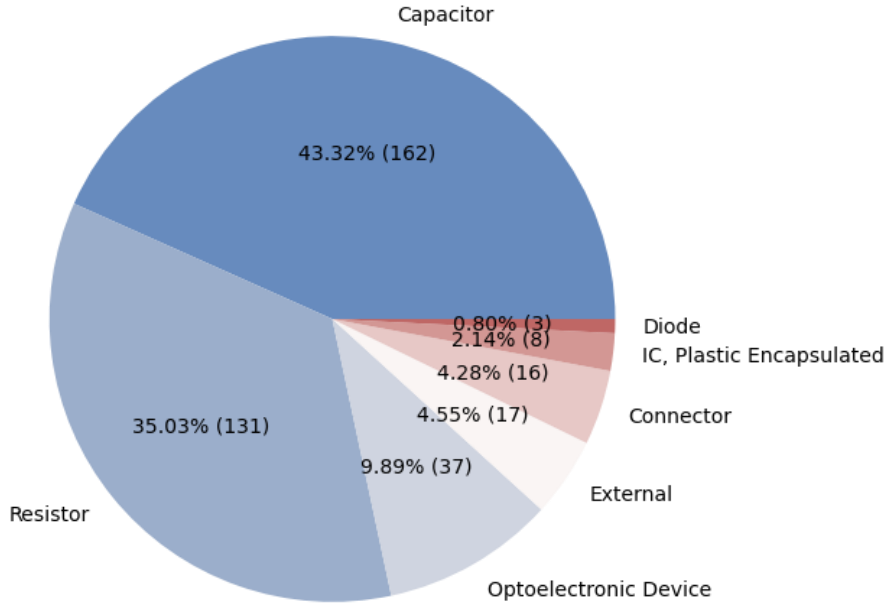
CIBFX Reliability Study

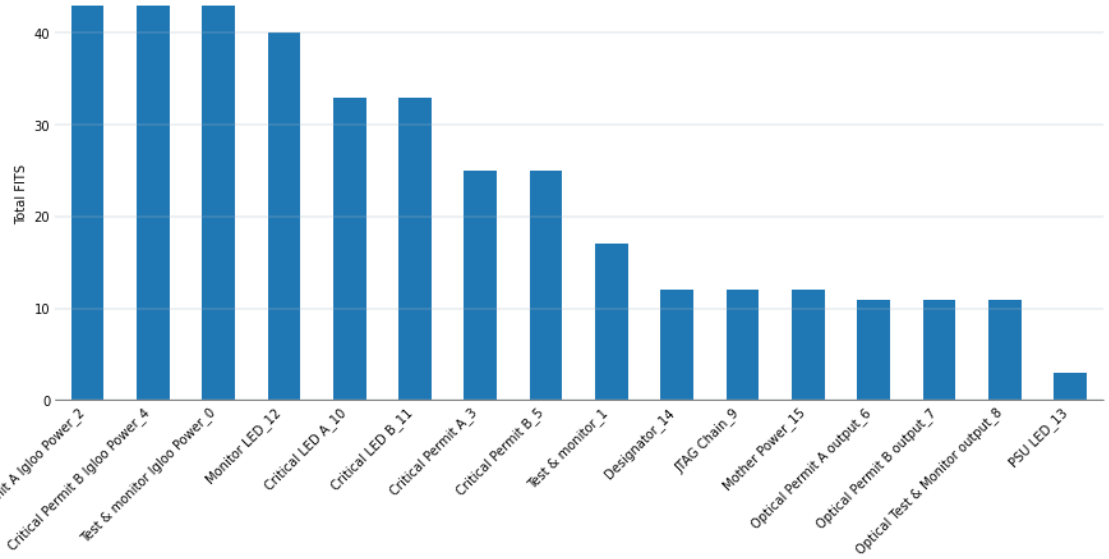
Summary of the FMECA – results and conclusions

List of contents

Failure rate prediction
For CIBFX Motherboard

- **Total of 374 components.**
  - Capacitors & resistors taking top spots.
  - Third group is made of LEDs.
  - Then externals: a mix of components not assigned to other categories (see next slides).
  - Then there are connectors, integrated circuits (plastic encapsulated) and diodes.
- **The 16 design pages of the project**
  - Most of components (44 in each) are in 3 Igloo Power pages.
  - Those are followed by LED pages (30-40 each).
  - Then Critical Permit and Test & Monitor.
  - Remaining have roughly 10 components each.





Failure rates (CIBFX Motherboard)
Of capacitors

- **10 Tantalum, 152 ceramic capacitors:**
  - Voltages for 153 identified automatically:
    - Minimal rating: 10V.
    - Maximum stress fraction: 0.3.
    - More than 75% below 0.1.
  - 9 operating voltages missing (can be added for completeness).
- **Total of 127 FIT:**
  - An individual capacitor adds 0.78 FIT each.
  - Maximum failure rate: 4 FIT for 3 ceramic capacitors with 0.33 stress factor.
  - Minimum failure rate: 0.34 FIT.
  - Tantalum: 1.2 FIT

Failure rates (CIBFX Motherboard)
For resistors

- **131 resistors adding 94 FIT.**
  - Each contributes roughly the same 0.72 FIT (with small deviation).
- **All assigned matching power rating (0.125W or 0.25W)**
- **All assigned** “Fixed, Metal Film” **217Plus sub-category.**

