Components Parameter Estimation with References

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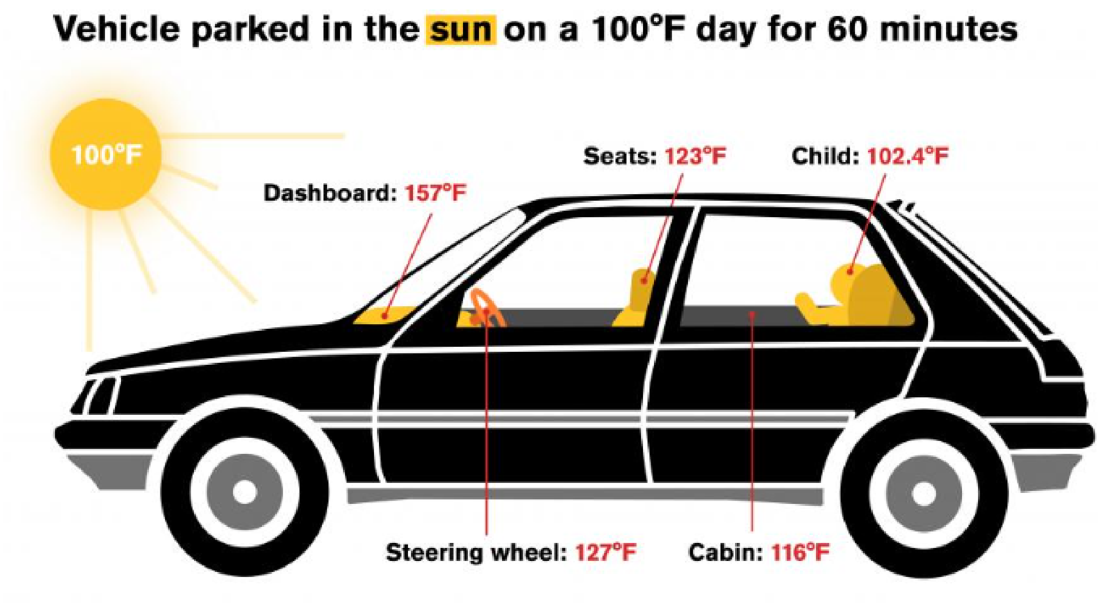
Parameters applicable to overall device

1) Operating Temperature

- The operating temperature claimed by the commercially available telematics devices is in the range of -40° C to +85° C.
- In India the highest temperature ever recorded was 51.0 °C (123.8 °F) in Phalodi, Rajasthan and the lowest Temperature ever recorded was -48 °C (-54.4 °F) in Drass, Jammu and Kashmir.
- From the research studies performed we can infer that the car temperature can reach up to 20°C greater than ambient temperature, making the upper limit close in our case close to 71°C to 75°C. For the lower limit, the temperature will always be greater than the lowest temperature.
- The results of the study performed at Arizona State University to measure temperatures inside the car on a 100°F (37.7°C) day can be seen as follows:



The maximum Temperature reached was 157°F(69°C) which was on the dashboard of the vehicle.

- Thus, for the telematics device in our case, the ideal temperature range would be **-40°C to 80°C.**

References:

1. [List of countries and territories by extreme temperatures - Wikipedia]
2. [Temperature variations in a parked vehicle - ScienceDirect]
3. [PARKED CARS GET DANGEROUSLY HOT, EVEN ON COOL DAYS, STANFORD STUDY FINDS | News Center | Stanford Medicine]
4. [Study: Hot cars can hit deadly temperatures in as little as one hour | ASU News]
5. [(PDF) Maximum Vehicle Car Temperatures under Different Meteorological Conditions (researchgate.net)]

2) Humidity

- Humidity levels in which the insurance based telematics devices are operational is 5%RH to 95%RH.
- Ideal range of humidity found in cars varies from 40%RH to 60%RH.
- 40 - 60% RH is ideal for vehicles as this is dry enough to prevent condensation, mould and rust forming without being too dry in order not to dry leather interiors or rubber tyres out excessively.
- Hence, for the purpose of the device being developed, the device must be operational in a range of **5%RH to 95%RH**.

References:

1. [Categorisation for air quality assessment in car cabin - ScienceDirect]
2. https://www.mdpi.com/1996-1073/13/11/2987
3. [Standard 55 – Thermal Environmental Conditions for Human Occupancy (ashrae.org)]

3) Dimensions

- Considering the proposed location and placement of the device in the car and after benchmarking other devices in this segment, the dimensions of the device would be **150 x 100 x 50 mm**.

References:
1. Benchmarked data of telematics devices for insurance based telematics: Benchmarked telematics devices - Google Sheets
2. Proposed device placement in car: Low Cost Telematics Device Design Flow and Methodology - Google Docs

4) Weight

- From the Benchmarking done, the estimated weight of the device should be in the range of **75 to 120 grams**.

