**University of Minnesota**

**FMU Communication Protocol**

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# Ethernet Interface

The Ethernet interface is the primary means of communication with the flight management unit (FMU). Data is transmitted using UDP packets on port number 55455.

## Packet Format

The UMN protocol format is as follows:

|  |  |  |
| --- | --- | --- |
| Byte # | Description | Value |
| 0 | Header 0 | ASCII ‘U’ (0x55) |
| 1 | Header 1 | ASCII ‘M’ (0x4D) |
| 2 | Header 2 | ASCII ‘N’ (0x4E) |
| 3 | Payload Type | See packet definition. |
| 4 | Length (LSB) | Payload length (# of bytes 6 to N). |
| 5 | Length (MSB) |
| 6 … N | Payload | See packet definition. Multi-byte values use little endian. |
| N + 1 | CRC (LSB) | CRC-16-CCITT of bytes 3 to N. |
| N + 2 | CRC (MSB) |

## Packet Summary

|  |  |  |
| --- | --- | --- |
| Payload Type | Data Direction | Description |
| 0x00 | Host to FMU | Host Heartbeat |
| 0x01 | Host to FMU | Control Surface Command |
| 0x7F | Host to FMU | Host Debug / Exception |
| 0x80 | FMU to Host | FMU Heartbeat |
| 0x81 | FMU to Host | IMU Data |
| 0x82 | FMU to Host | GPS Data |
| 0x83 | FMU to Host | Air Data |
| 0x84 | FMU to Host | Control Surface Data |
| 0xFF | FMU to Host | FMU Debug / Exception |

## Packet Definitions

### Host Heartbeat (0x00)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Message Type | Host Heartbeat (0x00) | | | | |
| Description | This packet provides periodic status and monitoring of the host. | | | | |
| Data Direction | Host to FMU | | | | |
| Frequency | 1 Hz | | | | |
| Message Structure | Header | Type | Length (Bytes) | Payload | CRC |
| 0x55, 0x4D, 0x4E | 0x00 | 16 | See below. | CRC-16-CCITT |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Byte Offset | Data Format | Scaling | Name | Unit | Description |
| 0 | UINT32 | - | fwVersion | - | Firmware version ID. |
| 4 | UINT32 | - | hwVersion | - | Hardware version ID. |
| 8 | UINT32 | - | serialNum | - | Serial number. |
| 12 | UINT32 | - | msUptime | ms | System uptime in milliseconds. |

### Control Surface Command (0x01)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Message Type | Control Surface Command (0x01) | | | | |
| Description | This packet provides control surface command information. | | | | |
| Data Direction | Host to FMU | | | | |
| Frequency | 100 Hz typical | | | | |
| Message Structure | Header | Type | Length (Bytes) | Payload | CRC |
| 0x55, 0x4D, 0x4E | 0x01 | 3N | See below. | CRC-16-CCITT |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Byte Offset | Data Format | Scaling | Name | Unit | Description |
| 3(N-1) + 0 | UINT8 | - | surfaceID | - | Control surface ID, 0-31. |
| 3(N-1) + 1 | INT16 | 1e3 | position | rad | Control surface position in scaled radians, input range: +/- 1570. |

### Host Debug / Exception (0x7F)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Message Type | Host Debug / Exception (0x7F) | | | | |
| Description | This packet provides host debug and exception information. | | | | |
| Data Direction | Host to FMU | | | | |
| Frequency | Asynchronous | | | | |
| Message Structure | Header | Type | Length (Bytes) | Payload | CRC |
| 0x55, 0x4D, 0x4E | 0x7F | 0-1024 | See below. | CRC-16-CCITT |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Byte Offset | Data Format | Scaling | Name | Unit | Description |
| 0 | UINT8[] | - | debugData | - | Application defined debug and exception data. Examples include numeric data memory dumps or ASCII formatted text strings. |

### FMU Heartbeat (0x80)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Message Type | Host Heartbeat (0x80) | | | | |
| Description | This packet provides periodic status and monitoring of the FMS. | | | | |
| Data Direction | FMU to Host | | | | |
| Frequency | 1 Hz | | | | |
| Message Structure | Header | Type | Length (Bytes) | Payload | CRC |
| 0x55, 0x4D, 0x4E | 0x80 | 20 | See below. | CRC-16-CCITT |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Byte Offset | Data Format | Scaling | Name | Unit | Description |
| 0 | UINT32 | - | fwVersion | - | Firmware version ID. |
| 4 | UINT32 | - | hwVersion | - | Hardware version ID. |
| 8 | UINT32 | - | serialNum | - | Serial number. |
| 12 | UINT32 | - | msUptime | ms | System uptime in milliseconds. |
| 16 | UINT16 | - | inputVoltage | mV | Input voltage in millivolts. |
| 18 | INT16 | 1e2 | boardTemp | C | Board temperature. |

