Micromite GPS LoRa MOTE

Micromite GPS LoRa MOTE is targeted to design engineers to quickly evaluate LoRaWAN and its sensor applications. Micromite is a PIC32MX170 microcontroller firmware that is based on Geoff Graham's MMBasic interpreter (http://geoffg.net/micromite.html) that allows convenient application software development in BASIC language. Micromite through its serial console interface provides support for program editing, debugging plus communication with the BASIC application. This is an excellent environment for LoRaWAN applications because no other compiler, no other hardware debugger and programmer is required for software development. The console port of Micromite has built in USB-UART bridge (http://www.microchip.com/MCP2221A) that allows single USB connection to the free MM Edit integrated development environment (http://www.c-com.com.au/MMedit.htm). The USB connection is used also for charging the internal LiPo battery. The GPS Mode is intended to analyze how large is the geographic coverage of LoRaWAN even from a moving vehicle. The Sensor Mode is targeted for demonstration of fixed position sensor networks. Beside internal sensors the Micromite GPS LoRa MOTE has a peripheral connector for handling external sensors or actuators. This option is demonstrated by GSS COZIR CO2 sensors (https://shop.chipcad.hu/Welcome/Default.aspx?scenarioID=360&pid=1878), however, users are encouraged to implement their own sensor support through two UART, one I2C and three digital/analog/PWM peripheral lines to discover LoRaWAN capabilities in their own Proof of Concept projects. The latest BASIC program version and full documentation of the MOTE can be downloaded from here:

http://www.chipcad.hu/letoltes/MMGPSMOTE.zip

Operation modes and changing between modes

- Console mode
  Purpose: MMBasic program development.
  MMBasic application can be broken by "control C" on Console
  MMBasic application can be restart again by "run" command.
  See: Micromite User Manual http://geoffg.net/Downloads/Micromite/Micromite%20Manual.pdf
  Micromite Kézikönyv http://www.chipcad.hu/letoltes/MkII-magyar.pdf
- Service mode: *See: Appendix D, Service Mode*
- GPS Mode: *See below*
- Sensor mode: *See below*
- C Class operation, Multicast Demo: *See below*

Micromite GPS LoRa MOTE has one push button and three LEDs. The yellow LED lights while battery is charged from micro USB connector. The yellow light stops when battery is fully charged (4.2V). The built in **MCP73831T-2ACI/OT** (https://shop.chipcad.hu/Welcome/Default.aspx?scenarioID=301&StockCode=MIC3875#TabControl-2) battery charger circuit controls charging and during discharging disconnects itself from battery at 3.5V. The green and red LEDs are controlled by Micromite MMbasic application. While application is up and running, one of them is pulsing once in every second but both LEDs are dark during Micromite sleep. The green LED pulses during satellite acquisition and trace or sensor measurements then after valid values are captured red LED pulses till the end of LoRaWAN transmit. During satellite acquisition and trace Micromite monitors if push button is pressed. The program differentiates between short, long and very long button presses. The short press should last less than a second and the long one should last till the red LED lights or the very long till both LEDs light continuously. The short button press initiates one sensor measurement and transmit to LoRaWAN. The long button press changes operation mode from GPS to Sensor. The very long button press changes operation to Multicast demo mode. In

Sensor Mode the long button press can also be used to change mode back to GPS but because of long sleep times, the button should be pressed till green LED lights (not longer than a minute). Because of the long sleep times the short button press is not defined in Sensor Mode. From Multicast Demo mode the long button press can change back to GPS Mode also (maximum length of button press can be up to 15 seconds).

1. GPS Mode

Micromite GPS LoRa MOTE has a built in SQ-SEN-200 motion sensor that allows GPS operation in GPS Mode. While motion is detected the MOTE searches GPS/GNSS satellites and if valid coordinates are captured then transmits them to LoRaWAN four times in every minute. After 6 minutes without motion the MOTE goes to sleep for unlimited time then only its SQ-SEN-200 motion sensor can wake it up. In a moving vehicle Micromite GPS LoRa MOTE operates continuously and after stopping the MOTE automatically puts itself in low power consumption sleep mode. The frequency of coordinate broadcasts will strongly influence total power consumption. After each transmit the MOTE goes to sleep for **short sleep time** that is at least 5 seconds but it can be extended up to 260 seconds by downlink message. The downlink message can modify cycle time of coordinate broadcast from quarter minute to four minutes. The 4minute cycle time consumes 16 times less energy than ¼ minute cycle time so it extends battery life 16 times longer. See: *Appendix B: GPS Modes of operation.*

Micromite GPS LoRa MOTE can handle external sensors and as example an optional CO2 COZIR sensor can be connected to peripheral connector (https://shop.chipcad.hu/Welcome/Default.aspx?scenarioID=360&pid=1878). When Micromite GPS LoRa MOTE is operated in a car and an optional CO2 sensor plus a buzzer is connected, the MOTE measures CO2 concentration before going to sleep. When CO2 value exceeds the programmable **CO2 concentration limit** an audible alert sound is generated to warn vehicle driver to switch on incoming fresh air inflow for avoiding drowsiness and finally prevent accidents. This danger is shown in BBC report with GSS. https://www.youtube.com/watch?v=bNXup6E7P1g

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8 bytes "**Short payload**" ChipCAD uplink format in GPS Mode:

Port	Payload
202	4370550d860b0083

Port number 202

Payload:

latitude 24bit signed number, angle domain -90 to +90 degrees

longitude 24bit signed number, angle domain -180 to +180 degrees

altitude 16bit unsigned number, height domain 0 to 15000 meters

Minimum LoRaWAN transmit cycle time range: 15sec - 270sec

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14 bytes "**Long payload**" ChipCAD uplink format in GPS Mode:

