HORIZON HOBBY, LLC.

Specification for Spektrum® X-Bus Telemetry Sensors

Enabling Use of Non-Spektrum Sensors

Rev O

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Specification for communicating on the X-Bus so that data from non-Spektrum devices can be displayed on the Spektrum AirWare™ -based transmitters.

Specification for Spektrum® X-Bus Telemetry Sensors

1 INTRODUCTION

With the advent of third-party display (J-Link), annunciation (vSpeak), and data display systems (Robo-Software and TLMViewer.com), we feel it is in everybody's best interests to open the telemetry system by sharing correct implementation data. With that mindset, the purpose of this document is to enable third-party telemetry sensors, both commercial and hobbyists, that can use the Spektrum X-Bus telemetry system as a data transport mechanism for custom sensors including items such as:

- an ESC,
- fuel flow meter,
- high-current battery “fuel gauge” (mAh),
- digital status (for example, landing gear status lights),
- thrust/strain gauge,
- air tank pressure, or
- an individual cell monitor for LiPo batteries.

The intent is that publication of this document will ensure that these third-party devices can inter-operate with one another and with Spektrum products in a non-interfering, cooperative manner. Spektrum will provide an interface to allow generic data display and alarms on certain levels of transmitter products, although they obviously cannot be as thoroughly integrated into the radios as Spektrum products are.

2 AUDIENCE

This document is intended for non-Horizon personnel to be able to develop sensors which function correctly in the Spektrum X-Bus Air Telemetry System. This document includes sufficient information to allow a sensor to be created such that it reports data useful to the users.

3 RELATED DOCUMENTATION

All necessary technical information is contained within this document, including diagrams and source code guidance.

4 LEGAL INFORMATION

Spektrum X-Bus Telemetry Data Application
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All correspondence regarding this document shall be through the Horizon Hobby legal department:

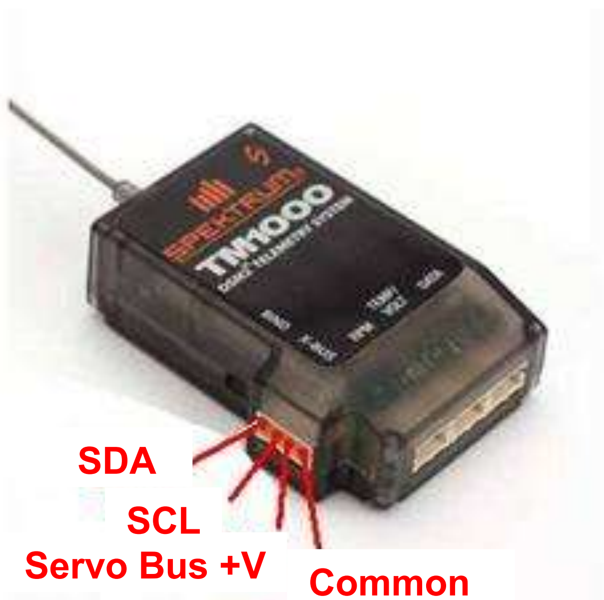
Horizon Hobby, LLC
Legal Department
2904 Research Road
Champaign, IL 61822 USA

5 ELECTRICAL DATA

Throughout this document, references to the TM1000 shall be understood to refer to both the TM1000 device or Spektrum receivers equipped with an X-Bus such as AR7350, AR9350, AR6600T, etc. which are hereafter referred to as "T-series receivers" whether they include the T suffix on the name or not. There are differences between the TM1000 and the T-series receivers which are noted where necessary. Unless such differences are noted, it should be assumed that the telemetry receivers and TM1000 operate identically. For maximum compatibility, it is required that the devices work with the telemetry receivers as these have an optimized interface.

All sensors are powered by the X-Bus. The X-Bus port bus provides the servo bus voltage (3.5 to 9.6V) at a current limited by the JST contact rating (1A). The operational limit in an application may be quite a bit lower, depending upon the method of powering the servo bus.

The X-Bus uses I2C to communicate. Termination resistors are in the TM1000. The pins are defined according to this picture:



Every device shall be responsible to regulate the supply to a level useful for its operation. The I2C signals must be 3.3V logic, and the pins in open drain mode so as to not interfere with the logic levels.

