



1. INTRODUCTION

This document is a specification for the Guppy LoRaWAN asset tag. Contact info@digitalmatter.com for more information.

1.1. Revision History

Date	Version	Changes
2017-09-13	1.0	Initial release
2017-11-20	1.1	Added default downlink values
2017-11-30	1.2	Added downlink 8
2018-07-11	1.3	Added downlinks 9 and 10, extended uplink 1
2019-03-11	1.4	Updated downlinks 6 and 8, added downlinks 11 and 12

2. DEVICE BEHAVIOUR

The Guppy's behaviour can be configured by setting a variety of parameters using a USB programming adapter, or by sending a subset of those parameters during a downlink message. The details of these parameters can be found on the [product support website](#).

2.1. Uplink

The Guppy uses an accelerometer to detect movement, allowing it to decide when an asset is in-trip, and when it is stationary. This allows it to schedule transmissions as infrequently as possible, to maximize battery life. You can configure the Guppy to transmit a status update:

- Periodically (ie. 24-hour heartbeat)
- At configured times of the day
- At the start of a regular or after-hours trip
- During the trip
- At the end of the trip
- When the 'Man Down' status changes
- When a Tilt trigger goes off

2.1.1. Device Statistics

The Guppy transmits a device statistics message once every 3 days, to allow monitoring of device activity and associated battery usage. The device statistic messages can be disabled to prevent tracking disruption in regions where the transmit duty cycle restrictions are a bottleneck (868 MHz regions can limit transmissions to 1 every 3 minutes).

2.2. Downlink

LoRaWAN potentially allows for a downlink with every regular data uplink, but most networks will only allow a few per day. When a parameter update is sent down to the Guppy, it responds with an application layer acknowledgement uplink as soon as possible. In some

regions, this could take several minutes. If the next uplink received is not the expected acknowledgement, the downlink should be resent.

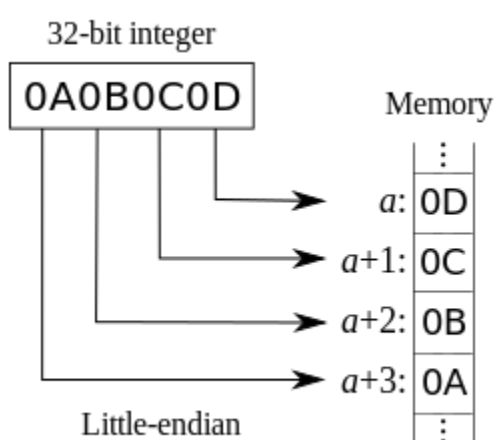
3. MESSAGES

3.1. Number Formats

3.1.1. Little Endian

Except where noted, all data in the payloads is LITTLE ENDIAN. Be aware of this when converting data fields that consist of more than one byte from the data payload.

<https://en.wikipedia.org/wiki/Endianness#Little>



3.1.2. Signed (Negative) Numbers

When a field is specified as *signed*, it is represented in 'two's complement' form. Be aware of this when converting signed fields from the data payload. Where unspecified, assume that fields are unsigned.

https://en.wikipedia.org/wiki/Two's_complement

3.2. Uplink

LoRaWAN uplink payloads can be as small as 11 bytes in some regions (for the longest-range transmissions). The packet headers already include the device serial number, and a 'port number' from 1 to 223, which we will use as a message type.

3.2.1. Uplink Port 1: Status Update

Offset	Description
0.0	0: Out of trip, 1: In-trip
0.1 - 0.7	Battery voltage, LSb = 14 mV, 2 V offset
1 (BYTE)	Temperature, LSb = 0.5 °C, -40 °C offset
2.0	Man down (no movement for configured period), optional
2.1 - 2.7	<i>Inclination</i> (see configuration and usage guide), 0-120: 0-180°, optional

3 (BYTE)	<i>Azimuth</i> (see configuration and guide), 0-239: 0-358.5°, optional
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This message includes two optional bytes, which are only sent if either the Man Down or Tilt feature is enabled. They are not enabled by default.

