HULC-M ADS-B Receiver unit Datasheet V1.2

confidential information *primary specification*

1 INTRODUCTION

With the HULC-M, GNS-Electronics presents a new full-featured Mode-S and ADS-B receiver unit, which can be used immediately thanks to its integrated 1090MHz antenna.
Due to its high reception sensitivity and precise signal processing, the Hulc-M has an excellent range.
The integrated GNSS receiver and the high accuracy timer also allow the Hulc-M to be used together with at least 3 other receivers in the region to determine the position of an aircraft by multilateration (MLAT).

Features

- Mode-S & ADS-B all-in-one receiver
- High dynamic range of > 100dB
- No “doughnut effect”
- Simple power supply via USB
- Improved functionality by using a TCXO
- High Precision PPS synchronized absolute timestamp
- Weatherproof design, outdoor use

Applications

- Aviation safety
  - “Virtual Radar” for small aircrafts
  - Add-on data for flight navigation
- Ground equipment
  - Virtual Radar for ground based equipment
  - Hand held “plane spotting” devices
  - Data loggers for internet based online Virtual Radar systems
- Feeder for MLAT servers
  - Thanks to the high-precision time stamps that are added to each received Mode S / ADS-B frame, the Hulc-M can be used as feeder for a Multilateration (MLAT) server.

original size

V 1.2, Aug 31th 2020

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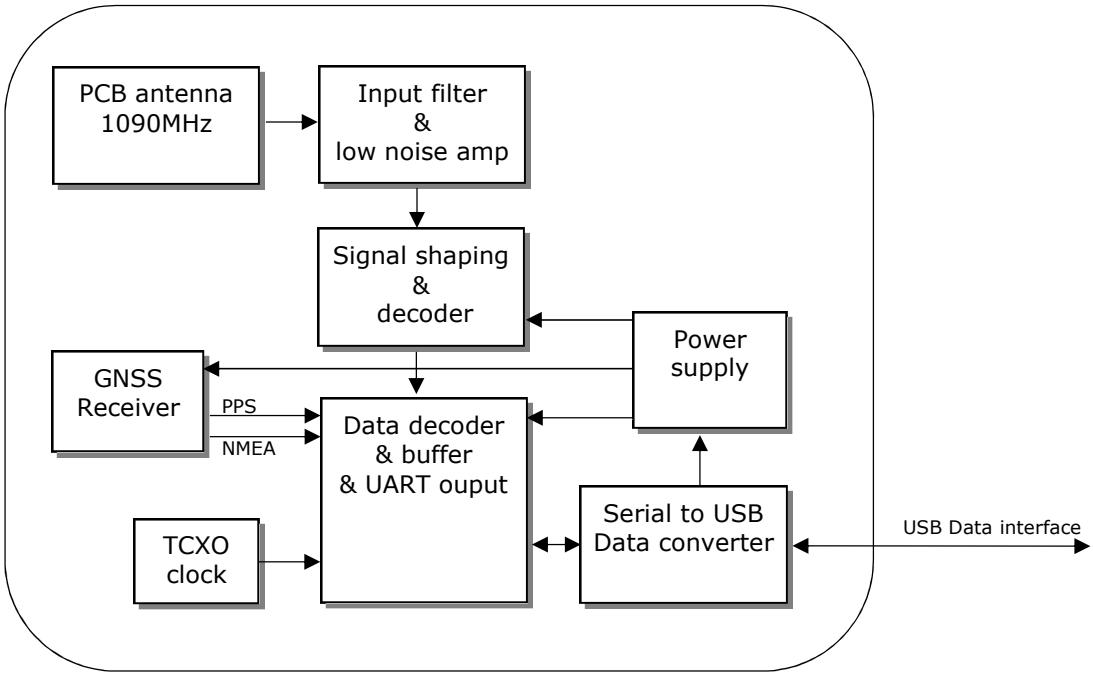
2 BLOCK DIAGRAM



Hulc-M Block Diagram

3 DETAILED DESCRIPTION

Hulc-M is a high performance receiver unit for Mode-S and ADS-B messages.
The improved RF architecture and outstanding decoder circuit together with the enhanced firmware provides maximum performance at minimum space and power requirements.
Power supply and data interface are established via a USB connection. Thanks to the integrated narrowband 1090MHz antenna, the Hulc-M is immediately ready to receive.

Hulc-M receives all Mode-S data frames. If the data bandwidth is not sufficient, all short squitters can be suppressed using a filter function.

Hulc-M features a special ultra fast signal level adaption that overcomes the so called “doughnut effect”. This input stage allows to receive very strong “near” and and very weak “far” signals at the same time without losses.