Port	Payload
202	4370550d860b00830112931417 23

Port number 202

Payload:

latitude 24bit signed number, angle domain -90 to +90 degrees

longitude 24bit signed number, angle domain -180 to +180 degrees

altitude 16bit unsigned number, height domain 0 to 15000 meters

HDOP 8bit unsigned number, ten times Dilution of Precision parameter, domain 1 to 250

Temperature 8bit signed number, internal temperature, domain -128 to 127 degrees

Battery charge 2 BCD digits, percentage domain 1%-99%, relative charge between 3.5V-4.2V

GPS timestamp HHMMSS 3 bytes
Minimum LoRaWAN transmit cycle time range: 25sec - 280sec

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16 bytes Semtech GPS LoRa MOTE payload format is available to utilize online tracking application of Loriot NS

Port	Payload
2	00000000000000514383a0d921d009a

Port number 2
Payload:
battery voltage 1-254 relative charge of battery
latitude 24bit signed number, angle domain -90 to +90 degrees
longitude 24bit signed number, angle domain -180 to +180 degrees
altitude 16bit unsigned number, height domain 0 to 15000 meters
Minimum LoRaWAN transmit cycle time range: 15sec - 270sec

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12 bytes Adeunis GPS format is available to utilize online tracking application of Loriot NS

Port	Payload
1	d2164728239001905030f11

Port number 1
status 1 byte
temperature 1 byte
latitude 4 byte BCD, angle domain -90 to +90 degrees
longitude 4 byte BCD, angle domain -180 to +180 degrees
battery voltage 16bit binary [mv]
Minimum LoRaWAN transmit cycle time range: 15sec - 270sec

In GPS Mode the MOTE transmits with DR=0 and DR=6 data rates alternately. The default DR0:DR6 ratio is 1:1, one DR6 packet is inserted between each DR0 packets. The number of inserted DR6 packets can be set from 0 to 15. When this number is 0 the transmit duty cycle is 1% per channel at 15second transmit cycle time. When the number of inserted DR6 packets is 15, the transmit duty cycle is only 0.06% on Multi SF channels and only 0.025% on DR6 channel. The 17dB sensitivity difference between DR0:SF12/125kHz and DR6:SF7/250kHz can be significant in urban areas but it is usually compensated by high density of gateways. If radio propagation is influenced by reflected radio waves then it is better to keep number of DR6 packets low. In case of airplanes or boats this number can be increased without increasing PER packet error rate. Using mainly DR6 avoids interference problems with fixed sensor networks and lowers interference with portable vehicles that are using mainly DR0. Users are encouraged to optimize tracking their moving applications by this parameter.

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10 bytes status of Micromite GPS LoRa MOTE. Status contains BASIC variables that are stored in Flash memory. Except program version all BASIC variables can be modified by downlink messages, see “4. Downlink: Control from application server”.

Port	Payload
203	2306051300000ffff0386

Port number 203
GPSDeviceID: Higher hex digit. 0 walk, 1 bike, 2 car, 3 boat, 4 airplane, 5 balloon, E Semtech GPS Format, F Adeunis GPS- format. ID domain: 0 to 15

OnePPSMin: Lower hex digit. The number of 1PPS pulses before GPS measurement. Domain 1 to 15
MaxTime: One byte. Inactivity time of motion sensor (in minutes) in GPS Mode before sleep. Domain 1 to 255
GPSFullOperationTime: One byte. Full ON power time in minutes. Domain 1 to 255
NRofDR6: Higher hex digit, number of DR6 between DR0 transmits in GPS Mode. Domain 0 to 15
NumberOfUncnfInSensorMode: Lower hex digit. One quarter of UNCNF number between CNF transmits: 1 to 15
Short Sleep Time 8 bit unsigned number. In second this time is added to sleep time of GPS mode: 0 to 255
Long Sleep Time 8 bit unsigned number. In minute this time is added to sleep time of sensor mode: 0 to 255
CO2 limit 16 bit unsigned number. If limit is above 10000 the CO2 measurement is ignored in GPS mode and interim wakeups in sensor mode. Domain 0-65535. The limit value 65534 initiates beacon activity of sensor mode: after transmitting sensor payload, the node sends status and GPS payloads additionally. This is useful for checking operation of network server plus application servers. Beacon GPS payload coordinates are static, longitude and latitude are repeated from last GPS measurement and the altitude is zero. The zero altitude differentiates real static GPS payload from payload of real GPS Mode. If altitude is zero, the coordinates are transmit from stored variables, if not zero than coordinates are generated by GPS receiver.
BASIC program version number four BCD digit. This variable is set by programming of Micromite. Actual version is 3v86.

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2. Sensor Mode

Sensor Mode is targeted to fixed position sensor applications. GPS/GNSS receiver is switched off, the MOTE uses its internal and optional external sensors. The internal temperature and battery voltage sensors can be supplemented by external sensors through peripheral connector of the MOTE. For quick learning we offer a Micromite Peripheral Panel and an optional GSS COZIR sensor then users are encouraged to use own sensors. The MOTE periodically measures sensors then transmits their values to LoRaWAN. Between measurements Micromite switches off all peripherals and goes to sleep for **long sleep time** that is at least 1 minute but it can be extended up to 256 minutes by downlink message. The longer the **long sleep time** the lower the power consumption.

In Sensor Mode the MOTE uses adaptive data rate, automatically employs the highest bit rate for reliable LoRaWAN communication. See Appendix E

Though long sleep time can be extended up to 256 minutes Micromite wakes up once in every minute for a short while and checks if button is pressed or not. If it is pressed, then and lights green LED and goes back to GPS Mode when the button is released. The MOTE has an intelligent CO2 concentration measurement option to optimize power consumption. An upper CO2 limit can be set by downlink message. If CO2 limit is not activated then it measures sensors only at the end of long sleep time. If upper CO2 limit is activated, the CO2 concentration is measured once in every minute. If measured value is higher than upper limit the MOTE transmits sensor data immediately whatever time is set for long sleep time. If measured value is less than the limit then MOTE goes back to sleep without transmitting it.