Short example: **C382**

- **C3**
 - 11000011 in binary
 - 1 - in trip
 - 1100001 - $97 \times 0.014 + 2.0 = 3.358 \text{ V}$
- 82
 - 130 in decimal
 - $130 \times 0.5 + -40.0 = 25 \text{ °C}$

Long example: **C38245B1**

- **C382**
 - As above
- 45
 - 01000101 in binary
 - 1 - man down
 - 0100010 - $34 \times 1.5 = 51^\circ$ Inclination
- **B1**
 - 177 in decimal
 - $177 \times 1.5 = 265.5^\circ$ Azimuth

3.2.2. Uplink Port 2: Downlink Ack

Offset	Description
0.0 - 0.6	Sequence number (identifies downlink to server)
0.7	0: Downlink rejected, 1: Downlink accepted
1	Firmware major version
2	Firmware minor version

Example: **D30102**

- **D3**
 - 11010011 in binary
 - 1010011 - sequence number 83
 - 1 - downlink accepted
- 0102
 - Firmware 1.2

3.2.3. Uplink Port 3: Device Statistics

Offset	Description
0.0 - 0.6	Initial battery voltage, LSb = 14 mV, 2 V offset
0.7 - 1.7	Uptime, LSb = 1 week
2 (UINT16)	Tx count, LSb = 32 Tx attempts

4 (UINT16)	Trip count, LSb = 32 trips
6 (BYTE)	Wakeups per trip

Example: 8CF3DC7B943818

- 8CF3 little endian
 - F38C in hex
 - 1111001110001100 in binary
 - 0001100 - $12 \times 0.014 + 2.0 = 2.168$ V
 - 111100111 - 487 weeks uptime
- DC7B little endian
 - 7BDC in hex
 - $31708 \times 32 = 1014656$ transmissions
- 9438 little endian
 - 3894 in hex
 - $14484 \times 32 = 463488$ trips
- 18 in hex
 - 24 wakeups per trip

3.2.4. Uplink Port 4: RTC Correction Request

Offset	Description
0.0	0: RTC not yet set, 1: RTC already set
0.1 - 3.7	Cookie, to be included in the reply
4 (UINT32)	Seconds since 2013-01-01 00:00:00 UTC

This message provides the Guppy's current RTC time, and requests a correction. The correction is calculated by subtracting the supplied timestamp from the gateway's reception timestamp. The cookie prevents the correction from being applied twice.

The message is only enabled if the Guppy has been configured with *After Hours* times (see downlink port 2). If you don't configure your Guppies for *After Hours* support, you don't need to implement the RTC Correction Response message (downlink port 6).

When enabled, corrections are requested every 28 days, with retries every 3 days if there is no reply. The requests are sent opportunistically, after the Guppy has woken from sleep in response to movement or a heartbeat. Retry times are more aggressive (as short as 10 minutes) for the first 100 retries immediately following battery insertion.

Example: 8CF3DC7B9438180A

- 8CF3DC7B little endian
 - 7BDCF38C in hex
 - 01111011110111001111001110001100 in binary
 - 0 - RTC not yet set
 - 01111011110111001111001110001100 - cookie is 1039038918
- 9438180A little endian
 - 0A183894 in hex
 - 169359508 seconds since 2013-01-01 00:00:00 UTC
 - 2018-05-15 04:18:28 UTC

3.2.5. Example JavaScript Decoder

For example code, please refer to the Digital Matter Support website. Search for “Decoding the Guppy LoRaWAN Payload”. Use your browser (F12) to inspect the Java Script source behind the webpage.

3.3. Downlink

LoRaWAN downlink payloads can be as small as 11 bytes in some regions (for the longest-range transmissions). The packet headers already include a ‘port number’ from 1 to 223, which we will use as a message type. The Guppy sends an explicit acknowledgement uplink (port 2) on reception of a downlink, except where noted. It sends the acknowledgement only once, on its next uplink attempt. The uplink includes a sequence number to help identify the specific downlink being acknowledged, despite any queuing / buffering in the network. ‘Confirmed’ and ‘unconfirmed’ downlinks are handled in the same way.

3.3.1. Downlink Port 1: Set Trip Parameters

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Disable stats messages (uplink port 2), 0 is default (message enabled)
1 (BYTE)	Max time between fix attempts out of trip (‘heartbeat’), 1-127: 1-127 mins, 129-255: 1-127 hours, default 24 hours
2 (BYTE)	Trip end timeout, LSB = 10s without accelerometer detecting movement, 0 disables trip tracking entirely (heartbeats only), default 5 mins
3 (BYTE)	Time between fix attempts in-trip during work hours, 1-127: 1-127 seconds, 129-255: 1-127 minutes, 0 or 128 disables, default 10 mins
4 (BYTE)	Time between fix attempts in-trip after hours, 1-127: 1-127 seconds, 129-255: 1-127 minutes, 0 or 128 disables, default 10 mins
5.0	Fix on start of trips during work hours, default true
5.1	Fix on end of trips during work hours, default true
5.2	Fix on start of trips after hours, default true
5.3	Fix on end of trips after hours, default true
5.4 - 5.5	Reserved, set to zero
5.6	Disable wakeup filtering during work hours, 1: only apply accelerometer wakeup threshold and count, 0: apply threshold, count, and filter, default 0
5.7	Disable wakeup filtering after hours, 1: only apply accelerometer wakeup threshold and count, 0: apply threshold, count, and filter, default 0
6 (BYTE)	Accelerometer wakeup threshold, 1-8: 63-504 mG, default 126 mG
7 (BYTE)	Accelerometer wakeup count, 0-12: 0-960 ms, default 80 ms