References:
1. Benchmarked data of telematics devices for insurance based telematics: Benchmarked telematics devices - Google Sheets

5) Cost

- From the benchmarked data of telematics devices most of the telematics devices offering similar functionalities have a cost in the range of $85 to $200 (₹6800 to ₹16000).
- Considering the bill of materials cost, housing cost and cost of manufacturing the PCB for the telematics device in the scale of 2 to 5 devices the total cost would lie in the range of **₹ 8200 to ₹ 9500.**

References:
1. Benchmarked data of telematics devices for insurance based telematics: Benchmarked telematics devices - Google Sheets
2. Total estimated cost of telematics device: Benchmarked data.xlsx - Google Sheets

Parameters specific to components:

1) Global positioning system receiver module

a) Receiver Sensitivity

- It is the lowest signal level at which a GNSS receiver is able to track and achieve a position fix on overhead satellites. If the receiver receives a signal that is lower than this level, it is not able to get a position fix.
- From the benchmarking performed we can observe that the range of receiver sensitivities is from -164 dBm to -167 dBm.
- Telematics device manufacturers like Ruptela and Atrack are using the Ublox EVA M8M modules with receiver sensitivity of -167 dBm while manufacturers like Teltonika have used their own GPS receiver modules having receiver sensitivity of -165 dBm.
- Automotive grade GPS module IC’s commercially available also have a receiver sensitivity in the range of -163 dBm to -167 dBm.
- Hence the device being developed must have a receiver sensitivity in the range of **-164 dBm to -167 dBm.**

References:

1. Benchmarked data of telematics devices for insurance based telematics: Benchmarked telematics devices - Google Sheets
2. Commercially available GPS receiver modules : Benchmarked data.xlsx - Google Sheets

b) Time to First Fix (TTFX)

- Time to First Fix (TTFF) describes the time and process required for a GPS device to acquire enough satellite signals to provide accurate navigational information.
- There are usually three categories that TTFF is split up into:
- A "cold" or "factory" start refers to a situation in which the GPS device must acquire all data in order to start navigation, like if the

device is brand new or has recently been factory reset. TTFF may take up to 12 minutes.

- A "warm" or "normal" start means the GPS has most of the data it needs in its memory and within a minute or less. A warm start happens when the device has been off for a day or so, but not off for so long that the data is outdated.
- "Hot" or "standby" is when the GPS device can get a signal quickly since it already has a valid position and correct almanac and ephemeris data. The device has normally been off for just a few hours.
- Most of the Telematics devices have cold start times in the range of 32 to 35 seconds, warm start time of 25 to 35 seconds and hot start time of 1 to 2 seconds.
- Hence for the device being developed the cold start, warm start and hot start timings must be in the range of **30 to 35 seconds, 22 to 25 seconds and 1 to 2 seconds** respectively.

References:

1. Benchmarked data of telematics devices for insurance based telematics: Benchmarked telematics devices - Google Sheets
2. Commercially available GPS receiver modules : Benchmarked data.xlsx - Google Sheets

c) Accuracy Range

- GPS Accuracy refers to the degree of closeness of the indicated readings to the actual position.
- Most insurance based Telematics devices have an accuracy of 2.5m.
- Hence a GPS accuracy range of **2 to 2.5m** would be conducive for the telematics device being developed.

References:

1. Benchmarked data of telematics devices for insurance based telematics: [Benchmarked telematics devices - Google Sheets]

d) Number of channels

- The number of channels that the GPS module runs will affect the time to first fix (TTFF). Since the module doesn't know which satellites are in view, the more frequencies/channels it can check at once the faster a fix will be found.
- Insurance based Telematics devices currently available in the market have GPS channels ranging from 33 to 99 channels.
- Number of channels for the telematics device being developed, should be in the range of **72 to 99 channels** to maintain signal strength in even .

References:

1. Benchmarked data of telematics devices for insurance based telematics: [Benchmarked telematics devices - Google Sheets]

2) Inertial measurement unit

a) Range

- It is the greatest amount of acceleration and angular velocity can be measured and accurately represented as an output.
- Atrack Telematics devices have a 3 axis accelerometer with ±16g range and a 3 axis gyroscope with a range of ±2000 dps, other devices do mention usage of a 3 axis accelerometer but are not using a gyroscope.
- For the application of telematics device the accelerometer range must lie between **±16g to ±32g** and the gyroscope must have a range of **up to ±2000 dps**.

- The reason for selecting the following ranges is that the accelerometer plays an instrumental role in crash detection and hence must be able to sustain and detect crashes which generally happen in the range of 10g to 20g.
- Similarly the gyroscope data can be useful for roll-over detection and shock detection.