Failure rates (CIBFX Motherboard)
For external components

Part number	Description	Qunatity	Failure rate [FIT]	Designator	Reference
ADP1740ACPZ	Low-Dropout Linear Regulator	2	0.51	IC1, IC2	Analog Wafer Fabrication Data [1]
MC100EPT20DT	LVTTL/LVCMOS to Differential LVPECL	3	4.83	IC4, IC11, IC18	Onsemi Reliability Data [2]
MC100EPT21DT	Differential LVPECL/etc to LVTTL/LVCMOS	3	4.83	IC5, IC12, IC19	Onsemi Reliability Data [2]
M2GL010-TQG144	IGLOO2 FPGA	3	8	IC6, IC14, IC20	Device Reliability Report UG116 [3]
24AA025E48-I/SN	Serial EEPROMs	1	2	IC8,	Microchip Reliability Data [4]
PCA9552PW	I2C-BUS LED Driver	2	2	IC10, IC16	NXP Semiconductors Reliability Data [5]
LFSPXO018045	Surface Mount Clock Oscillator	3	7.76	OSC1, OSC2, OSC3	CFPS-73 document [6]
	TOTAL	**17**	**83.28**		

Table 1. Failure rates of components in the CIBFX Motherboard; 90% confidence level interval, 55 deg C, 0.7 eV activation

Failure rate prediction
For CIBFX Connectors

Structure of the project:

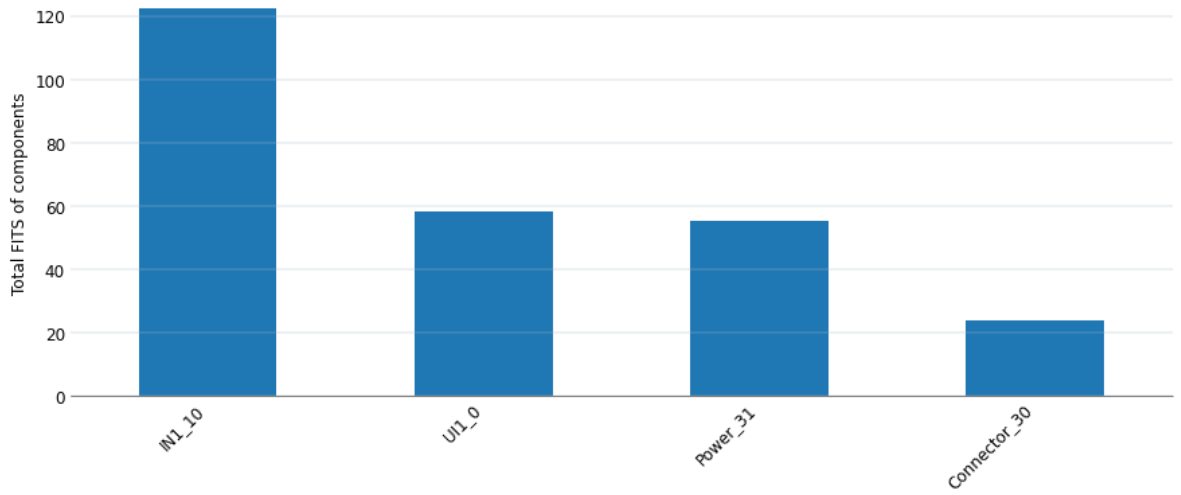
1. **Power - single**
   39 components, adding 50 FITs.

2. **Connector – single**
   12 components, adding 24 FITs (2 x 12 connectors)

3. **IN – x20**
   11 components, adding 122 FITs (80 relay, 14 x 2 transistors).

4. **UI – x10**
   16 components, adding 58 FITs (14 transistor, 6 x 3 optocouplers, 4-5 x 4 TVS)

