Mean Time Between Failures (MTBF) is a measure of the reliability of a system or component. It is defined as the average time between failures of a system during operation. To estimate the MTBF of your gas sensing system, we need to consider the MTBF of each individual component and then combine them to estimate the overall MTBF of the system.

Here are the steps to calculate the MTBF theoretically:

1. **Determine the MTBF of each component:**
   * Look up the MTBF or failure rate (λ) for each component used in your system. This information is often provided in the datasheets or reliability reports from the manufacturers. If this information is not available, you can use generic reliability data for similar components.
   * For example, typical MTBF values or failure rates for similar components might be found in reliability databases or from industry standards.
2. **List the components and their MTBF values:**
   * Raspberry Pi Pico
   * Gas sensor MQ2
   * BB13 (if it's a specific board or interface, otherwise, include any interfacing components)
   * Traffic lights (LEDs or any controller circuits)
3. **Convert MTBF to failure rates if necessary:**
   * The failure rate (λ) is the reciprocal of MTBF: λ=1MTBF\lambda = \frac{1}{\text{MTBF}}λ=MTBF1​
   * Ensure all units are consistent (e.g., hours).
4. **Combine the failure rates:**
   * If the components are in series (i.e., the failure of any single component leads to system failure), sum their failure rates to get the system failure rate: λsystem=λ1+λ2+λ3+…\lambda\_{\text{system}} = \lambda\_1 + \lambda\_2 + \lambda\_3 + \ldotsλsystem​=λ1​+λ2​+λ3​+…
   * For components with MTBF values, convert these to failure rates first and then sum.
5. **Calculate the system MTBF:**
   * The system MTBF is the reciprocal of the system failure rate: MTBFsystem=1λsystem\text{MTBF}\_{\text{system}} = \frac{1}{\lambda\_{\text{system}}}MTBFsystem​=λsystem​1​

**Example Calculation**

Assume the following MTBF values for simplicity:

* Raspberry Pi Pico: 1,000,000 hours
* Gas sensor MQ2: 200,000 hours
* Traffic light LEDs: 100,000 hours

Convert these MTBF values to failure rates:

* λPico=11,000,000\lambda\_{\text{Pico}} = \frac{1}{1,000,000}λPico​=1,000,0001​ failures per hour
* λMQ2=1200,000\lambda\_{\text{MQ2}} = \frac{1}{200,000}λMQ2​=200,0001​ failures per hour
* λLEDs=1100,000\lambda\_{\text{LEDs}} = \frac{1}{100,000}λLEDs​=100,0001​ failures per hour

Sum the failure rates:

λsystem=λPico+λMQ2+λLEDs\lambda\_{\text{system}} = \lambda\_{\text{Pico}} + \lambda\_{\text{MQ2}} + \lambda\_{\text{LEDs}}λsystem​=λPico​+λMQ2​+λLEDs​ λsystem=11,000,000+1200,000+1100,000\lambda\_{\text{system}} = \frac{1}{1,000,000} + \frac{1}{200,000} + \frac{1}{100,000}λsystem​=1,000,0001​+200,0001​+100,0001​ λsystem=0.000001+0.000005+0.00001\lambda\_{\text{system}} = 0.000001 + 0.000005 + 0.00001λsystem​=0.000001+0.000005+0.00001 λsystem=0.000016 failures per hour\lambda\_{\text{system}} = 0.000016 \text{ failures per hour}λsystem​=0.000016 failures per hour

Calculate the system MTBF:

MTBFsystem=1λsystem\text{MTBF}\_{\text{system}} = \frac{1}{\lambda\_{\text{system}}}MTBFsystem​=λsystem​1​ MTBFsystem=10.000016\text{MTBF}\_{\text{system}} = \frac{1}{0.000016}MTBFsystem​=0.0000161​ MTBFsystem=62,500 hours\text{MTBF}\_{\text{system}} = 62,500 \text{ hours}MTBFsystem​=62,500 hours

So, the estimated MTBF of your system is 62,500 hours. This is a rough estimate and should be validated with actual operational data for higher accuracy.