In order to maintain compatibility with other products, it is strongly urged that any sensors include two X-Bus ports to allow them to be daisy-chained in the same manner as Spektrum sensors.

The connector used in the TM1000 and all Spektrum sensors is JST part number S4B-ZR(LF)(SN) or Digikey part 455-1671-ND.

6 HARDWARE-LEVEL PROTOCOL

The TM1000 is an I2C master device talking at 100kHz to the slaves. For best future compatibility, devices should support 400kHz as well.

Every device shall reply to a poll with a 16-byte message, the first byte of which is always the polled I2C address. The remaining bytes are defined in the section on the telemetry header file.

Shortly after the TM1000 starts, it polls all addresses on the bus. During this enumeration phase, the attached devices must reply with their address as the first byte of the reply. The remainder of the first message will be discarded by the TM1000, but the full 16-byte message must be available for the TM1000 to clock in. If a device does not answer the enumeration correctly, the TM1000 will not poll it any more. It is therefore of utmost importance that the first two polls of an I2C address be answered correctly. Some third-party vendors have chosen to stretch the I2C clock per Philips' I2C specification, however Spektrum discourages this practice. T-series receivers may have other things going on during enumeration and expect enumeration to be completed at a given time. If a device or devices stretch the clock too far, this can cause failure both of the enumeration but perhaps also of other receiver activities.

The TM1000 is fully supportive of clock stretching to allow slow-to-start devices to enumerate properly. If your device will be slow to start, it is recommended that you select a higher address [QUESTION: Does the TM1000 increment or decrement addresses when polling the bus? How about the receivers?]. If you need assistance with developing a sensor which complies with the startup requirements, please contact Spektrum and we may be able to arrange for an external engineer experienced with the Spektrum protocol to assist you.

Note that there are enumeration timing differences between the TM1000 and the T-series receivers. The TM1000 polls the bus twice during enumeration, while T-series poll it only once. Both polls are important for device response. Also, the time between consecutive address polls during enumeration in the T-series is much faster than between addresses in the TM1000 device.

Need a picture of a scope showing traces for TM1000 and T-series during power up, highlighting the timing differences between poll speeds.

The TM1000 transmits data to the ground at a rate of one message per 22ms. The time between polls for any single device is dependent upon the number of sensors which enumerated on the bus and, for T-series receivers, the priority configuration of the various internal and external devices. If timing is a critical function for a particular device, it is necessary that the device provide its own clock source and not utilize the X-Bus for timing.

7 ADDRESSING & DEVICE TYPES

The telemetry header file used by all Spektrum AirWare-based transmitters is found on our Github site, https://github.com/SpektrumRC/SpektrumDocumentation/tree/master/Telemetry. This file defines the device type codes for all Spektrum products and known reserved values. The device type codes are used as I2C bus addresses by default, but the protocol also provides a means for them to differ.

Products using the telemetry capabilities of the Bi-Directional SRXL interface must also comply with the addressing mechanism, although they do not need to worry about enumeration. Please refer to the Spektrum Bi-Directional SRXL PDF for using serial device telemetry.

Spektrum reserves the right to use addresses not listed as we deem necessary. We do not intend to interfere with other products, and therefore urge anybody making a device to provide a mechanism to select different addresses should the need arise. Commercial vendors are urged to contact Spektrum in order to coordinate addresses and prevent interference. As you review the list, you may notice that certain manufacturers have reserved addresses.

Note that Spektrum is the owner of all address assignments, and does not guarantee that any unused address will be available in the future. Only addresses specifically assigned are guaranteed not to change. Addresses 0x09 and below shall not be used by any third-party devices.

For each of the messages in the header file it should be noted that they begin with the fields *identifier* and *sID*. The *identifier* field is always under all circumstances an exact match to the I2C address, and needs to be the first byte of any reply as noted in the hardware-level section. The second byte, *sID*, serves as a way to allow either multiple devices of the same type to live on the bus, or for a device to retain its type code when there is a conflict of the addresses. At this time, none of the AirWare radios fully support data from multiple instances of the same device type, although they do recognize them as being different devices. Devices should be re-addressable by writing to an internal address parameter as specified in a later section in this document.

