Exposure Calculation Report

Silicon Laboratories Finland Oy
Radio Module, Model: MGM240L

In accordance with FCC CFR 47 Part 2.1091 and Health Canada Safety Code 6

Prepared for: Silicon Laboratories Finland Oy
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Matthew Russell	Senior Engineer (RF)	Authorised Signatory	17 June 2022

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EXECUTIVE SUMMARY
The calculation of exposure for this product was found to be compliant at a minimum distance of 20 cm with FCC CFR 47 Part 2.1091 and Health Canada Safety Code 6 assuming continuous exposure of 6 minutes or more. If alternative antennas are used with greater gains, the distance must be recalculated.

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Contents

1 Report Summary

1.1 Report Modification Record

Alterations and additions to this report will be issued to the holders of each copy in the form of a complete document.

Issue	Description of Change	Date of Issue
1	First Issue	17-June-2022

Table 1

1.2 Introduction

Applicant	Silicon Laboratories Finland Oy
Manufacturer	Silicon Laboratories Finland Oy
Model Number(s)	MGM240L
Hardware Version(s)	1.0
Software Version(s)	4.0.x (Gecko SDK)
Specification/Issue/Date	• FCC 47 CFR Part 2.1091: 2020 Radiofrequency radiation exposure evaluation: mobile devices • ISED Canada: Health Canada Safety Code 6:2015
Order Number Date	6000479546 / 00 / 03 24-March-2022
Related Document(s)	• FCC 47 CFR Part 1.1310: 2020 Radiofrequency radiation exposure limits • OET65:97 Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields

1.3 Brief Summary of Results

The wireless device described within this report was compliant with the restrictions related to human exposure to electromagnetic fields for both general public and worker/occupational exposures at the minimum compliance distances calculated.

The calculations shown in this report were made in accordance with the procedures specified in the applied test specification(s).

1.3.1 Configuration - Single Transmitter

Regional Requirement	RAT	Calculated RF exposure level at minimum compliance boundary of 0.2m							
		S Power Density (W/m^2)		E Field (V/m)		H Field (A/m)		B Field (µT)	
		Result	Limit	Result	Limit	Result	Limit	Result	Limit
FCC	Bluetooth Low Energy	0.02	50.00	2.69	N/A	0.0071	N/A	0.0090	N/A
FCC	802.15.4	0.02	14.48	2.95	N/A	0.0078	N/A	0.0098	N/A
CANADA	Bluetooth Low Energy	0.02	31.64	2.69	109.21	0.0071	0.2897	0.0090	N/A
CANADA	802.15.4	0.02	13.45	2.95	71.22	0.0078	0.1889	0.0098	N/A

Table 2 – Worker/Occupational Exposure Results

The calculations show that the EUT complies with the worker/occupational exposure levels described in in the listed specifications in Annex A at the point of investigation, a minimum of 0.2 m.

Regional Requirement	RAT	Calculated RF exposure level at minimum compliance boundary of 0.2m							
		S Power Density (W/m^2)		E Field (V/m)		H Field (A/m)		B Field (µT)	
		Result	Limit	Result	Limit	Result	Limit	Result	Limit
FCC	Bluetooth Low Energy	0.02	10.00	2.69	N/A	0.0071	N/A	0.0090	N/A
FCC	802.15.4	0.02	2.90	2.95	N/A	0.0078	N/A	0.0098	N/A
CANADA	Bluetooth Low Energy	0.02	5.35	2.69	44.91	0.0071	0.1191	0.0090	N/A
CANADA	802.15.4	0.02	1.66	2.95	25.03	0.0078	0.0664	0.0098	N/A

Table 3 – General Public Exposure Results

The calculations show that the EUT complies with the general public exposure levels described in in the listed specifications in Annex A at the point of investigation, a minimum of 0.2 m.

1.4 Product Information

1.4.1 Technical Description

Internally regulated, and shielded, PCB radio module implementing the Bluetooth Low Energy (BLE) and 802.15.4 wireless standard protocols, to enable low-power wireless communication for IoT applications. The BLE portion supports the 1M, 2M, and 125/500K coded PHYs from the spec, all based on the GFSK modulation. The 802.15.4 portion provides the base wireless protocol for higher-level communication standards like Zigbee and Thread. The product comes in a single hardware variant with an integral antenna, a meandered inverted F PCB trace.

1.4.2 Transmitter Description

The following radio access technologies and frequency bands are supported by the equipment under test.