The signal picked from air is filtered and decoded without any host processing requirements.
The GNSS receiver integrated in the Hulc-M and the TCXO used make it possible to add a highly precise absolute timestamp to each Mode-S frame received.
A relative RSSI is also provided for each frame. These extensions allow the Hulc-M to be used as part of an MLAT receiver network or even as a standalone receiver with which the distance to the transmitters of the received signals can be estimated.
In both cases an appropriate host system with application must read and interprete the data and present them through the UI.

3.1 UART Interface details

Hulc-M must be connected to the host system by a USB Interface. Serial data (SPP protocol) are forwarded to the host system via this interface.
Commands, replies and data are transferred using the new 'Hulc' protocol.
'Hulc' protocol is based on the well-known ‘BEAST’ protocol.

For safe communication, implementing hardware handshake via RTS and CTS is recommended.
I/O levels are 3.3V (see electrical data).

Hulc-M UART Default Settings		
Parameter	**HULC protocol**	**Unit**
Baud rate	921600	bit / sec
Data length	8	bit
Stop bit	1	
Parity	none	
Handshake	RTS/CTS	hardware

3.2 Power supply

Hulc-M needs a single power supply of 4.3..5.5V provided by USB interface. The current consumption is ~100mA at full operation.

3.3 Integrated ADS-B antenna

The integrated antenna is a PCB antenna with an isotropic omnidirectional beam characteristic specially developed for this purpose. For antenna installation, it's important to know that ADS-B signals will spread linear only. Any obstacles like buildings, mountains or woods will mute or even totally block ADS-B-signals.
Antenna should be mounted to have an unobstructed "view" in all directions from a raised location.
.

ATTENTION: Risk of fire and injury ! For any raised mounted antenna constructions like roof antennas or aerial masts, it's mandatory to follow the rules for lightning protection.
In case of doubt please consult a professional specialist

4 ELECTRICAL SPECIFICATION

4.1 Absolute Maximum Ratings

Parameter	Value	Unit
Supply voltage range: V_{dd}	0 to 5.5	V
Operating ambient temperature range	-20 to +70	°C
Storage temperature range	–40 to +85	°C
Maximum input level	+5	dBm

4.2 Recommended Operating Conditions

Parameter	Min	Typ	Max	Unit	Note
V_{dd}	4.3	5.0	5.5	V	Power-supply voltage
Operating temperature	-20		70	°C	Full specified performance

4.3 Characteristics

Parameter	Min	Typ	Max	Unit	Note
general					
Frequency		1090		MHz	ADS-B – mode S
Output data frequency		921600		kBit/sec	Uart baudrate
UART baud deviation			0.1	%	
sensitivity	-105		+5	dBm	Frame detection level(*1)
Power consumption					
Current full operation		130	150	mA	
Supply voltage	4.3	5.0	5.5	V	

(*1) : measured sensitivity of the receiver with wired feed. For more details see 4.3.1 Receiver Sensitivity Details

4.3.1 Receiver Sensitivity Details

Signal strength	Percentage Frame Reception Rate
-98 dBm	100 %
-100 dBm	70%
-105 dBm	<1 %

5 ADS-B DATA

There are 25 possible types that will be all available, but for Virtual Radar applications, type 11 and 17&18 (extended squitter) are most important.
The following table shows all types in a short form. For further information, please refer to ADS-B specifications, for example the publications from ICAO (International Civil Aviation Organization).

Mode-S reply available sentences							
DF	**Type**						**content**
00000	VS:1	7	RI:4	2	AC:13	AP:24	Short air-air surveillance (ACAS)
00001	27 or 83					P:24	Reserved
00010	27 or 83					P:24	Reserved
00011	27 or 83					P:24	Reserved
00100	FS:3	DR:5	UM:6	AC:13		AP:24	Surveillance, altitude reply
00101	FS:3	DR:5	UM:6	ID:13		AP:24	Surveillance, identify reply
00110	27 or 83					P:24	Reserved
00111	27 or 83					P:24	Reserved
01000	27 or 83					P:24	Reserved
01001	27 or 83					P:24	Reserved
01010	27 or 83					P:24	Reserved
01011	**CA:3**		**AA:24**			**PI:24**	**All-call reply**
01100	27 or 83					P:24	Reserved
01101	27 or 83					P:24	Reserved
01110	27 or 83					P:24	Reserved
01111	27 or 83					P:24	Reserved
10000	VS:1	7	RI:4	2	AC:13	MV:56	AP:24	Long air-air surveillance (ACAS)
10001	**CA:3**	**AA:24**		**ME:56**			**PI:24**	**Extended squitter**
10010	**CF:3**	**AA:24**		**ME:56**			**PI:24**	**Extended squitter/non transponder**
10011	AF:3	104						Military extended squitter
10100	FS:3	DR:5	UM:6	AC:13	MB:56		AP:24	Comm-B, altitude reply
10101	FS:3	DR:5	UM:6	ID:13	MB:56		AP:24	Comm-B, identify reply
10110	27 or 83					P:24	Reserved for military use
10111	27 or 83					P:24	Reserved
11xxx	1	KE:1	ND:4	MD:80		AP:24	Comm-D (ELM)