### IMU Data (0x81)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Message Type | IMU Data (0x81) | | | | |
| Description | This packet provides IMU sensor data. | | | | |
| Data Direction | FMU to Host | | | | |
| Frequency | 100 Hz typical | | | | |
| Message Structure | Header | Type | Length (Bytes) | Payload | CRC |
| 0x55, 0x4D, 0x4E | 0x81 | 84 | See below. | CRC-16-CCITT |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Byte Offset | Data Format | Scaling | Name | Unit | Description |
| 0 | UINT64 | - | fmuTime | ns | FMU timestamp. |
| 8 | UINT16 | - | imuType | - | IMU Type:  0 = VN-100  1 = MPU-9150 |
| 10 | UINT16 | - | imuValid | - | Set as 1 if data is valid, 0 otherwise.  Bit 0: Mag  Bit 1: Accel  Bit 2: Gyro  Bit 3: Temp  Bit 4: Press  Bit 5: Attitude  Bit 6-15: Reserved |
| 12 | UINT64 | - | timeStartup | ns | Time since IMU startup. |
| 20 | UINT64 | - | timeSyncIn | ns | Time since last IMU sync pulse trigger. |
| 28 | FP32 | - | magX | Gauss | Uncompensated magnetic X-axis. |
| 32 | FP32 | - | magY | Gauss | Uncompensated magnetic Y-axis. |
| 36 | FP32 | - | magZ | Gauss | Uncompensated magnetic Z-axis. |
| 40 | FP32 | - | accelX | m/s/s | Uncompensated acceleration X-axis. |
| 44 | FP32 | - | accelY | m/s/s | Uncompensated acceleration Y-axis. |
| 48 | FP32 | - | accelZ | m/s/s | Uncompensated acceleration Z-axis. |
| 52 | FP32 | - | gyroX | rad/s | Uncompensated angular rate X-axis. |
| 56 | FP32 | - | gyroY | rad/s | Uncompensated angular rate Y-axis. |
| 60 | FP32 | - | gyroZ | rad/s | Uncompensated angular rate Z-axis. |
| 64 | FP32 | - | temp | C | IMU temperature. |
| 68 | FP32 | - | pressure | kPa | Barometric pressure. |
| 72 | FP32 | - | yaw | deg | Estimated yaw attitude. |
| 76 | FP32 | - | pitch | deg | Estimated pitch attitude. |
| 80 | FP32 | - | roll | deg | Estimated roll attitude. |

### GPS Data (0x82)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Message Type | GPS Data (0x82) | | | | |
| Description | This packet provides GPS sensor data. | | | | |
| Data Direction | FMU to Host | | | | |
| Frequency | 1 Hz typical | | | | |
| Message Structure | Header | Type | Length (Bytes) | Payload | CRC |
| 0x55, 0x4D, 0x4E | 0x82 | Variable | See below. | CRC-16-CCITT |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Byte Offset | Data Format | Scaling | Name | Unit | Description |
| 0 | UINT64 | - | fmuTime | ms | FMU timestamp. |
| 8 | UINT16 | - | gpsType | - | GPS Type:  0: Novatel OEMStar  1: U-blox |
| 10 … N | UINT8[] | - | gpsData | - | GPS receiver data. Though not guaranteed, a best effort will be made to segment GPS data on packet boundaries. |

### Air Data (0x83)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Message Type | Air Data (0x83) | | | | |
| Description | This packet provides air pressure sensor data. | | | | |
| Data Direction | FMU to Host | | | | |
| Frequency | 1 Hz typical | | | | |
| Message Structure | Header | Type | Length (Bytes) | Payload | CRC |
| 0x55, 0x4D, 0x4E | 0x83 | 13 | See below. | CRC-16-CCITT |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Byte Offset | Data Format | Scaling | Name | Unit | Description |
| 0 | UINT8 | - | airDataID | - | Air Data Sensor ID 0-31 |
| 1 | FP32 | - | statisPress | kPa | Static Pressure |
| 5 | FP32 | - | dynamicPress | kPa | Dynamic Pressure |
| 9 | FP32 | - | temperature | C | Temperature |

### Control Surface Data (0x84)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Message Type | Control Surface Status (0x84) | | | | |
| Description | This packet provides control surface status | | | | |
| Data Direction | FMU to Host | | | | |
| Frequency | 100 Hz typical | | | | |
| Message Structure | Header | Type | Length (Bytes) | Payload | CRC |
| 0x55, 0x4D, 0x4E | 0x84 | 9N | See below. | CRC-16-CCITT |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Byte Offset | Data Format | Scaling | Name | Unit | Description |
| 3(N-1) + 0 | UINT8 | - | surfaceID | - | Control surface ID, 0-31. |
| 3(N-1) + 1 | INT16 | 1e3 | cmdPosition | rad | Commanded surface position. |
| 3(N-1) + 3 | INT16 | 1e3 | actPosition | rad | Actual surface position. |
| 3(N-1) + 5 | UINT16 | - | inputVoltage | mV | Input voltage in millivolts. |
| 3(N-1) + 7 | UINT16 | - | inputCurrent | mA | Input current in milliamps. |