14 bytes uplink message in Sensor Mode:

Port	Payload
209	12ca02ed01e912112009c401201e9

Port number 209
Temperature 8bit signed number, temperature domain -128 to 127 degrees
Battery voltage 8bit BCD number, percentage domain 1%-99%, relative charge, voltage between 3.5V-4.2V
The battery voltage is updated at every wakeup from sleep. The battery voltage is also available for network server to request through packet header. The 3.5V-4.2V battery voltage domain is normalized to 1 to 254 single

byte value. The network server can request this value at any time.
COZIR CO2 concentration 16bit unsigned number, ppm domain: 400 to 10000
COZIR relative humidity 16bit unsigned number, ‰ domain: 0-1000
COZIR temperature 8bit signed number, temperature domain: -128 to 127 degrees
Temperature of SM1131 8bit signed number, internal temperature, domain -50 to 85 degrees
Air-pressure of SM1131 24bit unsigned number, pressure domain 400 to 1800 hPa
TH06 temperature 8bit signed number, temperature domain: -128 to 127 degrees
TH06 **relative humidity** 16bit unsigned number, ‰ domain: 0-1000

3. C-Class operation, Multicast Demo Mode

C-Class, Multicast Mode demonstrates how to use RN2483 LoRa module in C-Class and how to put several nodes into Multicast operation at the same time. The RN2483 module of the MOTE is preprogrammed with ABP keys in A-Class. During the demo the Micromite temporally changes the LoRa module keys (deveui, devaddr, nwkskey and appskey) to a C-Class node's ABP keyset then keeps open an RX2 window continuously. The application server can send command to the node any time and the node is capable to decode and execute the command. We use an RGB color LED connected directly to PWM 1 peripheral and control the colors by http://www.mylora.hu/demo.
Many nodes can receive and execute commands at the same time but this multicast mode is one way communication from the server towards multicast nodes. If confirmations were required we recommend to modifying the Micromite program that after decoding and executing a command the node should change back to its A-Class mode then confirm the new state with an uplink message. Present Micromite BASIC program (3v85 or higher) switches off downlink counter verification in order to allow all nodes to process downlink messages synchronously. However, this technic should be modified in final applications that should prevent interference from downlink message replications, for example with adding a timestamp into payload. The timestamp inside the payload would meet two goals: may prevent the node from processing replicated downlink messages and synchronize RTC of nodes. Nodes shouldn't process downlink messages with timestamp that is less than equal with timestamp of last valid downlink message.

4. Downlink: Control from application server

Operation parameters can be modified from application server. The MOTE interprets five bytes long downlink commands that use port 209 exclusively. The first byte is the command number that has four byte parameters.

Port	Payload
209	00caed07d0

Port number 209
Control: 8bit unsigned number
00: Sets Short Sleep Time, Long Sleep Time and CO2 upper limit without other action. Both Sleep Time are stored in Flash memory.

Short Sleep Time: 8bit unsigned number. In GPS Mode the sleep time will be this parameter plus 5 seconds at short payload and 15 seconds at long payload formats. Time domain: 0 to 255 seconds
Long Sleep Time: 8bit unsigned number. In Sensor Mode sleep time will be this parameter plus 1 minute. Time domain: 0 to 255 minutes.
CO2 upper limit: 16bit unsigned number. Concentration domain: 0 to 65535 ppm or 6.5535%

01: Requests a sensor data in GPS Mode. Same as short push button press in GPS Mode additionally it sets Short Sleep Time, Long Sleep Time and CO2 upper limit.

02: Change Modes of operation. In GPS Mode changes to Sensor Mode and in Sensor Mode back to GPS Mode. Same as long push button press. Additionally, it sets Short Sleep Time, Long Sleep Time and CO2 upper limit.

03: Changes between short and long payload formats in GPS Mode. Additionally, it sets Short Sleep Time, Long Sleep Time and CO2 upper limit.

04: In GPS or Sensor Mode the first 04 command sets Group Filter then changes to C-Class Multicast Mode. In C-Class Multicast mode sets intensities of Red, Green and Blue color LEDs when command filter is identical to the group filter of the node. If Filter=00 the MOTE restarts in GPS Mode.

Port	Payload
209	04221010 10

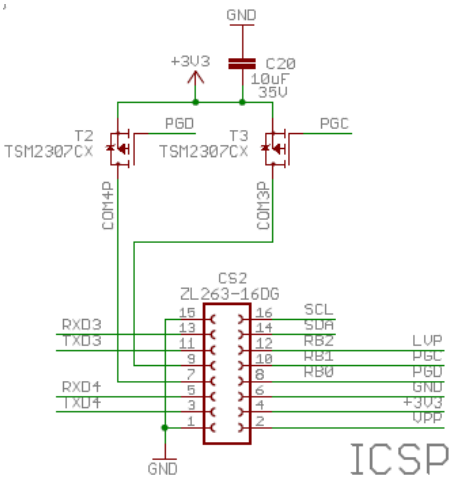
Port number 209
Filter: Two BCD digits. Filter domain: 0 to 99. Zero restarts in GPS Mode, 1-99 Group Filter.
Red LED: Two BCD digits. Intensity percentage domain: 0 to 99%.
Green LED: Two BCD digits. Intensity percentage domain: 0 to 99%.
Blue LED: Two BCD digits. Intensity percentage domain: 0 to 99%.

05: Sets BASIC variables and stores them in Flash memory.