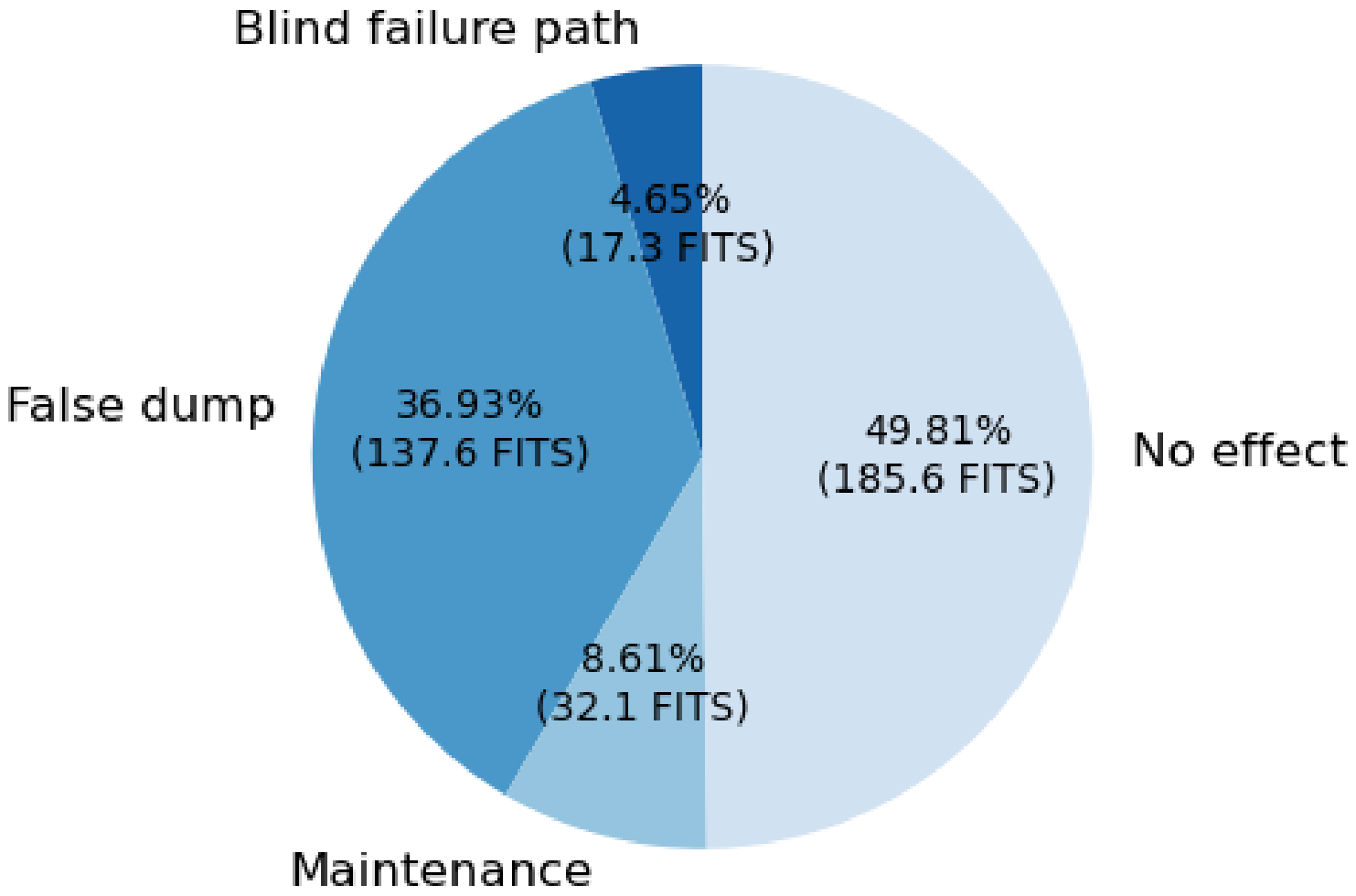
5. **Total**
   463 components, 3104 FITs.