Use of the sID field is quite simple:

When sID is zero, then the device type (TELE_DEVICE_xxx) is the same as the bus address *identifier*. This is the norm for all Spektrum products. If *sID* is non-zero, then *sID* is the device type and *identifier* serves only to provide a unique I2C address.

On an SRXL interface the ID and sID fields can be used to enable an interaction with an Android app to enable configuration of a device from the transmitter (aka “Forward Programming”). Information on Forward Programming is available under NDA.

8 DATA FORMATS

If a user is developing a sensor which is intended to mimic a Spektrum sensor, the developer should note that Spektrum sensors are a mixed bag of big- and little-endian data. Spektrum also uses packed BCD for Turbine and GPS but does not support these formats for third-party products.

All third-party sensors shall report their data in big-endian format (MSB at lower address) if they are to be displayed on the transmitter screens. All data shall be binary 8, 16 or 32 bits.

The TM1100 module notifies the transmitter that it is in use by setting the high bit of the *identifier* field. This is informational-only to the transmitter and does not affect operation.

The DSMX Ultra Micro receivers provide Flight Log data only, using the standard QoS record structure. The receiver voltage field is fixed at 0xFFFF, indicating “no data” to the transmitter.

The transmitter uses two sentinel values to indicate that there is “no data” for a field. For an unsigned value, a value with all bits set to one (ie, 0xFFFF or 0xFFFFFFFF) indicates this. For most messages, a signed value indicating “no data” value is denoted by all bits set except the sign bit, i.e. 0x7FFF or 0x7FFFFFFF. Please refer to the specific message and data element for exceptions.

These values and standards are also utilized by post-flight systems to properly display logged data.

9 ACCESSING INTERNAL DEVICE CONFIGURATION

Because of the possibility of address conflicts, multiple identical devices on the bus, and such, it is strongly recommended that all devices be capable of reconfiguration. The method chosen is at the discretion of the developer, but Spektrum suggests that configuration over I2C for at least the bus address. The recommended method is to behave like a memory device, such as a standard 24xx128. This provides a means for reading and writing parameters within the device using a standard interface without jeopardizing normal telemetry operation. (Note that an EEPROM would operate within addresses 0x50 through 0x57, corresponding to the User Defined messages in the telemetry H file.)

Device configuration may be performed with multiple devices on the bus, so long as they each already have a unique address. If the purpose of the configuration is to ensure a unique address, then configuration must be performed with only a single device connected.

The recommended minimum configuration is for the telemetry bus address. It should be configurable at emulated EEPROM address 0x0100. To do that, one would clock the current device telemetry address with the R/W bit cleared (write request) and wait for the ACK. Clock in an 8-bit high address of 0x01, wait for ACK, clock in the 8-bit low address of 0x00, wait for ACK. Next, clock in the new address, wait for ACK, clock in the device type, wait for ACK, and then issue a STOP condition.

All future accesses to this device will now occur using the new device address. Take care to differentiate the device address (7 bits) from the memory address within the device (16 bits).

10 FORWARD PROGRAMMING

Forward Programming (FP) is typically associated with SRXL-based devices, but can also be performed over I2C with certain receivers.

Forward Programming over I2C (FPI) is always initiated by the telemetry device. This may be in response to a pushbutton or other user action, and must be done after the device has enumerated and is being regularly polled by the receiver. FPI should never be performed while the model is active (flying, etc.). The transmitter always enforces a throttle-off condition to enter FP, and Spektrum receivers always enforce throttle-off when they are in FP mode themselves.

Only one device in a system can be in FP mode at a time.

When a device wishes to enter FPI mode, its normal response to the ID/sID is replaced with ID/0x09 as part of a 14-byte FP initialization request message. If the receiver accepts the request, it will immediately cease polling other I2C devices and concentrate on the requesting device. The device must be able to support polls by the receiver at 22ms intervals. The actual polling rate will be determined by the receiver and transmitter interactions as well as the behavior of the device in FPI mode.

Uplink FPI messages (from the operator to the device) shall be written to the I2C bus as simulated memory writes to address 0x0900 of variable lengths as supported by the FP protocol over the RF link.

Downlink FPI messages shall be fixed 14-byte data packets with the ID/0x09 prefix.