Port	Payload
209	05230506 13

Port number 209
GPSDeviceID: Hex digit. 0 walk, 1 bike, 2 car, 3 boat, 4 airplane, 5 balloon, E Semtech GPS Format, F Adeunis GPS-format. ID domain: 0 to 15
OnePPSMin: The number of 1PPS pulses before GPS measurement. 1PPS domain 1 to 15
MaxTime: Inactive time in minutes in GPS Mode before sleep. MaxTime domain 1 to 255
GPSFullOperationTime: Full ON power time in minutes. GPSFullOperationTime domain 1 to 255
NRofDR6: Hex digit, number of DR6 between DR0 transmits in GPS Mode. NRofDR6 domain 0 to 15
NumberOfUncnfInSensorMode: ¼ the number of UNCNF transmits between CNF. Domain 1 to 15

5. Using external peripheral connector



Micromite GPS LoRa MOTE has a 16pin connector that is aimed for several purposes:

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- C**2: 2, 4, 6, 8, 10, 12 ICSP pins** can accommodate a PICKit3 programmer for Micromite firmware update.

- **C2: 1, 2 reset pins**. Micromite GPS LoRa MOTE spends most of its time in sleep mode. Hardware reset may help to initiate Micromite console mode even from sleep. No reset button is provided but with an external wire jumper the MOTE can easily be reset.

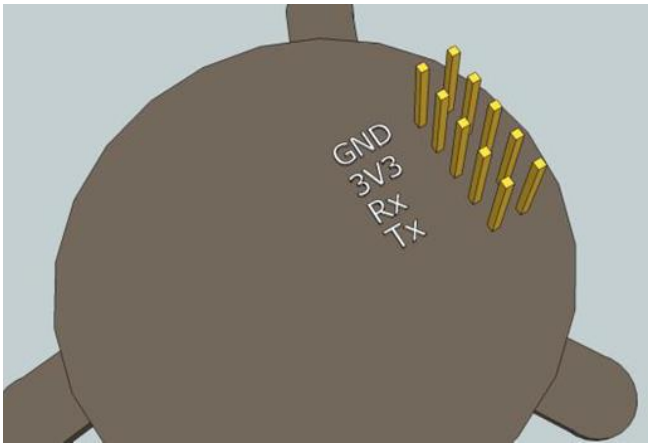
- **C2: 9, 11, 13, 15 COM3 port**. COM3 sensor can be operated from switched COM3P 3.3V power supply to minimize its power consumption.

- **C2: 1, 3, 5, 7 COM4 port**. COM4 sensor can be operated from switched COM4P 3.3V power supply to minimize its power consumption.

- **C2: 14, 16 I2C bus**.

- **C2: 8, 10, 12 digital, analog I/O or three PWM channels** (for driving RGB LED).

6. Connection of COZIR CO2 sensor and buzzer



COZIR CO2 sensors uses 9600 baud UART serial communication with 3.3V logical level that matches to Micromite. The Micromite GPS LoRa MOTE uses COM3 for COZIR sensor on its COM3 UART port:

C2:15 COZIR GND
C2:09 COZIR 3V3
C2:11 COZIR RX
C2:13 COZIR TX

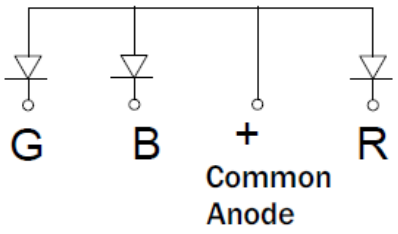
Micromite can drive a buzzer in GPS mode when a COZIR CO2 sensor is connected. After sending GPS/GNSS coordinates to LoRaWAN the Micromite measures CO2 concentration and if it is higher than upper limit then drives a buzzer with one second warning signal. The buzzer frequency is equal in Hertz with the CO2 concentration in PPM value. Car drivers can easily test the effect of closing fresh air inflow to the car. The warning buzzer can be connected to C2 peripheral connector:

C2: 8 buzzer
C2:12 buzzer

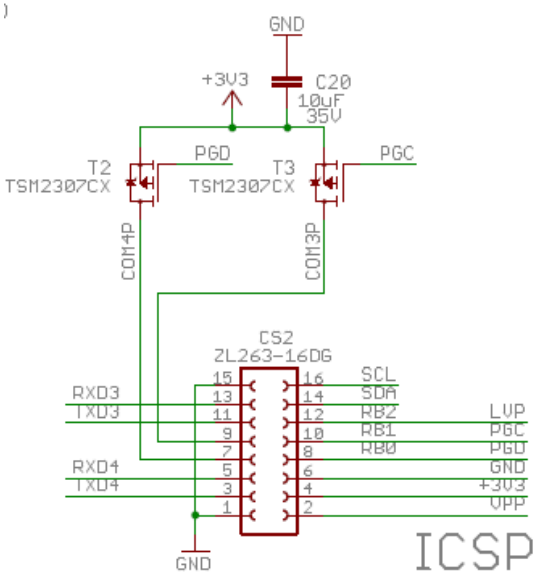
7. Connection of RGB LED in Multicast Demo

We recommend a low power FYL-5019RBGW1C-CA RGB LED with serial cathode resistors to connect directly to MOTE's peripheral connector:

C2: 4	Common anode 3.3V	
C2: 8	Red	130 Ohm
C2: 10	Blue	33 Ohm
C2: 12	Green	33 Ohm



8. Connection of SM1131 barometric air-pressure sensor



Pin Configuration

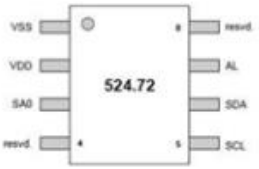


Figure 1: Pin Configuration

Pin Description

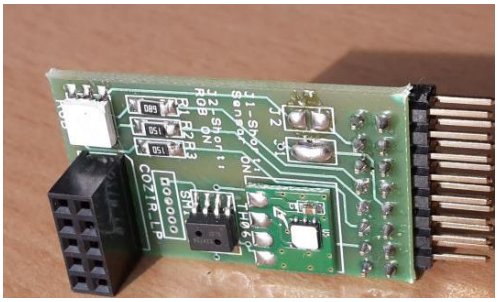
Pin	Name	Type	Description
1	VSS	S	Ground (Negative device supply)
2	VDD	S	Supply voltage
3	SA0	D_I	I2C secondary slave address, pin coding
4	resvd.	-	reserved, connect to VSS (on PCB)
5	SCL	D_I	I2C clock input
6	SDA	D_B	I2C data I/O
7	AL	D_O	Alarm output (optional)
8	resvd.	-	reserved, connect to VSS (on PCB)