3.3.2. Downlink Port 2: Set After-Hours 1

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero
1 (BYTE)	Start of after-hours period on Monday, LSb = 7m30s since 00:00 local time, setting to end time indicates no after-hours period, default 0
2 (BYTE)	End of after-hours period on Monday, LSb = 7m30s since 00:00 local time, setting to start time + 1 indicates a 7m30s after-hours period, set start time to 00:00 and end time to 24:00 to indicate the whole day is after-hours, default 0
3 (BYTE)	Start of after-hours period on Tuesday, see above
4 (BYTE)	End of after-hours period on Tuesday, see above
5 (BYTE)	Start of after-hours period on Wednesday, see above
6 (BYTE)	End of after-hours period on Wednesday, see above
7 (BYTE)	Start of after-hours period on Thursday, see above
8 (BYTE)	End of after-hours period on Thursday, see above

3.3.3. Downlink Port 3: Set After-Hours 2

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero
1 (BYTE)	Start of after-hours period on Friday, LSb = 7m30s since 00:00 local time, setting to end time indicates no after-hours period, default 0
2 (BYTE)	End of after-hours period on Friday, LSb = 7m30s since 00:00 local time, setting to start time + 1 indicates a 7m30s after-hours period, set start time to 00:00 and end time to 24:00 to indicate the whole day is after-hours, default 0
3 (BYTE)	Start of after-hours period on Saturday, see above
4 (BYTE)	End of after-hours period on Saturday, see above
5 (BYTE)	Start of after-hours period on Sunday, see above
6 (BYTE)	End of after-hours period on Sunday, see above

3.3.4. Downlink Port 4: Set Time Zone

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7 - 1.1	Reserved, set to zero
1.2 - 2.1	Offset of normal time zone from UTC, LSb = 15 minutes, signed , default 0
2.2 - 2.5	Daylight saving time shift, LSb = 15 minutes, 0 disables, default 0

2.6 - 3.0	Start of DST Nth day of month, 1: First day, ..., 5: Fifth day, 6: Last day, 0: Use absolute date instead of relative '2 nd Sunday of October' style
3.1 - 3.5	1-7: Monday-Sunday, or 1-31: Day of month (absolute date), local time
3.6 - 4.1	1-12: January-December
4.2 - 5.2	Offset from 00:00 local time, LSb = 15 mins, signed , can select hours in previous days like '02:00 on Friday before last Sunday of October local time' would need Offset = (2hr - 48hr) * 4 = -184
5.3 - 5.5	End of DST Nth day of month, 1: First day, ..., 5: Fifth day, 6: Last day, 0: Use absolute date instead of relative '2 nd Sunday of October' style
5.6 - 6.2	1-7: Monday-Sunday, or 1-31: Day of month (absolute date), local time
6.3 - 6.6	1-12: January-December
6.7 - 7.7	Offset from 00:00 local DST, LSb = 15 mins, signed , can select hours in previous days like '02:00 on Friday before last Sunday of April local DST' would need Offset = (2hr - 48hr) * 4 = -184

3.3.5. Downlink Port 5: Set LoRaWAN Channels

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero
1.0 - 1.3	Minimum data rate to use when ADR is disabled, default is 0 (DR0)
1.4 - 1.7	Maximum data rate to use when ADR is disabled, default is 2 (DR2)
2 - 10	Uplink channel mask, set bits are enabled channels, LSb of the 1 st byte is channel 0, MSb of the 9 th byte is channel 71, set all zeros (default) for the region-specific defaults

The Guppy will spread its transmissions out over the allowed data rates in such a way as to equalize the time spent on-air at each data rate. For the default setting of DR0-DR2, this gives a 16 / 30 / 54% split between the three data rates and maximizes the gateway's capacity. However, the relative range of the three data rates are 100, 75, and 50% respectively. When ADR is enabled, the network server controls the data rate instead.

The uplink channel mask should be left 0 (default) in regions where the network join channels are fixed. In these regions, the gateway will tell the Guppy which channels to use, during the Join procedure.

