VOLT REG POS ADJ 1.5A TO263/DDPAK/D2PAK/SOT404	1	U12	0.18	0.18
IC MICROCONTROLLER ARM CORTEX-M4 RA6M2-SERIES 120MHZ 512KB FLASH, 384K RAM, LQFP-144	1	U1	0.01	0.01
IC REG LDO 3.3V 1A SOT-89-5	1	U1302	1.29	1.29
IC REG SWITCHING 1.2-12V 2A 300KHZ SOP-FD-8	1	U1201	1.03	1.03
IND WIREWOUND 47UH ±20 1.8A UNSHIELDED	1	L1201	0.27	0.27
RES FILM 0 OHM 0.25W 1206	1	R1205	0.20	0.20
RES FILM 0K OHM 50V 1A 0.063W 0402	2	R301,R302	0.20	0.40
RES FILM 10K OHM 0.100W (1/10W) 5% 0603 ROHS COMPLIANT	32	R35,R36,R37,R38,R39,R40,R41,R42,R43,R44,R45,R46,R47,R48,R49,R50,R51,R52,R53,R54,R55,R56,R57,R58,R59,R60,R61,R62,R63,R64,R65,R66	0.20	6.39
RES FILM 13K 0.1W (1/10W) 1% 0603	1	R1202	0.20	0.20
RES FILM 1K .063W 5% 0402 LEAD FREE	22	R401,R402,R407,R408,R410,R411,R412,R413,R414,R418,R419,R421,R422,R423,R424,R425,R426,R427,R428,R431,R1006,R1009	0.20	4.39

Description	Qty	Ref Design	Device Fit	System Fit
RES FILM 1K 5% ±200PPM/°C 1/10W 0603	2	R1008,R1011	0.20	0.40
RES FILM 243 0.1W (1/10W) 1% 0603, ROHS COMPLIANT	1	R77	0.20	0.20
RES FILM 4.7K .063W 5% 0402 LEAD FREE	19	R303,R304,R305,R306,R307,R308,R309,R310,R315,R403,R404,R405,R406,R1001,R1003,R1005,R1007,R1010,R1012	0.20	3.80
RES FILM 68.1K 0.1W (1/10W) 1% 0603, ROHS COMPLIANT	1	R1201	0.20	0.20
RES SMD 22K OHM 5% 1/16W 0402	2	R1002,R1004	0.20	0.40
RES SMT_0603 TC200 5% 120 OHM LF-ROHS	1	R71	0.20	0.20
Res Thick Film 0603 1K Ohm 1% 0.1W(1/10W) ±100ppm/°C Lead Free	34	R3,R4,R5,R6,R7,R8,R9,R10,R11,R12,R13,R14,R15,R16,R17,R18,R19,R20,R21,R22,R23,R24,R25,R26,R27,R28,R29,R30,R31,R32,R33,R34,R69,R70	0.20	6.79
RES THICK FILM 931 0.1W 1% 0603, LEAD FREE	2	R67,R68	0.20	0.40
RLY FORM C 5V 5A/3A 30VDC G5Q LF-ROHS	2	K1,K2	33.45	66.89
SW DIP SMT TAPE SEAL 8 POS LF-ROHS	1	S1	14.97	14.97
TERM HDR FOR QWK DISC 3 POS ROHS	1	TB11	0.22	0.22
TERM HDR FOR QWK DISC 4 POS ROHS	9	TB1,TB2,TB3,TB4,TB5,TB6,TB7,TB8,TB9	0.29	2.65
TERM HDR FOR QWK DISC 5 POS ROHS	1	TB10	0.37	0.37
TERM HDR FOR QWK DISC 6 POS ROHS	1	TB12	0.44	0.44
TRANSISTOR NPN 40V 0.6A SOT-23	2	Q1,Q2	0.09	0.19

Total FIT	261.263
Environmental Factor	1.500
System Duty Cycle	100%
System FIT	391.894
System MTBF	2,551,707

5 Appendix B — MTBF Input Factors

5.1 Failure Rate

$$\boldsymbol{\lambda = \lambda b * \pi 1 * \pi 2 * \pi 3 * \pi 4}$$

where

$\boldsymbol{\lambda}$ **=** failure rate

$\boldsymbol{\lambda b}$ **=** base failure rate

$\boldsymbol{\pi t}$ **=** operating temperature factor

$\boldsymbol{\pi es}$ **=** electrical stress factor

$\boldsymbol{\pi q}$ **=** quality factor

$\boldsymbol{\pi ec}$ **=** environmental condition factor

5.2 Temperature Factor

The prediction process uses a Temperature Factor to model the effect of temperature on failure rate. The value of this factor is based on the device operating temperature and the type of device. The value is normalized to a temperature of 40ºC, which produces a Temperature Factor of 1.0 for all device types. When actual device operating temperature differs from the normalized temperature, the actual device operating temperature may be used. In general, temperatures less than 40ºC result in a factor less than 1 and temperatures greater than 40ºC result in factors greater than 1. The prediction program contains temperature models for each component type which calculates the factor.

5.3 Electrical Stress Factor

The prediction process assumes an electrical stress percentage of 50% (electrical stress factor = 1). If the device's application produces electrical stress percentage higher or lower than this base value, then the failure rate must be adjusted using the electrical stress factor. The prediction program contains electrical stress models for each component type which calculates the factor.