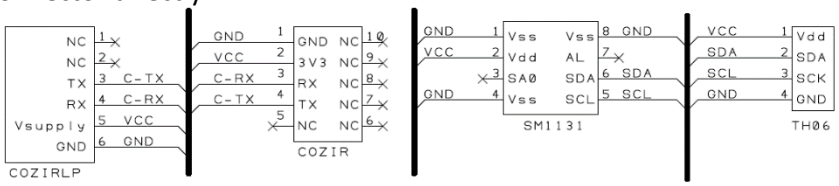
Note: A = Analog, D = Digital, S = Supply, I = Input, O = Output, B = Bidirectional, NC - not connected

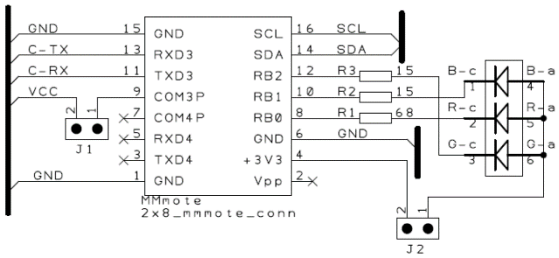
C2: 9 switched 3.3V power supply to VDD
C2:15 GND to Vss
C2:16 SCL
C2:14 SDA

9. Micromite Sensor Board

For easy connection of all external sensors we created Micromite Sensor Board that contains SM1131 barometric air pressure sensor, TH06 temperature and humidity sensor, RGB LED and additionally it can be populated by COZIR sensor. It can be connected to peripheral connector directly:







RB0/RB1/ and RB2 pins of Micromite have different functions in Sensor and Multicast Modes. In sensor mode J1 is closed and J2 open. In Multicast Mode J1 is open and J2 closed. Because these modes are not frequently changed J1 and J2 switches provide long time function to the board that can be modified by soldering.

10. Opening and closing plastic case of Micromite GPS LoRa MOTE

The Micromite GPS LoRa MOTE is housed in a black plastic case (78mm*40mm*22mm). The case has a base and a cover part and for the push button a plastic mechanical button extender. The case has no screw to fix the case but the PCB board is mechanically fixed among case part. The cased Micromite GPS LoRa MOTE can easily be moved to its locations and is resistive against environment stresses. However, the PCB is designed to meet additional requirements. The cased device can accommodate a 750mAh LiPo battery but if longer duration is required the board can be powered by 2000mAh battery also but due to its larger size without case. In its case GPS/GNSS receiver uses its internal patch antenna but the PCB can accommodate external antenna also. For example, in bicycle tracking one of the main design challenges is how to hide electronics against sabotage. The external antenna connector of both GPS/GNSS and LoRa radios can support experiments with hidden electronics and antenna designs in such projects right away.

When the case is open the firmware of RN2483 module can be updated by a PICKit 3 programmer through ICSP pads beside the module. The measurement of power consumption is supported by a 10 Ohm Shunt resistor that is short circuit with a jumper. After opening the case the jumper can be removed and a storage oscilloscope can be connected instead.

The PCB and the 750mAh standard LiPo battery can easily be placed in the case but with one trick. Let's put an insulator strip, or rubber tape onto the outer surface of the upper case to fully cover the slot of push button. Insert the mechanical button extender in the inner side of the cover and push firmly to allow the tape to hold it. Place the PCB and battery into the case playing attention that the battery wires face to LoRa antenna position and wires come to upper side battery connector on the PCB. Place the cover case onto bottom case part and firmly push them together. In its normal position the push button can easily be pressed and the case holds the PCB properly.

11. Packing list of Micromite GPS LoRa MOTE package

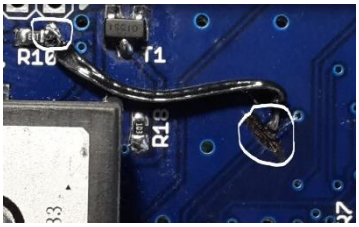
- Micromite GPS LoRa MOTE (cased with 750mAh battery)	1 piece
- ISM-868 SMA ant. + swivel 868MHz monopole antenna	1 piece
- Reset wire	1 piece
- micro USB cable	1 piece

The Micromite GPS LoRa MOTE is activated and tested in ChipCAD LoRaWAN but later it can easily be moved to other networks.

Appendix

A: Micromite GPS LoRa MOTE version history.

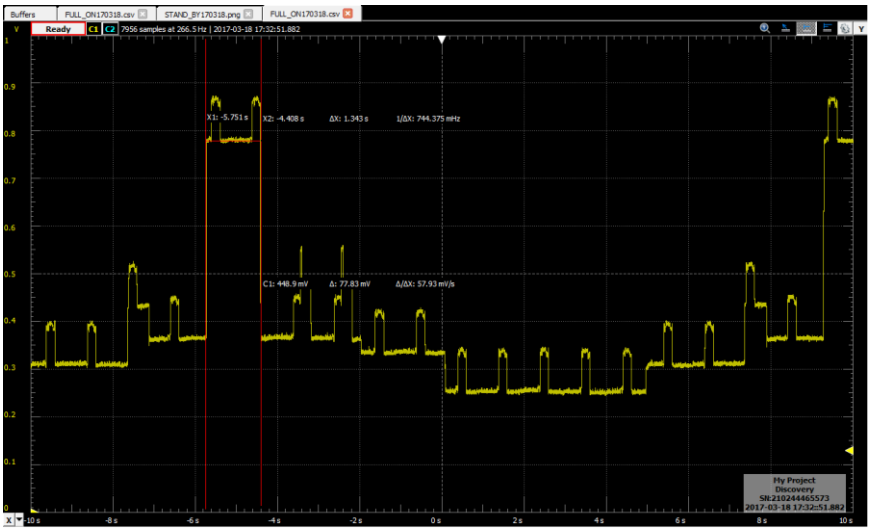
V1 was developed for ChipCAD IoT Conference June 6th 2016 but was never released to market, only used for demonstrations and in house experiments. It was exclusively designed as a LoRaWAN GPS tracker.
V2 combined LoRaWAN GP tracker with sensor functions, it was released to market on August 5 2016, MMTR-06A_SCH.pdf.