Radio Access Technology	Frequency Band (MHz)	Minimum Frequency (MHz)	Output Power (dBm)	Duty Cycle (%)
Bluetooth Low Energy	2400	2402	10	83
802.15.4	2400	2405	10	100

Table 4 – Transmitter Description

Note: Transmitter power includes upper bounds of uncertainty therefore maximum values are used in accordance with Section 2.4.

1.4.3 Antenna Description

The following antennas are supported by the equipment under test.

Radio Access Technology	Antenna Model	Gain (dBi)	Antenna length (cm)	Minimum Separation Distance (cm)
Bluetooth Low Energy	Integrated PCB trace antenna	+0.64	3.5	20
802.15.4	Integrated PCB trace antenna	+0.64	3.5	20

Table 5 – Antenna description

In the case of more than one type of antenna being supported by the equipment, the calculation is based on the maximum of the antenna gains. If other antennas can be used that have greater gains, the minimum separation distances will need to be recalculated.

Note: Antenna gain includes upper bounds of uncertainty therefore maximum values are used in accordance with Section 2.4.

2 Assessment Details

2.1 Assessment Method

The assessment method is by calculation of the power density S, electric field strength E, magnetic field strength H or magnetic flux density B.

The calculation uses the spherical model applicable under far field conditions and also radiating near field conditions where applicable (see Section 2.4).

$$S = E \times H = \frac{E^2}{\eta} = H^2 \times \eta = \frac{P \times G_i}{4 \times \pi \times r^2}$$

Where:
η - Impedance of free space (377 ohm in far field)
P – Average transmitter power W (P_{av} = P_{max} x Duty Cycle)
G_i – Antenna gain ratio relative to isotropic
r – Separation distance m

The magnetic flux density is related to the magnetic field strength by a constant:

$$B = \mu_o \times H$$

Where:
μ_o – Permeability of free space 4 x π E-7 H/m

This assessment assumes that exposure is continuous for 6 minutes or more in accordance with the averaging time required by the exposure standards at the stated minimum compliance boundary separation distance. Exposures of less than 6 minutes at other separation distances are not addressed by this report.

This assessment method of RF exposure is applicable to separation distances of 20 cm or more beyond the reactive near field boundary. Separation distances of less than 20 cm require a Specific Absorption Rate (SAR) assessment.

The reactive near field boundary and far field region boundary depend on the frequency and wavelength and also on the antenna dimension. The boundaries of the field regions are calculated in Section 2.3 to demonstrate the validity of using the spherical model.

The result is compared to the limits in Annex A to determine compliance or to calculate the required compliance distance. The calculation is based on the lowest frequency in each band as the most onerous requirement as the limits increase with frequency for frequencies above 10-50 MHz (dependent on region).

2.2 Individual Antenna Port Exposure Results

2.2.1 Calculation of Exposure at Specified Separation Distance

The frequencies shown in the tables below have been chosen based on the lowest possible frequency that the EUT can transmit. A full list of the regional requirements is shown in Annex A.

Regional Requirement	RAT	Frequency (MHz)	RF Exposure Level at minimum compliance boundary of 0.2 m							
			S Power Density (W/m^2)		E Field (V/m)		H Field (A/m)		B Field (µT)	
			Result	Limit	Result	Limit	Result	Limit	Result	Limit
FCC	Bluetooth Low Energy	2402	0.02	50.00	2.69	N/A	0.0071	N/A	0.0090	N/A
FCC	802.15.4	2405	0.02	14.48	2.95	N/A	0.0078	N/A	0.0098	N/A
CANADA	Bluetooth Low Energy	2402	0.02	31.64	2.69	109.21	0.0071	0.2897	0.0090	N/A
CANADA	802.15.4	2405	0.02	13.45	2.95	71.22	0.0078	0.1889	0.0098	N/A

Table 6 – Worker/Occupational Individual Transmitter Result

The calculations show that the EUT complies with the worker/occupational exposure levels described in in the listed specifications in Annex A at the point of investigation, a minimum distance of 0.2 m.