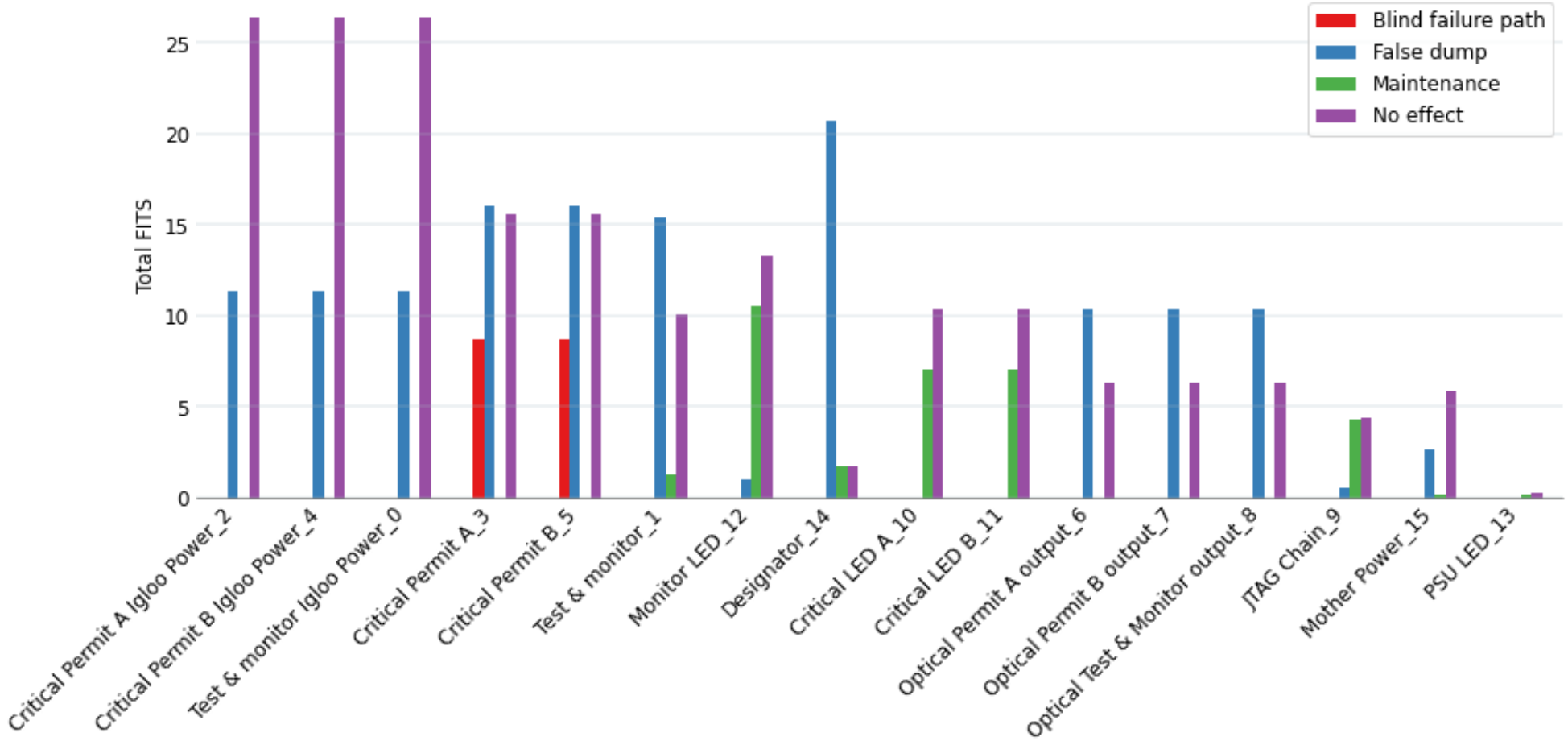
End-effect analysis

Results of the full FMECA

End-effects breakdown
For CIBFX Motherboard



End-effects failure rate (FITs) per page
CIBFX Motherboard



Blind failures
Only CIBFX Motherboard

- **Any of the following faults lead to a blind failure of a single path:**
  - 3 RS-422/RS-485 Receivers with Fault Detection in Critical Permit page: stuck high, failure rate: 0.17 FIT.
  - IGLOO2 FPGA: stuck high, failure rate: 8 FIT (assigning the entire failure rate of the FPGA).
- **This produces a combined failure rate of 8.7 FIT.**
  - Assuming that there are no inspections, this translates into the probability of 5.2×10^{-5} of experiencing a failure in a year (6000 hours, accouting for 250 operational days).
  - Probability that both paths fail at the same time during one year is then 2.7×10^{-9}.
- **Comparison with CIBF/CIBU**
  - FPGAs there are causing false dump (open, short, output stuck high/low)

CIBF Reliability Study

Blind Failures

- **CIBF – 2 failure modes:**
  - Components **IC2** and **IC19** (FOD060L): **optocouplers stuck low** in **User Permit A/B**;
  - Components **IC3** and **IC21** (74LVT14D): **inverter stuck high** in **User Permit A/B**;
- **CIBU:**
  - Same for user permit optocoupler and inverter (although “stuck high/low” mismatch + an additional “input open” inverter)
  - Additional blind failure on RS-485 transceiver on input open (to CIBM)
    - Fail-safe property of RS-485

nexperia

Reliability Monitoring Results

Quarters: Q1/2022 to Q4/2022
Based on structural similarity

Supplier	**User Part Number**
Nexperia B.V.	74LVT14D

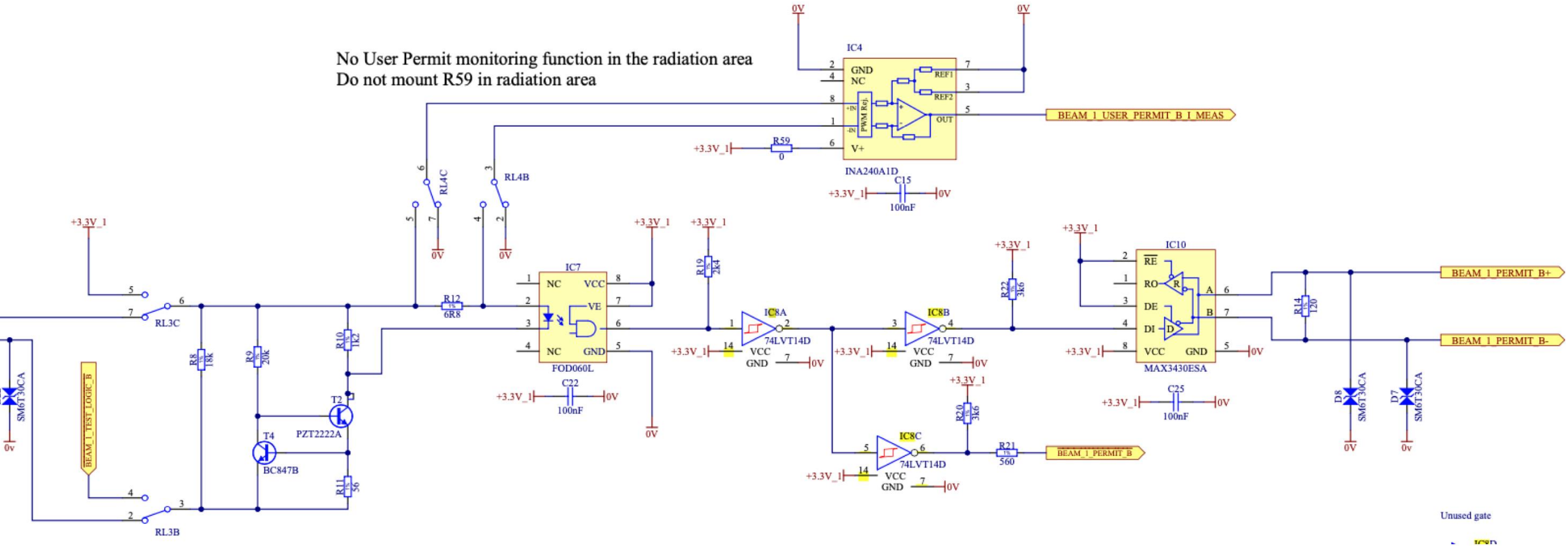
Part Description: Hex inverter Schmitt-trigger