In regions where the join channels are not specified (US902-928, AU915-928), you should set the channel mask to avoid continued transmission on unused channels. In these regions the gateway will usually not tell the Guppy which channels to use, resulting in significant packet loss if the mask hasn't been programmed.

3.3.6. Downlink Port 6: Set LoRaWAN Join / App EUI

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)

0.7	Set JoinEUI, 0: Use default JoinEUI, 1: Use supplied JoinEUI, default 0
1 - 8	JoinEUI, big endian , ie. default JoinEUI 70-B3-D5-70-50-00-00-01 is encoded with first byte as 0x70 and the second byte 0xB3

The acknowledgement will be transmitted **once** on the existing JoinEUI, and then the Guppy will switch to the new JoinEUI. It continues to use the already provisioned NwkKey and AppKey, which cannot be programmed over the air.

Note that:

- In LoRaWAN 1.0, the JoinEUI is known as the AppEUI
- In LoRaWAN 1.1, changing the JoinEUI resets three cryptographic counters:
 - RJCount1
 - DevNonce
 - JoinNonce
- So after changing the JoinEUI in 1.1, you must reset the counters on the join server

3.3.7. Downlink Port 7: RTC Correction Response

Offset	Description
0.0	0: Subtract from Guppy's timestamp, 1: Add to Guppy's timestamp
0.1 - 3.7	Cookie, from the RTC Correction Request
4 (UINT32)	Timestamp correction, in seconds (unsigned - always positive)

See uplink port 4 for the corresponding RTC Correction Request.

No Downlink Ack is sent for this message (see uplink port 2), as it is a one-off reply.

Example:

- Guppy reports a timestamp of 169359508, or 2018-05-15 04:18:28 UTC
- The gateway reports a packet reception time of 2018-05-15 04:18:35 UTC
 - This may be significantly different from the time that the application server receives the packet from the LoRaWAN network. Please be sure to use the actual on-air reception timestamp.
 - Subtracting the Guppy's timestamp from the Gateway's timestamp, we see that the Guppy is running 7 seconds slow.
- The application server queues a single downlink in response
 - Bit 0.0 is set, since the Guppy must increment its timestamp
 - The timestamp correction field is set to 7
 - The cookie is copied from the request, ensuring that the Guppy will only increment its timestamp at most once, no matter how the network decides to handle packet delivery / retries
 - If the Guppy doesn't receive the downlink, it will send another request later

3.3.8. Downlink Port 8: Set Advanced LoRaWAN Options

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero

1 (BYTE)	Days between network joins, 0 disables, default 7
2.0 - 2.1	ADR support, 0: Never, 1: When out-of-trip, 2: Always, default never
2.2 - 2.3	Reserved, set to zero
2.4 - 2.7	Initial frame repetitions (NbTrans/Reps), 1-15, default 1
3.0 - 3.3	Initial MaxCount0, sets uplinks between Rejoin0 attempts in LoRaWAN 1.1 OTAA, uplink interval equals $2^{(4+MaxCount0)}$, default 15
3.4 - 3.7	Initial MaxTime0, sets approx. time between Rejoin0 attempts in LoRaWAN 1.1 OTAA, uplink period equals $2^{(10+MaxTime0)}$ s, default 15
4.0 - 4.3	Initial AdrAckLimitExp, sets uplinks between ADR confirmation requests, uplink interval equals $2^{AdrAckLimitExp}$, default 6 (limit is 64)
4.4 - 4.7	Initial AdrAckDelayExp, sets uplinks between ADR backoff steps, uplink interval equals $2^{AdrAckDelayExp}$, default 5 (delay is 32)
5 (INT8)	Maximum Tx power limit, signed , -128-127: -128 to 127 dBm EIRP, default 127 (no limit)
6 (BYTE)	Random Tx delay, 0: disabled, 1-127: 1-127 seconds, 129-255: 1-127 minutes, default disabled

This downlink is supported from firmware version 1.4 onwards. Fields from offset 2.4 onwards are supported from firmware version 2.0. For a detailed description of these parameters, please see the *Configuration and Usage Guide* on the support website.