AA:Address announced ; AC:Altitude code ; AF:Application field ; AP:Address/parity ; AQ:Acquisition ; CA:Capability ; CC:Cross-link capability ; CF:Control field ; CL:Code label ; DF:Downlink format ; DI:Designator identification ; DR:Downlink request ; DS:Data selector ; ELM:Extended length message ; FS:Flight status ; IC:Interrogator code ; ID:Identità ; KE:Control, ELM ; MA:Message, Comm-A ; MB:Message, Comm-B ; MC:Message, Comm-C ; MD:Message, Comm-D ; ME:Message, extended squitter ; MU:Message, ACAS ; MV:Message, ACAS ; NC:Number of C-segment ; ND:Number of D-segment ; PC:Protocol ; PI:Parity/interrogator identifier ; PR:Probability of reply ; RC:Reply control ; RI:Reply information ; RL:Reply length ; RR:Reply request ; SD:Special designator ; UF:Uplink format ; UM:Utility message ; VS:Vertical status

6 COMMAND INTERFACE

The new Hulc protocol, which is used to transmit Mode-S messages, is compatible with the so-called Beast Binary protocol to facilitate the connection of the Hulc-M to existing software.
Commands are transmitted from the host to the Hulc-M via ASCII coded command messages.

6.1 Command Message (Host →Device)

The command-message has a simple ASCII based structure. Each message starts with a '#' (0x23) and ends with '<CR><LF>' (0x0D, 0x0A). In-between are one to 16 bytes in 2-digit hexadecimal representation using upper-case letters, separated by '-' (0x2D).

For example:

'#00<CR><LF>' or hexadecimal 0x23 0x30 0x30 0x0D 0x0A
'#43-02<CR><LF>' or hexadecimal 0x23 0x34 0x33 0x2D 0x30 0x32 0x0D 0x0A

The first byte is mandatory and holds the command while the remaining bytes are parameters. Available commands depend on the selected protocol and are discussed in the respective protocol section.

6.2 HULC Protocol

Serial Port Parameters: 921.600 bps, 8N1, RTS/CTS-Handshake
Message structure, line encoding ('escaping') and Mode-S data messages are compatible with Beast Binary Protocol.

6.2.1 Packetizing & Line Encoding

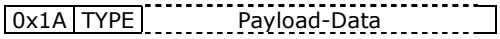
HULC Protocol uses the byte 0x1A as start-of-packet (SOP) marker. In order to avoid misinterpretation of normal data bytes with value 0x1A as SOP, each occurrence of data byte 0x1A is doubled in the data stream during transmission ('escaping'). It is thus necessary during reception to detect every 0x1A not followed by another 0x1A as an SOP marker and to reduce every occurrence of a double 0x1A to a single 0x1A data byte ('un-escaping').

Example of a 4-byte long packet including SOP marker and 0x1A data bytes:

Before Escaping:	**1A** 32 27 1A E8 57 F0 1A 6C
During Transmission:	**1A** 32 27 1A 1A E8 57 F0 1A 1A 6C
After Un-Escaping:	**1A** 32 27 1A E8 57 F0 1A 6C

6.2.2 Message Structure

All messages have the following basic structure (without escaping):

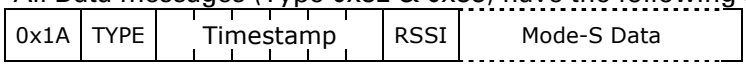


The following types are defined:

Type	Payload Size	Description
0x32	7 bytes	Mode-S Short Squitter raw data
0x33	14 bytes	Mode-S Extended Squitter raw data
0x48	variable	HULC Message, see below for details

Data Messages

All Data messages (Type 0x32 & 0x33) have the following structure:



Fields:

TYPE	8-bit	0x32 or 0x33 for Mode-S short or extended squitter respectively
Timestamp	48-bit[1]	Upper 18 bits are seconds since last midnight 00:00:00 UTC Lower 30 bits are nanoseconds of current second
RSSI	8-bit	Logarithmic field-strength indicator, uncalibrated
Mode-S Data	N * 8-bit	Mode-S raw data, N = 7 for TYPE 0x32 and N = 14 for TYPE 0x33

[1)] MSB-first

Timestamps:

There are two distinct timestamp formats, absolute and relative timestamps depending on whether a GPS receiver is attached or not. To find out which format is used check bit 15 (Gps Detected) in the status flag field of the HULC Status Message. Both timestamp formats are compatible with the respective timestamp formats used in the Beast Binary Protocol.