Regional Requirement	RAT	Frequency (MHz)	RF Exposure Level at minimum compliance boundary of 0.2 m							
			S Power Density (W/m^2)		E Field (V/m)		H Field (A/m)		B Field (µT)	
			Result	Limit	Result	Limit	Result	Limit	Result	Limit
FCC	Bluetooth Low Energy	2402	0.02	10.00	2.69	N/A	0.0071	N/A	0.0090	N/A
FCC	802.15.4	2405	0.02	2.90	2.95	N/A	0.0078	N/A	0.0098	N/A
CANADA	Bluetooth Low Energy	2402	0.02	5.35	2.69	44.91	0.0071	0.1191	0.0090	N/A
CANADA	802.15.4	2405	0.02	1.66	2.95	25.03	0.0078	0.0664	0.0098	N/A

Table 7 – General Public Individual Transmitter Result

The calculations show that the EUT complies with the general public exposure levels described in in the listed specifications in Annex A at the point of investigation, a minimum distance of 0.2 m.

2.3 Far Field Region Boundary Results

The far field region boundary calculation result is shown in Table 8:

Near Field / Far Field Boundary (Ref: FCC 1.1307(b)(3)(i)(C), Technical Guide for Interpretation and Compliance Assessment of Health Canada's Radiofrequency Exposure Guidelines 7.1)			
RAT Name	Frequency MHz	Reactive Near Field Boundary (Wave Impedance Dependent)	Far Field Boundary (Antennas on axis)
		$\lambda/2\pi$ (m)	$2D^2/\lambda$ (m)
Bluetooth Low Energy	2402	0.0199	0.0199
802.15.4	2405	0.1099	0.1099

Table 8 – Far Field Boundary (FCC, CANADA)

The table below shows the maximum calculated near field / far field region boundaries.

The compliance boundary of 0.2 m is in the far field region and therefore, the approach described in section 2.1 is valid.

Field Region	Reactive Near Field Region	Radiating Near Field Region	Far Field Region
Maximum Boundary	0.1099 m	N/A	> 0.1099 m
Validity of Regions	Spherical model potential under-estimate: SAR / test assessment required	Spherical model over-estimate and conservative	Spherical model valid
Compliance Boundary Location	N/A	N/A	0.2 m

Table 9 – Assessment Method Validity

2.4 Uncertainty

The basic computation formulas presented in section 2.1 are conservative formulas for the estimation of RF field strength or power density.

No uncertainty estimations are required when using these formulas but there is clear guidance on where and when these formulas are applicable. For the estimate of S, E or H to be conservative, the transmitter power P and antenna gain G_i values shall be the upper bounds of uncertainty therefore maximum values are used. (Reference EN 62232 clause 6.3.1, 6.3.2.1.2).

The spherical formula is valid under far field conditions which are established in section 2.3.

ANNEX A

REGIONAL REQUIREMENTS

Frequency Range (MHz)	Power Density (mW/cm^2) Note 1	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
0 - 0.3	-	-	-
0.3 - 3	100	614	1.63
3 - 30	900/f^2	1842/f	4.89/f
30 - 300	1	61.4	0.163
300 - 1500	f/300	-	-
1500 - 100000	5	-	-

Table A.1 – FCC CFR 47 Pt.1.1310 Worker/Occupational Limits

Frequency Range (MHz)	Power Density (mW/cm^2) Note 1	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
0 - 0.3	-	-	-
0.3 - 3	100	614	1.63
3 - 30	180/f^2	824/f	2.19/f
30 - 300	0.2	27.5	0.073
300 - 1500	f/1500	-	-
1500 - 100000	1	-	-

Table A.2 – FCC CFR 47 Pt.1.1310 General Public Limits

Note 1: The calculations and limits presented in this report for power density are in units of W/m^2. The conversion factor is; 1 mW/cm^2 = 10 W/m^2.

Frequency Range (MHz)	Power Density (W/m^2)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
10 - 20	10	61.4	0.163
20 - 48	44.72/f^0.5	129.8/f^0.25	0.3444/f^0.25
48 - 100	6.455	49.33	0.1309
100 - 6000	0.6455*f^0.5	15.60*f^0.25	0.04138*f^0.25
6000 - 150000	50	137	0.364

Table A.3 – Health Canada Safety Code 6 Worker/Occupational Limits

Frequency Range (MHz)	Power Density (W/m^2)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
10 - 20	2	27.46	0.0728
20 - 48	8.944/f^0.5	58.07/f^0.25	0.1540/f^0.25
48 - 300	1.291	22.06	0.05852
300 - 6000	0.02619*f^0.6834	3.142*f^0.3417	0.008335*f^0.3417
6000 - 15000	10	61.4	0.163

Table A.4 – Health Canada Safety Code 6 General Public Limits