3.3.9. Downlink Port 9: Set Tilt Parameters

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero
1.0	Enable Tilt reporting and Tilt triggers, default false
1.1	Retry trigger transmission attempts if network not ready (ie. join failed - uplinks are still unconfirmed even if retried), default false
1.2 - 1.7	Reserved, set to zero
2.0	Trigger 1 Angle, 0: Azimuth, 1: Inclination, default 0
2.1 - 2.2	Trigger 1 Axis, 0: Disabled, 1: X, 2: Y, 3: Z, default 0
2.3	Trigger 1 Type, 0: Delta Trigger, 1: Range Trigger, default 0
2.4 - 2.7	Trigger 1 Hysteresis, applies to range triggers only, range triggers at threshold +/- hysteresis, 0-15: 1.5-24°, default 1.5°
3 (BYTE)	Trigger 1 Min Angle, minimum angle for range trigger, or threshold angle for delta trigger, 0-239: 0-358.5°, default 0
4 (BYTE)	Trigger 1 Max Angle for range triggers, 0-239: 0-358.5°, default 0
5.0	Trigger 2 Angle, see above
5.1 - 5.2	Trigger 2 Axis, see above
5.3	Trigger 2 Type, see above

5.4 - 5.7	Trigger 2 Hysteresis, see above
6 (BYTE)	Trigger 2 Min Angle, see above
7 (BYTE)	Trigger 2 Max Angle, see above
8.0	Trigger 3 Angle, see above
8.1 - 8.2	Trigger 3 Axis, see above
8.3	Trigger 3 Type, see above
8.4 - 8.7	Trigger 3 Hysteresis, see above
9 (BYTE)	Trigger 3 Min Angle, see above
10 (BYTE)	Trigger 3 Max Angle, see above

For the definitions of the axes and angles, please see the configuration and usage guide. This downlink is supported from firmware version 1.8 onwards.

3.3.10. Downlink Port 10: Set Man Down Parameters

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero
1.0 - 1.1	Man Down fix on set, 0: no fix, 1: single fix attempt, 2: retry fix attempts if network not ready (ie. join failed - uplinks are still unconfirmed), default 0
1.2 - 1.3	Man Down fix on clear, see above
1.4 - 1.7	Reserved, set to zero
2 (BYTE)	Man Down timeout, 1-127: 10-1270 min, 129-255: 12-1524 hours, others disable, default 0

This downlink is supported from firmware version 1.8 onwards.

3.3.11. Downlink Port 11: Set Scheduled Upload Parameters

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	0: Single fix attempt, 1: Retry fix attempts if network not ready (i.e. join failed - uplinks are still unconfirmed), supported from firmware version 2.0 onwards, unconfigured default is no attempts
1 (BYTE)	Local time* of scheduled upload time 1, 1-192: 00:07:30-24:00:00 (7.5 min intervals), +- 5 minutes randomization, default 0 (disabled)
2 (BYTE)	Local time* of scheduled upload time 2, see above
3 (BYTE)	Local time* of scheduled upload time 3, see above
4 (BYTE)	Local time* of scheduled upload time 4, see above
5 (BYTE)	Local time* of scheduled upload time 5, see above
6 (BYTE)	Local time* of scheduled upload time 6, see above

7 (BYTE)	Local time* of scheduled upload time 7, see above
8 (BYTE)	Local time* of scheduled upload time 8, see above
9 (BYTE)	Local time* of scheduled upload time 9, see above
10 (BYTE)	Local time* of scheduled upload time 10, see above

*Local time takes time zone and daylight savings offset into account (configurable in Downlink 4).

The scheduled upload feature allows for heartbeats to be scheduled, rather than setting an upload interval. Each upload will occur within a 5 minute offset (i.e. scheduled upload at 13:00 could occur anywhere between 12:55 and 13:05). Up to 12 upload times may be configured per day. The first 10 upload times are configured with this downlink.

This downlink is supported from firmware version 2.0 onwards.

3.3.12. Downlink Port 12: Set Scheduled Upload Parameters (continued)

Offset	Description
0.0 - 0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved, set to zero
1 (BYTE)	Local time* of scheduled upload time 11, 1-192: 00:07:30-24:00:00 (7.5 min intervals), +- 5 minutes randomization, default 0 (disabled)
2 (BYTE)	Local time* of scheduled upload time 12, see above

*Local time takes time-zone and daylight savings offset into account (configurable in Downlink 4).

The scheduled upload feature allows for heartbeats to be scheduled, rather than setting an upload interval. Each upload will occur within a 5 minute offset (i.e. scheduled upload at 13:00 could occur anywhere between 12:55 and 13:05). Up to 12 upload times may be configured per day. The 11th and 12th upload times are configured with this downlink.

This downlink is supported from firmware version 2.0 onwards.

4. CONTACT INFORMATION

For the latest version of this document plus other product information please visit our website at www.digitalmatter.com/support, or contact DM at info@digitalmatter.com.