MIL-HDBK-217F Online Access

Telcordia SR-332 Overview

<https://pip.raspberrypi.com/categories/606-reliability>

TI Reliability Handbook

<https://reliabilityanalyticstoolkit.appspot.com/static/Mil-Hdbk-217_Environmental_descriptions.htm>

<https://www.winsen-sensor.com/d/files/PDF/Semiconductor%20Gas%20Sensor/MQ-2%20(Ver1.4)%20-%20Manual.pdf>

<https://www.crowcon.com/blog/how-long-will-my-gas-sensor-last/>

Electrochemical sensors for common gases such as carbon monoxide or hydrogen sulphide have an operational life typically stated at 2-3 years. More exotic gas sensor such as hydrogen fluoride may have a life of only 12-18 months. In ideal conditions (stable temperature and humidity in the region of 20˚C and 60%RH) with no incidence of contaminants, electrochemical sensors have been known to operate more than 4000 days (11 years). Periodic exposure to the target gas does not limit the life of these tiny fuel cells: high quality sensors have a large amount of catalyst material and robust conductors which do not become depleted by the reaction.

The Mean Time Between Failures (MTBF) values can vary significantly depending on the operational environment of the system. The terms "Ground Benign" and "Ground Mobile" refer to different environmental conditions under which the components are expected to operate. These classifications are used to account for the varying stress levels that components endure in different environments, which can impact their reliability and lifespan.

Here’s a detailed explanation of each:

**1. Ground Benign**

* **Definition:** Ground Benign typically refers to a controlled, non-stressful environment, such as an office or lab setting where conditions are stable and within optimal ranges for temperature, humidity, vibration, and handling.
* **Characteristics:**
  + Stable and mild temperature conditions.
  + Low humidity levels.
  + Minimal vibration and shock.
  + Controlled power supply with minimal electrical noise and surges.
  + Clean and dust-free environment.
* **Typical Applications:**
  + Desktop computers.
  + Laboratory equipment.
  + Office electronics.

**2. Ground Mobile**

* **Definition:** Ground Mobile refers to a more challenging environment, where the equipment may be subject to movement, varying environmental conditions, and physical stresses.
* **Characteristics:**
  + Variable and possibly extreme temperature fluctuations.
  + Higher humidity levels.
  + Exposure to significant vibration and shock (e.g., from transport vehicles or mobile machinery).
  + Potential for exposure to dust, dirt, and other contaminants.
  + More variable and potentially noisy power supply.
* **Typical Applications:**
  + Automotive electronics.
  + Equipment in construction vehicles.
  + Portable military gear.
  + Electronics in transport trucks or mobile units.

**Impact on MTBF**

**Ground Benign MTBF:**

* Components are expected to have higher MTBF values because they operate under optimal conditions with minimal stress.
* Example MTBF might be 1,000,000 hours for a microcontroller in an office setting.

**Ground Mobile MTBF:**

* Components are expected to have lower MTBF values due to increased stress and harsher operating conditions.
* Example MTBF might be 200,000 hours for the same microcontroller when used in an automotive application.

**Why the Difference?**

* **Stress Factors:** Higher temperatures, mechanical vibrations, and environmental contaminants can accelerate wear and tear on components.
* **Failure Modes:** Different failure modes may become more prevalent in harsher conditions (e.g., thermal cycling can cause solder joints to crack).
* **Degradation Rates:** The rate of degradation for materials and electronic components increases under stress, reducing their operational lifespan.

**Practical Example**

Assume you have a microcontroller with the following MTBF values:

* **Ground Benign:** 1,000,000 hours.
* **Ground Mobile:** 200,000 hours.

This implies that the microcontroller is expected to last, on average, 1,000,000 hours in a controlled, stable environment before a failure occurs. However, in a mobile, more stressful environment, the same microcontroller is expected to last, on average, only 200,000 hours before a failure occurs.

**Summary**

When designing and evaluating the reliability of a system, it is crucial to consider the operational environment. Components may have significantly different MTBF values depending on whether they are used in ground benign or ground mobile conditions. This helps in making informed decisions about component selection and system design to ensure reliability under the expected operational conditions.

<https://forums.raspberrypi.com/viewtopic.php?t=260388>

<https://forums.raspberrypi.com/viewtopic.php?t=211764#:~:text=With%20a%20proper%20power%20supply,application%20class)%20you%20can%20find>.

<https://aldservice.com/Free-MTBF-Calculator.html>