### FMU Debug / Exception (0xFF)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Message Type | FMU Debug / Exception (0xFF) | | | | |
| Description | This packet provides FMU debug and exception information. | | | | |
| Data Direction | FMU to Host | | | | |
| Frequency | Asynchronous | | | | |
| Message Structure | Header | Type | Length (Bytes) | Payload | CRC |
| 0x55, 0x4D, 0x4E | 0xFF | 0-1024 | See below. | CRC-16-CCITT |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Byte Offset | Data Format | Scaling | Name | Unit | Description |
| 0 | UINT8[] | - | debugData | - | Application defined debug and exception data. Examples include numeric data memory dumps or ASCII formatted text strings. |

# CAN Interface

Use standard 11-bit ID to conserve bandwidth.

Lower IDs have higher priority.

Maximum frame rate at 1 Mbps with 8 data bytes per frame is:

= 1Mbps / (108 bits per standard frame + 3 bit inter-frame spacing)

= 9009 frames per second

In practice this will be reduced due to bit stuffing, which occurs when a run of 5 successive ones or zeros are present in the data. Therefore, the worst case throughput is:

= 1Mbps / (108 bits per standard frame + 19 stuffed bits + 3 bit inter-frame spacing)

= 7,692 frames per second

The 11-bit CAN identifier is subdivided into fields representing priority, packet type, and node ID.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 11-bit Standard ID | | | | | | | | | | |
| SID10 | SID9 | SID8 | SID7 | SID6 | SID5 | SID4 | SID3 | SID2 | SID1 | SID0 |
| Priority 0: Critical  1: High  2: Medium  3: Low | | Packet Type 0-15: See packet definition. | | | | Node ID 0-31: User assigned.  This may be the destination or source ID depending on the packet context. | | | | |

## Packet Summary

|  |  |  |  |
| --- | --- | --- | --- |
| CAN Identifier | | |  |
| Priority | Type | 5-bit Node ID | Packet Description |
| 00 | 0000 | Source | Alert |
| 01 | 1000 | Destination | Servo Command |
| 10 | 1000 | Source | Servo Status |
| 11 | 1111 | Source | Announce |

## Packet Definitions

### Alert (ID: 00 0000 XXXXX)

This packet contains information on asynchronous error events.

|  |  |
| --- | --- |
| DATA1 | DATA0 |
| errCode MSB | errCode LSB |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Data Format | Scaling | Name | Unit | Description |
| UINT16 | - | errCode | - | 1: Power on reset.  2: Brown out reset.  3: Watchdog reset. |

### Servo Command (ID: 01 0010 XXXXX)

This packet is typically sent from the FMU to each servo node at a rate of 100Hz.

|  |  |
| --- | --- |
| DATA1 | DATA0 |
| cmdPos MSB | cmdPos LSB |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Data Format | Scaling | Name | Unit | Description |
| INT16 | 1e3 | cmdPos | rad | Commanded surface position. |

### Servo Status (ID: 10 0011 XXXXX)

This packet is typically broadcast from the servo node to the FMU at a rate of 100Hz.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| DATA7 | DATA6 | DATA5 | DATA4 | DATA3 | DATA2 | DATA1 | DATA0 |
| amps  MSB | amps  LSB | volts  MSB | volts  LSB | actPos  MSB | actPos  LSB | cmdPos MSB | cmdPos LSB |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Data Format | Scaling | Name | Unit | Description |
| INT16 | 1e3 | cmdPos | rad | Commanded surface position. |
| INT16 | 1e3 | actPos | rad | Actual surface position. |
| UINT16 | - | volts | mV | Input voltage in millivolts. |
| UINT16 | - | amps | mA | Input current in milliamps. |

### Announce (ID: 11 1111 XXXXX)

This packet is broadcast from each node at a rate of 0.5Hz to announce its presence on the network.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| DATA7 | DATA6 | DATA5 | DATA4 | DATA3 | DATA2 | DATA1 | DATA0 |
| serial  MSB | serial <<>> | serial <<>> | serial  LSB | majVer | minVer | revVer | nType |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Data Format | Scaling | Name | Unit | Description |
| UINT8 | - | nType | - | Node Type:  0 = FMU  1 = Servo |
| UINT8 | - | revVer | - | Software revision version number. |
| UINT8 | - | minVer | - | Software minor version number. |
| UINT8 | - | majVer | - | Software major version number. |
| UINT32 | - | serial | - | Serial number. |

# Document Revision Log

1. Initial draft.
2. Updated with CAN bus protocol specification.