Function Family: LVT
Process family: Sub micron
Package family: SO

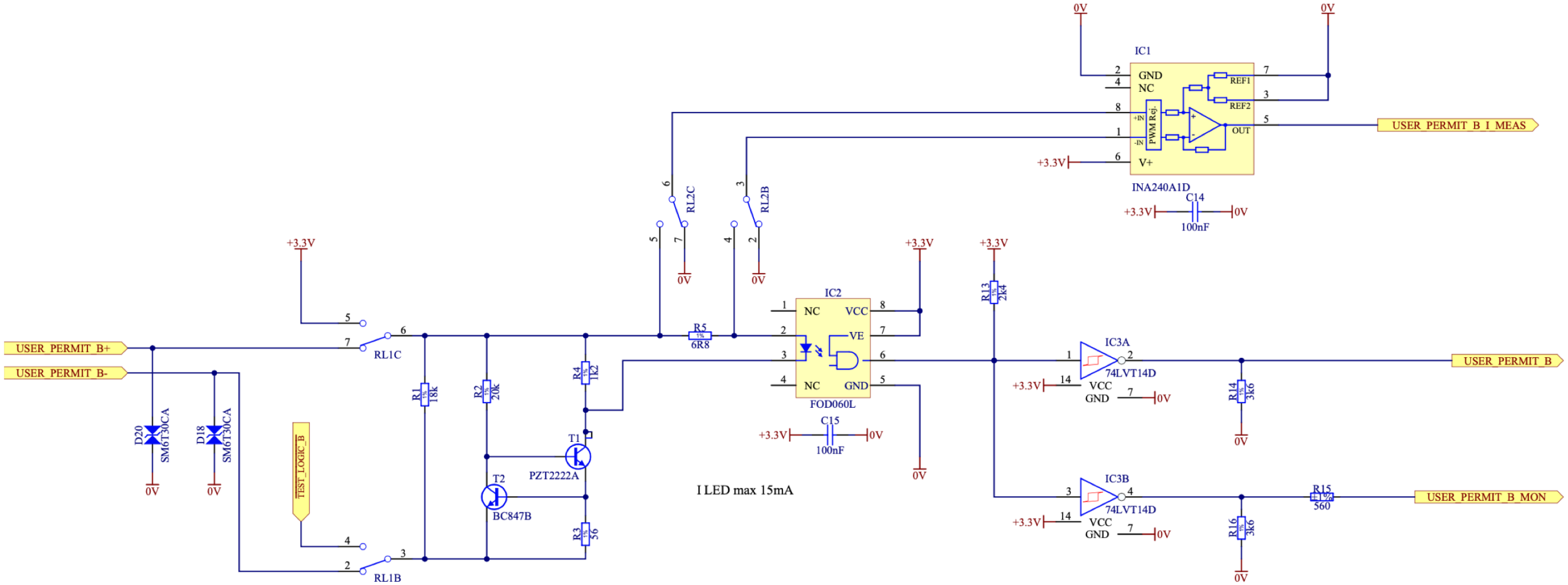
JESD47	Test	Test Conditions	Duration	# Lots	# Quantity	# Rejects
# 1	**TEST** Pre- and Post-Stress Electrical Test	Tamb = 25 °C	N/A	see below	all parts	see below
# 2	**PC** Preconditioning	JESD22-A113 MSL 1	N/A	460	29380	0
# 5a	**HTOL EFR** High Temperature Operating Life Extrinsic	JESD22-A108 Tj = 150°C $V_{CCMAX} \leq V \leq 1.2*V_{CCMAX}$	48 hours or 168 hours	132	33268	0
# 5b	**HTOL IFR** High Temperature Operating Life Intrinsic	JESD22-A108 Tj = 150°C $V_{CCMAX} \leq V \leq 1.2*V_{CCMAX}$	≥500 hours	89	7065	0
# 7	**TC** Temperature Cycling	JESD22-A104 -65 °C to 150°C	≥500 cycles	69	17630	4
# 9	**uHAST / HAST** unbiased or biased High Accelerated Stress Test	JESD22-A101 Tamb = 130 °C, RH = 85% V = V_{CCMAX}	96 hours	202	11750	0

https://assets.nexperia.com/documents/quality-document/74LVT14D_Nexperia_Product_Reliability.pdf