V3 released to market on March 22 2017, MMTR-07_SCH.pdf. Major software release improves GPS power management for accurate localization. It has minor hardware modification also: instead of CTS/RTS control, Micromite becomes able to reset RN2483 module. It is highly recommended to cut off RTS/CTS to RB13/RB12 and with a small piece of wire connect RB12 to 32, reset pin of RN2483. Micromite firmware should be 5.36 or higher.
V4 Redesigned PCB layout fixing all modification. Micromite firmware should be 5.4 lite version or higher.

B: GPS modes of operation.

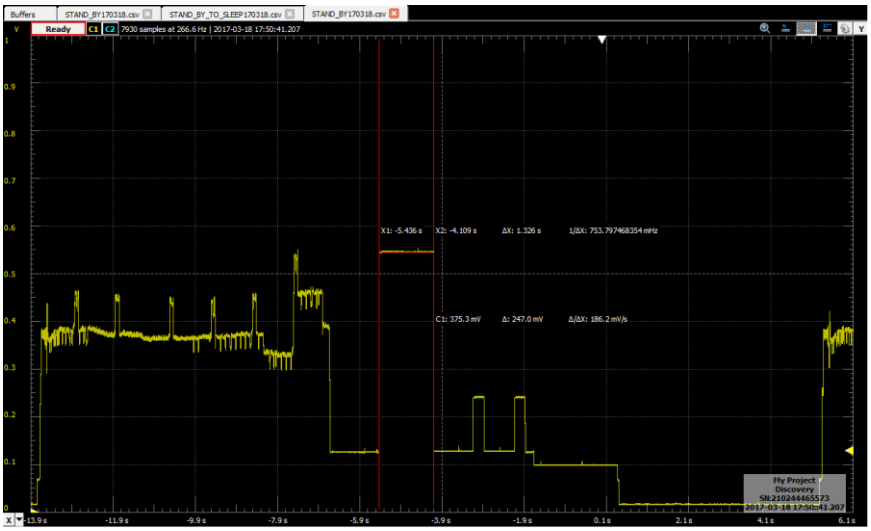
Removing jumper of R13 10 Ohm Shunt resistor, current consumption can be measured. The 100mV vertical scale of below scope diagrams corresponds to 10mA supply current. After waken up by motion sensor the GPS receiver gets continues power for 5 minutes in FULL ON mode. Then for saving battery power Micromite sends periodically GPS/GNSS receiver into standby after receiving valid coordinates:



GPS power FULL ON.
While motion sensor senses continuous motion Micromite controls a periodic sequence:

1. sleeps for short sleep time
2. reads valid GPS/GNSS coordinates
3. sends coordinates to LoRaWAN
4. sends RN2483 to sleep mode
5. goes to sleep for sleep time

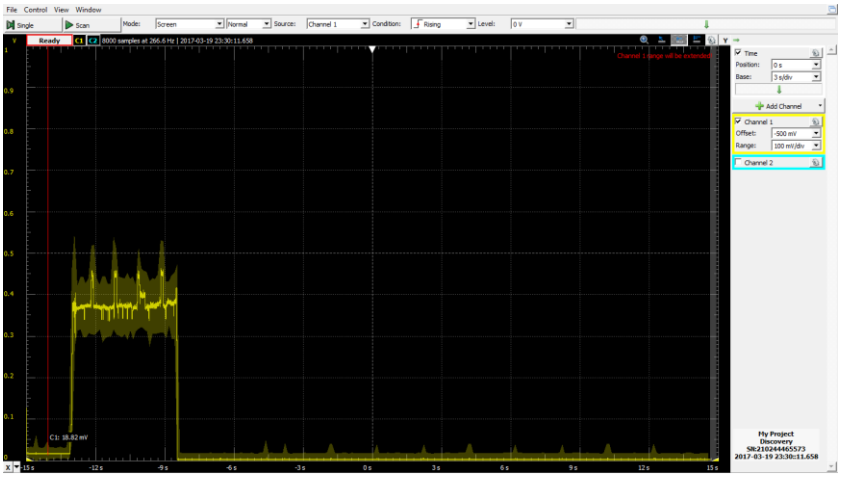
During this sequence GPS/GNSS gets continuous power for five minutes after waken up by motion sensor.



GPS Power STANDBY Mode.
While motion sensor senses continuous motion Micromite controls a periodic sequence:

1. sleeps for short sleep time
2. switches GPS/GNSS to FULL ON
3. reads valid GPS/GNSS coordinates
4. switches GPS/GNSS to STANDBY
5. sends coordinates to LoRaWAN
6. sends RN2483 to sleep mode

7. goes to sleep for sleep time

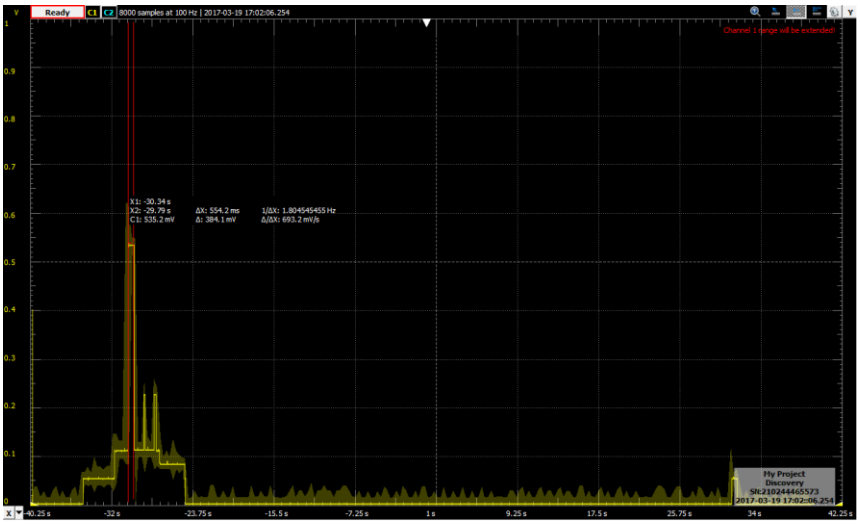


GPS sleep mode.

