

OPI Wired Frame Definition

Version	Date	Author	Comments
1.10	20131122	mpeng	1. Added Relax state related codes 2. Add go to “on” and “off” states 3. Added truesign related items (turn on/off spi, trigger) 4. Added battery cycle command
1.00	20130503	mpeng	1. Original

Introduction

This document defines the frame structure of OPI-specific digital data sent through links in units called frames. The goals of this frame structure are:

1. Easy data identification
2. Extendable for future types of data

The links utilized may be of any type and need not be wired. “Wired” used in this context means that data sent is not prone to corruption and errors. In other words, only frames that are verified to be non-corrupt are to be used. Contrast this to the Wireless Frame Definition: despite known bit corruption, the frame would still be used.

The frame itself does not provide any mechanism for denoting beginning and ending so this is left up to the link. Additionally, checksums for verifying the data are not utilized so that any errors need to be handled by the receiver processing. Examples of wired links that can be utilized are USB, UART, etc.

The frame length is variable and determined by the type of frame as denoted in the frame.

The frame is byte-based with each byte having 8 bits. Each byte is read in Big-endian fashion with the leftmost bit being the most significant bit.

Data may be encrypted as determined by each data code.

These wired frames assume 1-to-1 association of a slave and master. Therefore although slave and master code values may be the same, their interpreted meaning will not be the same depending on origination from a master or a slave. Furthermore, only certain frame types and data codes can originate from a slave. Likewise is true for a master.

Frame Structure

The frame contains an 8 bit datacode, a 16 bit frame length in bytes, and variable size payload. The frame length could be 64K bytes. However, for all practical purposes, payload data should be less than 1K. If used with the OPI Link Protocol, then the maximum should be equal to or less than 65532 to fit within a packet.

DataCode		Length		Payload
(1)		(2)		(Variable, defined by Length)

Figure 1: Frame structure with field size in bytes.

1. Data Code (1 byte) – This specifies the type of data contained in this frame. A possible 16 codes exists and allows for future expandability. One code is reserved for specifying additional codes in the data which allows further extension of code types if 255 is not enough.
2. Length (2 bytes) – This specifies the payload length in bytes. This data is stored with the high byte first and then the low byte.

3. Data (variable length ≤ 65532) – This is the actual data and its format is specified by the data code. It consists of data in bytes. In most cases, the payload is only a small fraction of the maximum.

Frame Types

Data Code	Sub-Data Code (payload[0])	Payload Length (bytes)	Description	Payload Format (bytes)	S/M
0x01	0x01	145/141	Interpreted/Fixed Received Wireless TrueSense Data	Timestamp (6); Wireless Frame PDN (1); Wireless Frame Misc (1); ADC Channel 0 64/62 13.5b samples (128/124); Temperature Code (1); Accelerometer (6); ED Measurement (1);	S
0x10	0x00	1	Request Interpreted Data from slave		M
0x10	0x01	1	Request Status from slave		M
0x10	0x10	1	Request wireless measurement of current channel from slave		M
0x10	0x11	3	Wireless measurements of current channel	ZigBee signal sense measurement (1); ED measurement (1);	S
0x10	0x20	1	Request events captured from slave		M
0x10	0x21	Variable	Captured events/tags from slave	Tag0 TimeStamp (6); Tag0 Type (1); ... TagN TimeStamp (6); TagN Type (1);	S
0x10	0x2F	1	Request events captured to be erased		M
0x10		127	UCD Status Info of slave	Receiver DSN (5); TimeStamp (6); "OPIUCD" (6); FirmWare Version (2); Mode (1); PDNs associated (8); ZigBee Channel (1); uSDType (1); chgrStat (1); PDN0 settings (12); PDN1 settings (12); PDN2 settings (12); PDN3 settings (12); PDN4 settings (12); PDN5 settings (12); PDN6 settings (12); PDN7 settings (12);	S

Data Code	Sub-Data Code (payload[0])	Payload Length (bytes)	Description	Payload Format (bytes)	S/M
0x13		0	Request to enter shutdown mode		M
0x14	0x00	1	Saved Relax State data request		M
0x14	0x01	15	Saved Relax State data	Beginning timestamp (6); Accumulated score (4); Packets used (4)	S
0x14	0x02	1	Request reset of Relax State variables		M
0x14	0x04	1	Thresholds & Offsets for Relax State algorithm request		M
0x14	0x05	21	Thresholds & Offsets for Relax State algorithm result	10 values (20)	S
0x14	0x06	21	Write Thresholds & Offsets for Relax State algorithm	10 values (20)	M
0x14	0x22	1	Latest 64pt 16bit FFT calc request		M
0x14	0x23	78	Latest 64pt 16bit FFT calc result	Half of 64pt 16bit FFT result (64)	S
0x18		0	Request to enter battery cycle mode		M
0x20	0x00	1	Request for plugged in module info		M
0x20	0x01	19	Plugged in module info	DSN (5); RTC (5); FirmWare Version (2); PDN (1); ZigBee Channel (1); RF Tx Mode Setting (1); RF TX power (1); Memory Module Write (1); RF TX Timeout (1);	S
0x20	0x02	2	Set plugged in module pdn	PDN (1)	M
0x20	0x03	2	Set plugged in module zigbee channel	ZigBee Channel (1)	M
0x20	0x04	2	Set plugged in module RF Tx behavior	RF Tx Set (1)	M
0x20	0x05	2	Set plugged in module RF Tx Power	RF Tx Pwr (1)	M