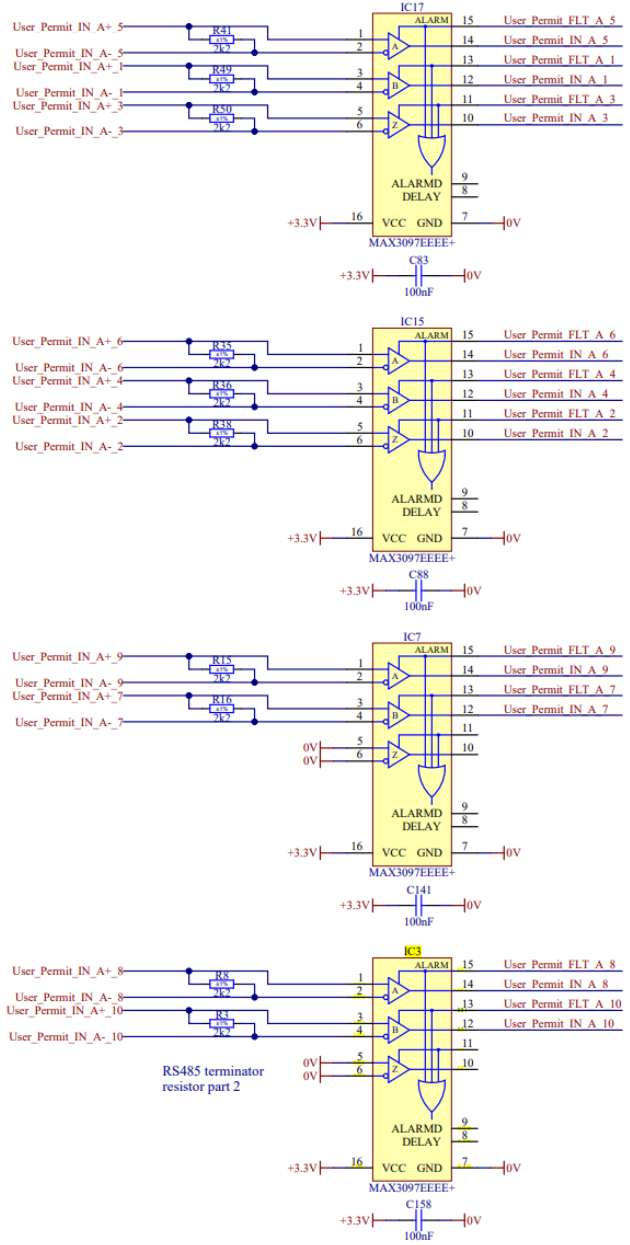
CIBU

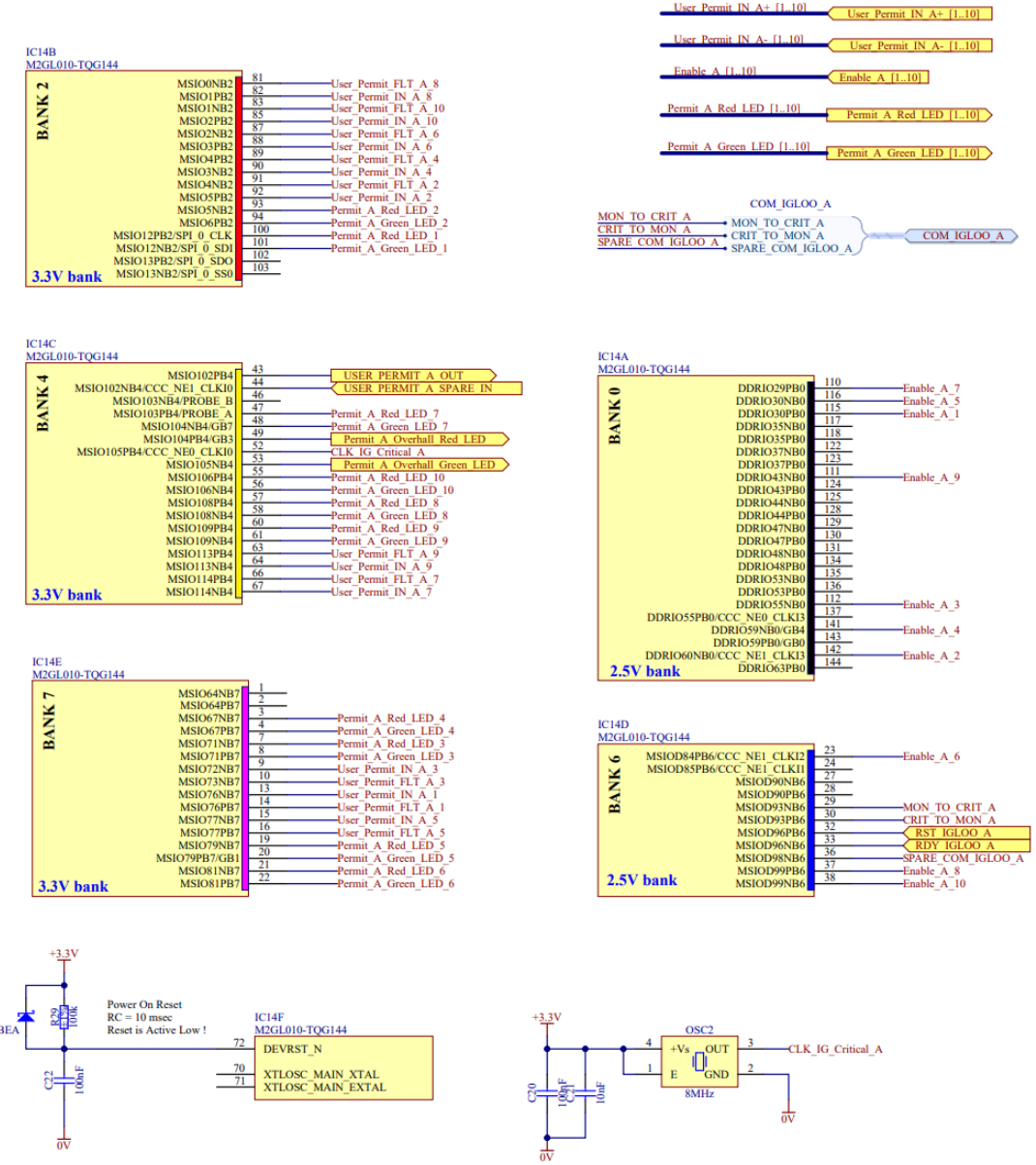

No User Permit monitoring function in the radiation area
Do not mount R59 in radiation area
IC4
INA240A1D
BEAM_1_USER_PERMIT_B_I_MEAS
R59
C15
100nF
RL4C
RL4B
RL3C
RL3B
R12
6R8
R8
18k
R9
20k
R10
1k2
R11
56
T2
PZT2222A
T4
BC847B
BEAM_1_TEST_LOGIC_B
SM6T30CA
IC7
FOD060L
C22
100nF
R19
2k4
IC8A
IC8B
IC8C
74LVT14D
R22
3k6
R20
3k6
R21
560
IC10
MAX3430ESA
C25
100nF
R14
120
BEAM_1_PERMIT_B+
BEAM_1_PERMIT_B-
BEAM_1_PERMIT_B
D8
D7
Unused gate