The content of the messages shall conform to the FP protocol and are outside the scope of this document. For more information please refer to Spektrum document “Forward Programming Specification for External Users.pdf”.

11 ELECTRONIC SPEED CONTROL

The AirWare-based transmitters include support for a generic Electronic Speed Control (ESC) device. Spektrum does not at this time sell a device which conforms to this telemetry standard, but is instead providing a common interface which may be supported by ESC manufacturers. Several are available from third parties such as Castle.

The ESC configuration screen provides the same functions available to other devices, that is, whether the status is actively monitored on the display. Alarms are available for the following conditions:

- Input Voltage too low
- Motor current too high
- FET temperature too high

The units and ranges for each of the fields in the telemetry message are found in the appendix in the definition for the ESC structure. The transmitter does not provide any filtering of data for any ESC fields.

12 FUEL FLOW METER

The AirWare-based transmitters may include support for a generic fuel flow and capacity metering device. Spektrum does not sell a device which conforms to this telemetry standard, but is instead providing a common interface which may be supported by third-party manufacturers.

The “Fuel” configuration screen provides the same functions available to other devices, that is, whether the status is actively monitored on the display. Alarms may be available for some of the following conditions:

- Tank 1 capacity consumed > user-defined value
- Tank 2 capacity consumed > user-defined value
- Fuel flow 1 too low
- Fuel flow 1 too high
- Fuel flow 2 too low
- Fuel flow 2 too high
- Temperature 1 too low
- Temperature 1 too high
- Temperature 2 too low
- Temperature 2 too high

The units and ranges for each of the fields in the telemetry message are found in the H file in the definition for the FUEL structure. The transmitter does not provide any filtering of data for any fields.

13 HIGH-CURRENT BATTERY CAPACITY

The AirWare-based transmitters include support for a generic battery current and capacity metering device. Spektrum SPMA9605 provides this function, alarming and reporting only the first set of message data (address 0x34) at this time. Third party devices are available which support both channels of data.

SPMA9604 provides similar capabilities for low-current applications using address 0x18. PowerSafe receivers use both channels of reporting in the low-current record (0x18 type) for each input power source.

The units and ranges for each of the fields in the telemetry message are found in the H file in the definition for the MAH structures. The transmitter does not provide any filtering of data for any fields.

14 DIGITAL INPUT AND AIR PRESSURE SENSOR

The AirWare-based transmitters may include support for a generic digital input and air pressure metering device. Spektrum does not sell a device which conforms to this telemetry standard, but is instead providing a common interface which may be supported by third-party manufacturers.

The “Air” configuration screen provides the same functions available to other devices, that is, whether the status is actively monitored on the display. Alarms may be available for the following conditions:

- Digital Bit set (bits 0-16)
- Digital Bit clear (bits 0-16)
- Pressure too low
- Pressure too high

The units and ranges for each of the fields in the telemetry message are found in the appendix in the definition for the DIGITAL_AIR structure. The transmitter does not provide any filtering of data for any fields.

15 THRUST/STRAIN GAUGE

The AirWare-based transmitters may include support for a generic thrust or strain metering device. Spektrum does not sell a device which conforms to this telemetry standard, but is instead providing a common interface which may be supported by third-party manufacturers.

The “Strain” configuration screen provides the same functions available to other devices, that is, whether the status is actively monitored on the display. Alarms may be available for the following conditions:

- Single Strain too high (any input above threshold)
- Sum Strain too high (sum of active strains above threshold)
- Strain Imbalance (delta of min/max strains on active inputs is above threshold)

The units and ranges for each of the fields in the telemetry message are found in the appendix in the definition for the STRAIN structure. The transmitter does not provide any filtering of data for any fields.

16 INDIVIDUAL CELL MONITOR

The AirWare-based transmitters include support for generic multi-tap voltage monitoring devices in both 6S and 14S combinations. Spektrum does not sell a device which conforms to this telemetry standard, but is instead providing a common interface which may be supported by third-party manufacturers.

NOTE: The Common (Ve-) connection of the X-Bus is connected to the receiver, which in an electric model is likely connected directly to the negative terminal in the battery string. It is strongly recommended that the voltage measurements be galvanically isolated from the battery pack being measured so as to prevent short circuits and ground loops. This isolation also permits battery packs of more than 6 cells to be monitored accurately and without concern for wiring problems.