While MOTE is moving its motion sensor restarts an inactivity motion timer. After stopping the motion sensor allows inactivity timer to reach its limit. After reaching maximum inactivity limit Micromite switches power off for all peripherals and goes to sleep for unlimited time. Only motion sensor can wake Micromite up again and the whole sequence starts again through FULL ON then STANDBY modes.

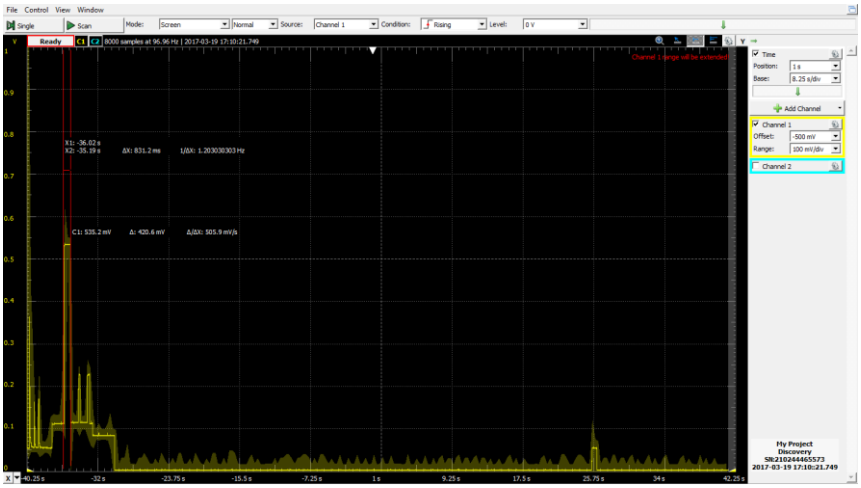
Quectel: L86 Hardware Design (Rev. L86_Hardware_Design_V1.0)
Quectel: L86 GNSS Protocol Specification (Rev. L86_GNSS_Protocol_Specification_V1.1)

C: Sensor modes of operation



In sensor mode MOTE measures its internal and external sensors then sends results to LoRaWAN. Between measurement the MOTE switches off its peripherals and goes to sleep for programmable long sleep time. The minimum sleep time is one minute but can be extended with 255 minutes by download message. Without connecting external CO2 sensor, the MOTE sends two byte payload of internal temperature and buttery charge. The channel transmission duty cycle is 0.55sec/60sec/8channels=0.1% at SF11 and 0.02% at SF7.

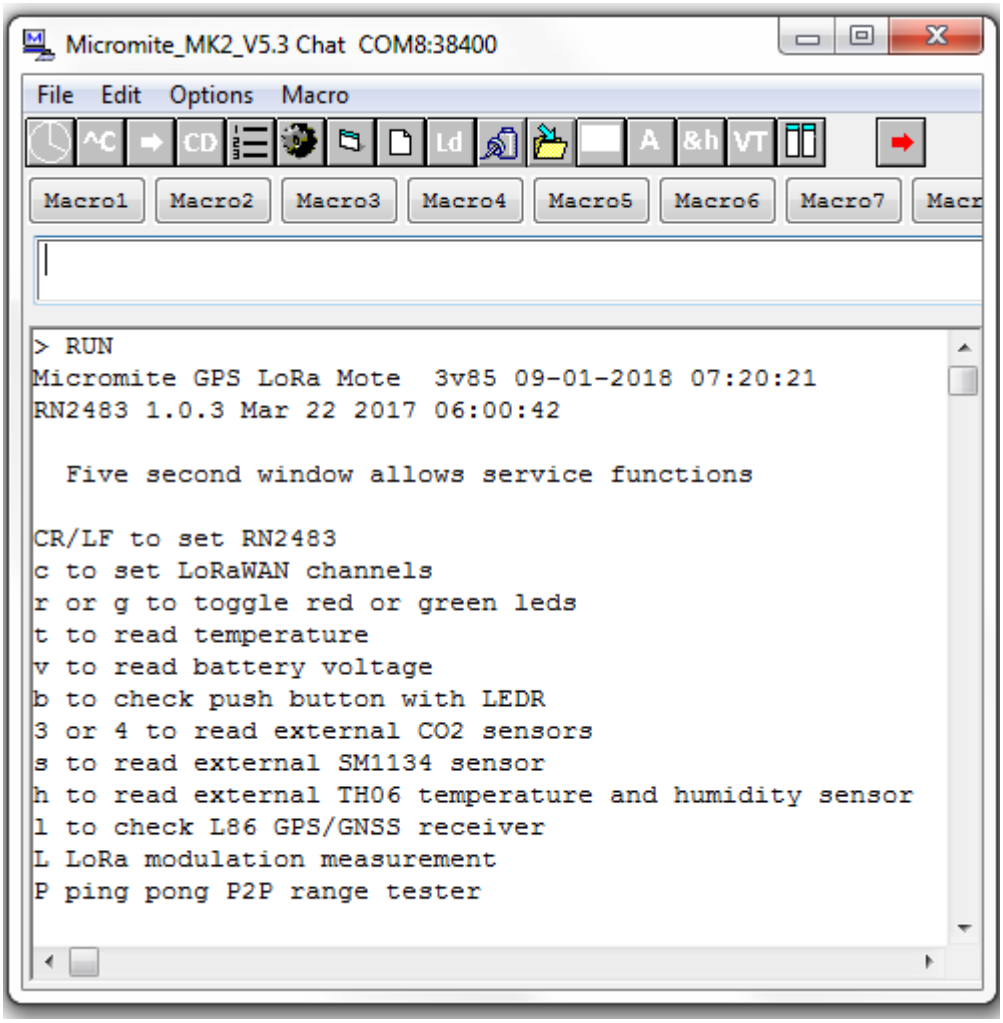
With external COZIR sensor the payload length is set automatically depending upon the sensor type. Beside CO2 concentration humidity and temperature values can be inserted automatically. The longest payload can be 7 bytes long. The channel transmission duty cycle is 0.83sec/60sec/8channels=0.18% at SF11 and 0.015% at SF7. The MOTE can be operated in smart sensor mode with automatic CO2 concentration upper limit monitoring. The long sleep time can be programmed up to 256 minutes