CIBF

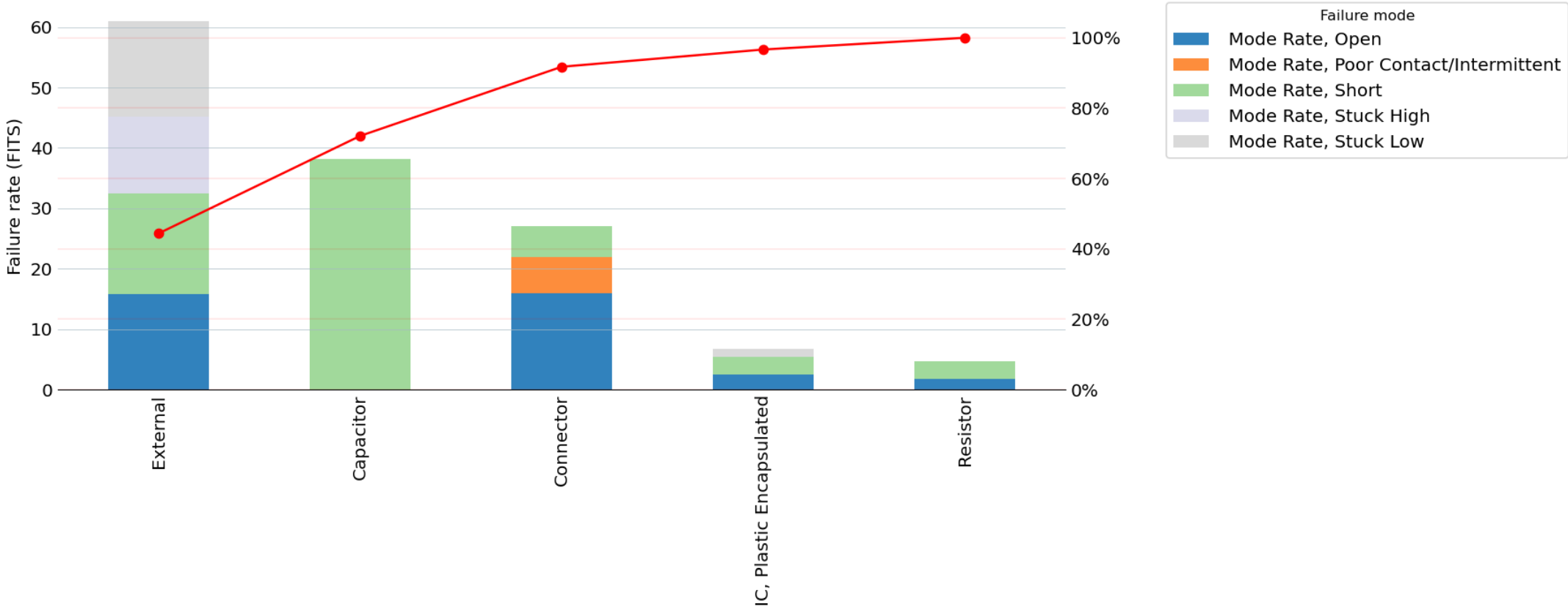

IC1
GND
NC
REF1
REF2
+IN
-IN
PWM Rgl.
OUT
V+
INA240A1D
C14
100nF
+3.3V
0V
USER_PERMIT_B_I_MEAS
RL2C
RL2B
IC2
NC
VCC
VE
NC
GND
FOD060L
C15
100nF
R5
6R8
R13
2k4
IC3A
74LVT14D
VCC
GND
R14
3k6
USER_PERMIT_B
IC3B
74LVT14D
R15
560
R16
3k6
USER_PERMIT_B_MON
USER_PERMIT_B+
USER_PERMIT_B-
RL1C
RL1B
R1
18k
R2
20k
R4
1K2
R3
56
T1
PZT2222A
T2
BC847B
D20
SM6T30CA
D18
SM6T30CA
TEST_LOGIC_B
I LED max 15mA

CIBFX


IC17
IC15
IC7
IC3
MAX3097EEEE+
RS485 terminator resistor part 2


IC14B
M2GL010-TQG144
BANK 2
3.3V bank
IC14C
BANK 4
IC14A
BANK 0
2.5V bank
IC14E
BANK 7
IC14D
BANK 6
COM_IGLOO_A
D2
PMEG4010BEA
Power On Reset
RC = 10 msec
Reset is Active Low !
IC14F
DEVRST_N
XTLOSC_MAIN_XTAL
XTLOSC_MAIN_EXTAL
OSC2
8MHz