Part	Electrical Stress Percentage
Capacitor	(Sum of applied dc voltage plus ac peak voltage) / (rated voltage)
Resistor, fixed	Applied power / rated power
Resistor, variable	(V2in / total resistance) / rated power
Relay, switch	Contact current / rated current
Diode, general	Average forward current / rated forward current
Diode zener	Actual zener current or power / rated current or power
Transistor	Power dissipated / rated power

5.4 Quality Factor

The device failure rates used for the prediction process reflect the expected field reliability performance of generic device types. The actual reliability of a specific device will vary as a function of the degree of effort and attention paid by an equipment manufacturer to factors such as device selection/application, supplier selection/control, electrical/mechanical design margins, equipment manufacture process control, and quality program requirements. The table below describes the four quality levels and presents the values for their associated Quality Factor:

Quality Level 0	This level shall be assigned to commercial-grade, reengineered, remanufactured, reworked, salvaged, or gray-market components that are procured and used without device qualification, lot-to-lot controls, or an effective feedback and corrective action program by the primary equipment manufacturer or its outsourced lower-level design or manufacturing subcontractors. However, steps must have been taken to ensure that the components are compatible with the design application. **Quality Factor = 6**
Quality Level 1	This level shall be assigned to commercial-grade components that are procured and used without thorough device qualification or lot-to-lot controls by the equipment manufacturer. However, (a) steps must have been taken to ensure that the components are compatible with the design application and manufacturing process; and (b) an effective feedback and corrective action program must be in place to identify and resolve problems quickly in manufacture and in the field. **Quality Factor = 3**
Quality Level 2	This level shall be assigned to components that meet requirements (a) and (b) of Quality Level 1, plus the following: (c) purchase specifications must explicitly identify important characteristics (electrical, mechanical, thermal, and environmental) and acceptable quality levels (i.e. AQLs, Defects per Million, etc) for lot control; (d) devices and device manufacturers must be qualified and identified on approved parts/manufacture’s lists (device qualification must include appropriate life and endurance tests); (e) lot-to-lot controls, either by the equipment manufacturer or the device manufacturer, must be in place at adequate AQLs/DPMs to ensure consistent quality. **Quality Factor = 1**
Quality Level 3	This level shall be assigned to components that meet requirements (a) thru (e) of Quality Levels 1 and 2 plus the following: (f) device families must be re-qualified periodically; (g) lot-to-lot controls must include early life reliability control of 100% screening (temperature cycling and burn-in), which, if the results warrant it, may be reduced to a “reliability audit” (i.e. a sample basis) or to an acceptable “reliability monitor” with demonstrated and accepted cumulative early failure values of less than 200ppm out to 10,000 hours; (h) where burn-in screening is used, the Percent Defective Allowed (PDA) shall be specified and shall not exceed 2% and (i) and ongoing, continuous reliability improvement program must be implemented by both the device and equipment manufacturers. **Quality Factor = .8**

5.5 Environmental Condition Factor

The prediction process defines 6 environmental conditions. A separate prediction should be made for each environmental condition to which the equipment may be exposed. The prediction process uses and Environment Factor as a quantitative expression for a condition's effect on failure rate The factor goes from 1 (ground-based, fixed, controlled environment) to 15 (for a space based commercial environment such as a commercial communication satellite).

Environment	**Factor**	**Nominal Environmental Conditions**
Ground, Fixed, Controlled	1	Vibration/shock stresses: Low Atmospheric variations: Low Temp cycling stresses: Low Application examples: Central offices, data center, environmentally controlled vaults, environmentally controlled remote shelters, and environmentally controlled customer premise areas.
Ground, Fixed, Uncontrolled (limited)	1.5	Vibration/shock stresses: Low to moderate Atmospheric variations: Low to moderate Temp cycling stresses: Moderate to High Application examples: Weather-protected remote terminals, outdoor equipment, and radio tower equipment.
Ground Fixed, Uncontrolled (moderate)	2.0	Vibration/shock stresses: Moderate to High Atmospheric variations: Low to moderate Temp cycling stresses: Moderate to High Application examples: Remote terminals and outdoor equipment in manholes, and near direct path of railroad, highway, and air traffic.
Ground, Mobile (both vehicular mounted and portable)	4.0	Vibration/shock stresses: Extreme Atmospheric variations: Low to moderate Temp cycling stresses: High Application examples: Equipment that can be in rapid motion relative to the ground, including cell phones and hand-held devices, portable operating equipment, and test equipment
Airborne, Commercial	6.0	Vibration/shock stresses: Extreme Atmospheric variations: High Temp cycling stresses: High Application examples: Passenger compartment of commercial aircraft
Space-based, Commercial (low earth orbit)	15.0	Vibration/shock stresses: Extreme Atmospheric variations: High Temp cycling stresses: High Application examples: Commercial satellites

5.6 Definition of Failure

The definition of a failure should be well understood. This is a crucial element in predicting system reliability parameters.

The following is not included in failure rate predictions:

- Manufacturing process-induced errors.
- Software failures.
- Failures from procedural errors.

Failures in systems with multiple functions may be hard to define. In complex equipment, it may be useful to distinguish between failures affecting maintenance or repair and those affecting service. For example, the failure of an LED is likely to cause a return, but may not cause a service outage. Consequently, LEDs should be included in the failure rate estimate when the estimate is used to determine return rates, but they could likely be disregarded if the estimate is used to determine service availability.