but at every minute Micromite checks its button if it is pressed and measure CO2 value if the upper limit is switched on, not 0ffffH. When the upper limit checking is allowed and the measured CO2 exceeds this limit, the MOTE send sensor data whatever sleep time is programmed. In smart sensor mode the power consumption can be kept low while the network server is kept informed about too high sensor value limit.

D: Service mode

Service mode can be accessed after resetting Micromite. During a five second service time window service functions can be initiated from console:



- **CR/LF** to set RN2483 — Allows manual control of RN2483. This service function can be finished by pressing ^C, or pressing ^C button of toolbar in Micromite Chat window. Then RUN the BASIC program again.
- **c** to set LoRaWAN channels — Configures 10 LoRaWAN channels according to Semtech EU868 standard. This service runs automatically then continues to GPS Mode.
- **r** or **g** to toggle red or green LEDs — This service function keeps for additional 5 second after pressing r or g.
- **t** to read temperature — This service function keeps for additional 5 second after pressing t.
- **v** to read battery voltage — This service function keeps for additional 5 second after pressing v.
- **b** to check push button with LEDR — Pushing button switches red LED on. This service function can be finished by pressing ^C, or pressing ^C button of toolbar in Micromite Chat window. Then RUN the BASIC program again.

- **3** or **4** to read external CO2 sensors	COZIR sensors can be tested on either COM3 or COM4. This service mode can be finished by pressing ^C, or pressing  button of toolbar in Micromite Chat window. Then RUN the BASIC program again.
- **s** to read external SM1113 sensor	Sends SM1113 temperature and pressure values to console. This service mode can be finished by pressing ^C, or pressing  button of toolbar in Micromite Chat window. Then RUN the BASIC program again.
- **h** to read external TH06 sensor	Sends TH06 temperature and humidity values to condole. This service mode can be finished by pressing ^C, or pressing  button of toolbar in Micromite Chat window. Then RUN the BASIC program again.
- **l** to check L86 GPS/GNSS receiver	After switching GPS/GNSS receiver on, its records are transferred to console port till pressing ^C, or pressing  button of toolbar in Micromite Chat window.
- **L** LoRa modulation measurement	A periodic LoRa modulated signal with 1mW power is available on antenna connector for RF signal measurement. Users are encouraged to modify this program according to needs of signal measurements. This service mode can be finished by pressing ^C, or pressing  button of toolbar in Micromite Chat window. Then RUN the BASIC program again.
- **P** Ping-pong range testing mode	Micromite MOTE is switched to ping-pong mode. Two Micromite MOTES can answer to each other continuously while they are in two-way radio communication range. During receiving green LED is lit and while transmitting the red LED is lit. The speed of LEDS flashing indicates existence of two-way communication or its absence. This service mode can be finished by pressing ^C, or pressing  button of toolbar in Micromite Chat window. Then RUN the BASIC program again.

E: Adaptive Data Rate, ADR

Adaptive Data Rate is a nice feature of LoRaWAN. It assures reliable two-way communication between end device and network server in slowly changing environments. The process allows adaption of LoRa modulation (bit rate, spreading factor, data rate) to different radio conditions and even to changing topologies of gateways.

The ADR is a combined process of network server plus end device. In Loriot network server the process needs these steps:

- Network server account must be commercial. This is a must because of the need for downlink direction.
- The whole process can be enabled and disabled by end devices. In GPS Mode ADR is always switched off and in Sensor Mode it is on.

- When ADR is enabled, this information is transmitted in the header of every uplink message. Then Loriot network server checks radio reports of gateways and after receiving 12 uplink messages successfully it may increase the data rate of the end device by sending a downlink message. This decision calculates enough decoding margin to gateways. The mac layer of RN2483 understands this and will increase its data rate.

- The opposite data rate correction is made by the mac layer of RN2483. Whenever an uplink message requires confirmation, the RN2483 repeats the message if it lacks confirmation. First the repeated message is using the same data rate but on a different channel. Then if the second message is not confirmed either, it lowers data rate by one and repeats. This process can iterate down till gets the reliable data rate for given conditions. Users should pay attention on the parameters of repetition, the number of available channels and transmission duty cycle control of the module. Important to know that gateways are half duplex modems, while they transmit they can't receive on RX channels. The more the gateway confirms the less it can listen! **Don't use confirmation requests too frequently!** Every 10th or even less uplink may request confirmation if there is no important event behind. This number may depend on number of end devices and density of gateways, on the robustness of the whole LoRaWAN network. With downlink command UNCNF/CNF uplink ratio can be modified between 4 to 64 depending upon requirements of application and network topologies.

The ADR process is not very quick. Mobile devices don't use ADR but fix position end devices can enjoy ADR for slow changes in the radio conditions and network topologies. ADR makes no sense in mobile applications because their movements maybe much faster than ADR process. However, for achieving more accurate route trace it is recommended to use not exclusively DR0 but higher data rates as well.