Relative Timestamp (No GPS):
Without a GPS receiver attached the timestamp is a 48-bit unsigned number counting 12 MHz cycles. The timestamp will wrap approximately every 271 days.

Absolute Timestamp (With GPS):
If a suitable GPS receiver is attached the 48-bit timestamp field is divided into the upper 18 bits which count the seconds since last midnight 00:00:00 UTC and the lower 30 bits which carry the nanoseconds of the current second. Timestamp nanoseconds are guaranteed to be less than one complete second.
Example: 0x3746554be940 = (56601 sec + 357296448 nsec) = 15:43:21.357296448 UTC

HULC Messages

All HULC messages (Type 0x48) have the following structure:

0x1A	0x48	ID	LEN	LEN bytes of Data

Fields:

ID: HULC Message ID
LEN: Number of bytes following

All multi-byte data within a HULC message is structured MSB-first!

The following IDs are defined:

ID	Description
0x01	Periodic HULC Status Message (~1/sec)
0x24	Reply to command

HULC Status Message (ID:1):

Periodic status message which is emitted every second

0x1A	0x48	0x01	0x18	SerNum	Flags	I.U.	xTime	Lat	Lon	Alt	Sat	HDOP

Length of Data is currently 24 bytes but may be increased in the future by appending more fields. Thus any parser handling this message type should test for (LEN >= 0x18) and handle all fields known to them ignoring any additional data.

Fields:

SerNum	32-bit[1]	Device Serial Number
Flags	16-bit[1]	Status Flags*
I.U.	16-bit	Internal Use
xTime	32-bit[1]	Unix-Timestamp (Seconds since midnight 1970-01-01, UTC)
Lat	32-bit[1]	Latitude as 32-bit BAM 2, thus 232 ≡ 360°
Lon	32-bit[1]	Latitude as 32-bit BAM 2
Alt	16-bit[1]	Signed altitude meters
Sat	8-bit	Number of satellites used in fix
HDOP	8-bit	HDOP * 10, thus a value of 12 is HDOP 1.2

[1)] MSB-first

[2)] https://en.wikipedia.org/wiki/Binary_scaling#Binary_angles

Status Flags:

1xxx xxxx xxxx xxxx - GPS device detected -> Using absolute timestamp
x1xx xxxx xxxx xxxx - GPS valid (GGA, RMC present)
xx1x xxxx xxxx xxxx - GPS currently has a valid fix
xxx1 xxxx xxxx xxxx - High accuracy absolute time is available via PPS
xxxx xxxx 1xxx xxxx - TX-Queue overflow since start-up (normal if HW-handshaking is used)
xxxx xxxx x1xx xxxx - TX-Queue overflow during last second (probably due to HW-handshaking)
xxxx xxxx xx1x xxxx - Excessive NMEA found (other than GGA/RMC)

Reply Message (ID:0x24) (to a command message):

0x1A	0x48	0x24	0x10	CMD	P00	P01		P14

Length of Data is always 16 bytes.

Fields:

CMD	8-bit	The command for which this message is the reply
P00..14	8-bit each	Total of 15 paramter for the reply

6.3 Command Messages (Host →Device)

The command-message has a simple ASCII based structure. Each message starts with a '#' (0x23) and ends with '<CR><LF>' (0x0D, 0x0A). In-between are one to 16 bytes in 2-digit hexadecimal representation using upper-case letters, separated by '-' (0x2D).

For example:
'#00<CR><LF>' or hexadecimal 0x23 0x30 0x30 0x0D 0x0A
The first byte is mandatory and holds the command while the remaining bytes are parameters which may be mandatory or optional depending on the command.