References:

1. Benchmarked data of telematics devices for insurance based telematics: Benchmarked telematics devices - Google Sheets
2. NXP Automotive Gyroscope for Safety Applications | NXP Semiconductors
3. Thresholds g-forces for Accident Detection | Download Table (researchgate.net)

b) Output data rate

- The Output data rate refers to the number of samples of data recorded every second.
- Since the data is to be recorded on a micro-SD card, the data rate must meet the criteria of having sufficient data samples to analyse data effectively as well as not generate large amounts of data which will become difficult to analyse and make the micro-SD card full in a very short span of time.
- Hence the ideal data rate for the telematics device being developed must be in the range of **100 Hz to 1000 Hz**.
- Previous tests conducted at 1.34KHz, 6.67KHz and 26.67KHz yielded approximately similar data accuracy, however higher sampling rates namely 6.67KHz and 26.67KHz generated gigabytes of data for a 15 minute test, making such rates unfeasible for long test as they will make the micro-SD card full in a very short time period.

References:

1. Connectivity and data plans shaping modern fleet management (motion-s.com)
2. IJGI | Free Full-Text | What is an Appropriate Temporal Sampling Rate to Record Floating Car Data with a GPS? (mdpi.com)
3. Commercially available IMU sensors with sampling rates: Benchmarked data.xlsx - Google Sheets

c) Bias Instability

- The bias is a constant offset of the output value from the input value.The bias instability is a measure of how the bias will drift during operation over time at a constant temperature. This parameter also represents the best possible accuracy with which a sensor's bias can be estimated.
- The ideal bias instability for automotive applications as inferred from the references must be **less than 500μg** for the accelerometer and **less than 0.03°/s** for the gyroscope.

References:

1. tronics_microsystems_-_white_paper_-_an_overview_of_mems_and_non-mems_high_performance_gyros.pdf (tdk.com)
2. Sensors | Free Full-Text | Customizable Stochastic High-Fidelity Model of the Sensors and Camera Onboard a Fixed Wing Autonomous Aircraft (mdpi.com)

d) Random Walk

- If a noisy output signal from a sensor is integrated, for example integrating an angular rate signal to determine an angle, the integration will drift over time due to the noise. This drift is called random walk, as it will appear that the integration is taking random steps from one sample to the next.
- The two main types of random walk for inertial sensors are referred to as angle random walk (ARW), which is applicable to

gyroscopes, and velocity random walk (VRW), which is applicable to accelerometers.

- The ideal values of angle random walk for automotive applications should be **less than 0.6m/sec/√h** and the velocity random walk must be **less than 1°/√h** as inferred from references.

References:

1. tronics_microsystems_-_white_paper_-_an_overview_of_mems_and_non-mems_high_performance_gyros.pdf (tdk.com)
2. Sensors | Free Full-Text | Customizable Stochastic High-Fidelity Model of the Sensors and Camera Onboard a Fixed Wing Autonomous Aircraft (mdpi.com)
3. Choosing the Most Suitable MEMS Accelerometer for Your Application—Part 1 | Analog Devices

e) Noise Density

- Noise density provides the value of noise divided by the square root of the sampling rate.
- From the references we can infer that the ideal noise density for the accelerometer and gyroscope must be **less than 500µg/√Hz and 1000mdps/√Hz** respectively.

References:

1. tronics_microsystems_-_white_paper_-_an_overview_of_mems_and_non-mems_high_performance_gyros.pdf (tdk.com)
2. Sensors | Free Full-Text | Customizable Stochastic High-Fidelity Model of the Sensors and Camera Onboard a Fixed Wing Autonomous Aircraft (mdpi.com)
3. Choosing the Most Suitable MEMS Accelerometer for Your Application—Part 1 | Analog Devices

3) Temperature and Humidity Sensor

a) Operating values

- From the analysis done above we can infer that the temperature and humidity sensor must effectively be able to measure temperatures in the range of **-40°C to 80°C** and humidity in the range of **5%RH to 95%RH.**

References:

1. Benchmarked data of telematics devices for insurance based telematics: Benchmarked telematics devices - Google Sheets
2. Categorisation for air quality assessment in car cabin - ScienceDirect
3. Temperature variations in a parked vehicle - ScienceDirect

b) Accuracy

- The primary reason for using a Temperature and Humidity sensor is to detect any anomalous change in Temperature and Humidity inside the car cabin that may harm the telematics device.
- Considering the application of the Telematics device being used, the accuracy range of the temperature sensor can be **±0.2 to ±0.3°C** and the accuracy range of the humidity sensor can be in the range of **±2 to ±3%RH**.

References

1. Precautions for Temperature and Humidity Sensor Measurement-Product News-Guangzhou Aosong Electronic Co., Ltd.
2. Sensor Accuracy over Time | HW-group.com