It is recommended that the user familiarize himself with the balance and voltage limit reporting functions within the two cell monitor support screens.

The units and ranges for each of the fields in the telemetry message are found in the appendix in the definition for the LIPOMON structure. The transmitter does not provide any filtering of data for any fields.

17 ATTITUDE & MAGNETIC COMPASS

The AirWare-based transmitters may include a facility to display data from an attitude and magnetic compass. This is currently envisioned as an information-only device which may be of use in certain applications but unable to generate alarms. Data which is unavailable due to limitations of the sensor hardware shall report a value of 0x7FFF to indicate “No data available.”

18 3-AXIS GYRO

The AirWare-based transmitters include a facility to display data from a 3-axis gyro system. This currently is envisioned as an information-only device which may be of use in certain applications, but unable to generate alarms. Data which is unavailable due to limitations of the sensor hardware shall report a value of 0x7FFF to indicate “No data available.”

19 USER-DEFINED DEVICES IN THE TX

The AirWare-based transmitters include a facility to display data from user-defined sensors according to four “user” structures defined in the Appendix. The four structures are associated with four different *identifier* field values.

DX-series transmitters have generic screens to show the data for each structure type. The transmitters allow the user to specify a short title for the screen, but not for individual fields, nor for specification of units. The Android radio will have better capability for user configuration of the presentation of the data for this screen, as one ought to expect with such a feature-rich platform.

The transmitter does not provide any filtering of data for any fields.

20 USER TEXT DEVICE

The AirWare-based transmitters include a facility to display text data directly on the screen in a formatted manner. This message would typically be used in conjunction with a bi-directional telemetry module such as the SPM4649T attached to a flight controller (FC) for purposes of configuring the FC using transmitter stick inputs (aka “Stick Programming”).

APPENDIX – HEADER FILE DATA

Note that some device types cannot be used by third-party devices, in particular voltage (0x01) and temperature (0x02), as these are reserved for internal use within the transmitter.

Header file has been made into a separate file which can be found here.
https://github.com/SpektrumRC/SpektrumDocumentation/blob/master/Telemetry/spektrumTelemetrySensors.h

REVISION HISTORY

Rev	Date	Author	Description
P0	2013-03-28	AK	For initial review.
P1	2013-04-04	AK	Fix address in JetCat_2 struct definition.
P2	2013-07-08	AK	Add RF data type/struct (Bug MD 1000).
P3	2013-07-10	AK	Add Gyro and Attitude/Compass info.
P4	2013-07-16	AK	Add 0x43 as reserved address. Correct text on TM1000.
P5	2013-11-19	AK	Change Dual Energy and MAH structs. Reserved addresses 0x30 and 0x32 for internal sensors, reassigned devices to 0x20 and 0x22.
P6	2014-03-31	AK	Correct ESC struct .currentBEC units to 100mA
P7	2014-05-05	AK	Revise ESC struct for powerOut and No Data sentinels
A	2015-01-16	AK	Release to the public.
B	2015-01-23	AK	Update temp resolution for ESC.
B’	2015-11-24	TB	Legal Information added for public release
C	2015-12-28	AK	Annotate Turbine fields as BCD per code.
D	2015-12-30	AK	Expand/Correct Turbine Status code values for more ECUs.
E	2016-02-16	AK	Integrate B’ into published document.
F	2016-03-06	AK	Correct Pbox ID in struct area, add Alpha6, add reference to SPMA9604/5.
G	2016-03-26	AK	Revise 6S, Add 14S LiPo Monitors
H	2016-07-28	AK	Add Lap Timer, Text Generator
I	2016-08-26	AK	Add dBm fields to RPM record
J	2016-08-30	AK	Update Lap Timer
K	2016-10-28	AK	Add RTC report device
L	2016-11-03	AK	Add Text description, update status of some sensors per Tx.
M	2016-12-16	MFA	Removed header file. Now a separate referenced file.
N	2018-03-14	AK	Enumeration, general comments/clean-up, add Forward Programming.
O	2019-10-16	MWO	Correct address and GitHub link to telemetry header file.