6.3.1 Available Commands

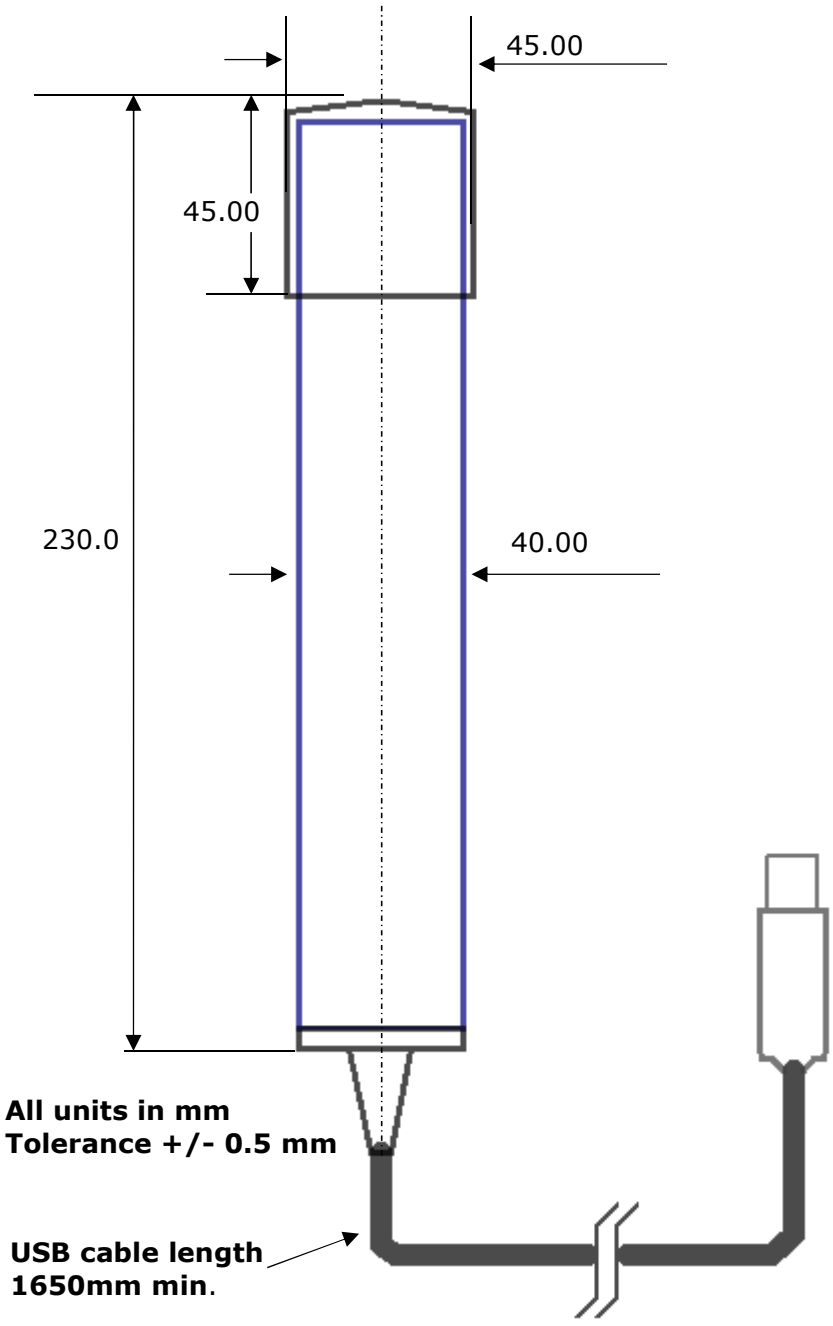
Command 0x00 – Version Request:

Cmd: #00<CR><LF>
Reply: 1A 48 24 10 **00** 00 80 04 81 yy ww bb xx xx xx xx xx xx xx xx

Parameter	Note
p00 .. p03	Fixed 00-80-04-81 for compatibility reasons
p04 .. p06	yy-ww-bb is Version year, week, build-number
p07 .. p14	Internal Use

Example
Cmd: #00<CR><LF>
Rpl: 1A 48 24 10 00 00 80 04 81 14 05 03 01 02 03 01 00 00 00 00
(14-05-03 -> v20.5.3)

7 PHYSICAL DIMENSIONS



8 ORDERING INFORMATION

Ordering information		
Type	**Part#**	**Description**
Hulc-M	4037735105706	Hulc-M evaluation kit

9 DOCUMENT REVISION HISTORY

Version	Revision	Date	Author	comment
V1.0	Primary	May 20 2020	M.Heinzel	Primary version
V1.1	Alpha release	July 10 2020	M.Heinzel	Chapter 4.3.1. (Receiver Sensitivity Details) added
V1.2	Alpha release	Aug 31 2020	M.Heinzel	Chapter 4.3. (Power Consumption) updated

Document status

Primary:	Primary version, document content for design purpose, informal release
Alpha release:	Key customer preview version, document content has been preliminarily tested and verified, indicators may be fine-tuned later
Beta release:	Document content is verified by complete product testing and content indicators
Production release:	The document is complete and final

10 DISCLAIMER