False dumps
In CIBFX Motherboard, 137 FIT



False dumps
In CIBFX Motherboard, 137 FIT

Id	PartNumber	AlternatePN	CategoryDescription	Page	Failure Mode Rate
15.60	M2GL010-TQG144	IC6	External	Test & monitor_1	6.400
0.14	LFSPXO018045	OSC3	External	Critical Permit B_5	6.208
15.10	LFSPXO018045	OSC1	External	Test & monitor_1	6.208
1.14	LFSPXO018045	OSC2	External	Critical Permit A_3	6.208
1.13	M2GL010-TQG144	IC14	External	Critical Permit A_3	4.800
0.13	M2GL010-TQG144	IC20	External	Critical Permit B_5	4.800
8.30	MC100EPT20DT	IC4	External	Optical Test & Monitor output_8	3.864
13.40	MC100EPT21DT	IC19	External	Optical Permit B output_7	3.864
8.40	MC100EPT21DT	IC5	External	Optical Test & Monitor output_8	3.864
12.30	MC100EPT20DT	IC11	External	Optical Permit A output_6	3.864

End-effects failure rate (FITs) per page
CIBFX Connectors

- **4 categories:**
  1. Power (x1)
     - 39 components
     - False dump: **1.32 FIT**
     - Maintenance: **67.6 FIT**
  2. Connector (x1)
     - 12 components
     - False dump: **20.7 FIT**
     - Maintenance: **1.7 FIT**
  3. IN (x20)
     - 11 components x 20 = 220
     - False dump: 27.8 x 20 = **556 FIT**
     - Maintenance: 84 x 20 = **1680 FIT**
  4. UI (x10) 16 components
     - 16 components x 10 = 160
     - False dump: 21.6 x 10 = **216 FIT**
     - Maintenance: 23.3 x 10 = **233 FIT**

False dumps
In CIBFX Connectors

Id	Part Number	Alternate PN	Category Description	Page	Failure Mode Rate
25.9	G6K-2F-Y-DC3	RL19	Relay	IN1_10	20.807088
9.5	SFH6186-5	IC3	Optoelectronic Device	UI1_0	4.639290
9.7	SFH6186-5	IC5	Optoelectronic Device	UI1_0	4.639290
9.3	SMBJ3V3	D11	Diode	UI1_0	4.571906
9.4	SMBJ3V3	D18	Diode	UI1_0	4.571906
25.2	SMBJ20CA	D17	Diode	IN1_10	3.440471
25.1	SMBJ20CA	D16	Diode	IN1_10	3.440471
23.1	354071	J20	Connector	Connector_30	2.006967
23.9	354071	J19	Connector	Connector_30	2.006967
23.8	354071	J18	Connector	Connector_30	2.006967

Maintenance in IN

AlternatePN	Category	PartNumber	CategoryDescription	failure_mode	Alpha	FailureModeRate	EndEffect
RL19	217-RE	G6K-2F-Y-DC3	Relay	Fails to Trip	55	44.0149937	Maintenance
RL19	217-RE	G6K-2F-Y-DC3	Relay	Short	19	15.2051796	Maintenance
T46	217-TR	BC847B	Transistor	Short	60	8.35926473	Maintenance
T47	217-TR	BC847B	Transistor	Short	60	8.35926473	Maintenance
T46	217-TR	BC847B	Transistor	Open	20	2.78642158	Maintenance
T47	217-TR	BC847B	Transistor	Open	20	2.78642158	Maintenance
D15	217-DI	ES1D	Diode	Short	80	1.79340759	Maintenance
R119	217-RS	R0805_2K_1%_0.125W_100PPM	Resistor	Open	30	0.21582689	Maintenance
R117	217-RS	R0805_1K_1%_0.125W_100PPM	Resistor	Open	30	0.21582689	Maintenance
R119	217-RS	R0805_2K_1%_0.125W_100PPM	Resistor	Short	10	0.0719423	Maintenance
R116	217-RS	R0805_10K_1%_0.125W_100PPM	Resistor	Short	10	0.0719423	Maintenance
R118	217-RS	R0805_10K_1%_0.125W_100PPM	Resistor	Short	10	0.0719423	Maintenance
R117	217-RS	R0805_1K_1%_0.125W_100PPM	Resistor	Short	10	0.0719423	Maintenance

Remaining questions

1. **Failure modes of optocouplers**
    1. In the FMECA, it was stated that “short” failure mode is not applicable.
    2. The goal of an optocoupler is to separate circuits from each other.
    3. Isn’t it possible that the circuit becomes shorted between isolated parts nevertheless, as a fault and failure to deliver expected functionality?
2. **Is there a testing procedure for the user connections possible similarly as is done for current loops in CIBU/CIBF?**

References

[1] https://www.analog.com/en/about-adi/quality-reliability/reliability-data/wafer-fabrication-data.html#

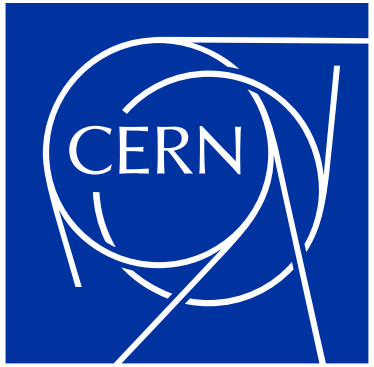
[2] https://www.onsemi.com/PowerSolutions/reliability.do?device=MC100EPT20DT

[3] https://docs.amd.com/r/en-US/ug116/The-Reliability-Program

[4] https://www.microchip.com/reliabilityreport/Default.aspx

[5] https://www.nxp.com/part/PCA9552PW#/

[6] Communication with the manufacturer



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