Data Code	Sub-Data Code (payload[0])	Payload Length (bytes)	Description	Payload Format (bytes)	S/M
0x20	0x06	2	Set plugged in module Memory Module write behavior	Memory module write setting (1)	M
0x20	0x07	9	Set pdnlist for this ucd	Pdnlist (8)	M
0x20	0x08	2	Set zigbee channel for this ucd	ZigBee Channel (1)	M
0x20	0x09	2	Copy current plugged in module sensor's settings	PDN Slot to use, valid is 0-7 (1)	M
0x20	0x0A	2	Forget module sensor's settings	PDN Slot to use, valid is 0-7 (1)	M
0x20	0x0B	1	Turn on microSD SPI interface		M
0x20	0x0C	1	Turn off microSD SPI interface		M
0x20	0x0F	7	Write current timestamp	Timestamp (6)	M
0x20	0x10	2	Set plugged in module RF Tx timeout	RF Tx timeout (1)	M
0x20	0x11	6	Set plugged in module real-time counter	Real-time counter (5)	M
0x20	0x20	1	Turn off plugged-in module		M
0x20	0x21	1	Turn on plugged-in module		M
0x20	0x22	1	Go to "off" state		M
0x20	0x23	1	Go to "on" state		M
0x20	0x24	1	Trigger plugged-in truesign (only works if SPI turned off)		M
0x20	0x25	7	Timestamp of when truesign is triggered	Timestamp (6)	S
0x2A	0x00	4	Request for 5 packets of interpreted data from memory module	Starting Packet Number (3)	M

Data Code	Sub-Data Code (payload[0])	Payload Length (bytes)	Description	Payload Format (bytes)	S/M
0x2A	0x02	Variable Max 726	5 Interpreted/Fixed Memory Module TrueSense Data	Pkt 1 Length (1); Pkt 1 Timestamp (6); Pkt 1 Wireless Frame PDN (1); Pkt 1 Wireless Frame Misc (1); Pkt 1 ADC Channel 0 64/62 13.5b samples (128/124); Pkt 1 Temperature Code (1); Pkt 1 Accelerometer (6); Pkt 1 Zero, for compatibility with DataCode 0x01, Sub-Data Code 0x01 (1); Pkt 2 Length (1) ...	S
0x2A	0x08	1	Request for memory module chip erase		M
0x40		0	OK		S
0x41		0	Not OK		S
0xFF		--	Extended Code	Data contains another pseudo-packet for future extensions in case current number of data codes is insufficient	S/M

Table 1: Data Code List

Extended Code 0xFF

The bytes following this data code are for a pseudo-frame that allows for even more data codes. This is functionally equivalent to using sub-data codes, but is reserved here for future use.

Data Related DataCode 0x01 Payload Descriptions

1. **Sub-DataCode 0x01:** Interpreted wireless data that was received: Timestamp, Paired Device Number (PDN), Miscellaneous data, ADC data, Temperature data, Accelerometer X, Y, and Z data, and CRC/ED information. The timestamp is 6 bytes starting with the MSB recording the time the packet was received. The timestamp is the number of ticks of a 4096Hz clock/counter from a reference date and time of September 28, 2012 08:00:00.000. The paired device number identifies the device the data is associated with using an unsigned byte. Miscellaneous data contains ADC sample length information, wireless datacode, and the battery information. The highest bit of this byte being 1 or 0 signifies the ADC data in this packet has 62 or 64 samples, respectively. Normally the bit should be 0. The next 3 bits (bit 6-4) signify the wireless datacode and is related to the wireless data received. If it is from the standard TrueSense, then it should usually be 1. The lowest bit of this byte represents the battery state. If the bit is 1, then the battery level is above 3.15V. If the bit is 0, then the battery level is below 3.15V. The ADC data is 128 or 124 bytes representing 64 or 62 samples, respectively. The ADC data is the signal from the electrodes of a TrueSense device represented in 2's complement in 16 bits with

the high byte coming first, sampled at 512Hz. The resolution of the ADC is 14 bits so the least significant 2 bits of each ADC sample is actually useless, except for the first sample (explained later in this paragraph). The physical range is $\pm 800\mu\text{V}$ with $+800\mu\text{V}$ corresponding to $+32767$ and $-800\mu\text{V}$ corresponding to -32768 . The temperature data, sampled every $1/8$ of a second, is 1 unsigned byte representing the temperature in Celsius according to the formula: $\text{Temperature} = \text{data} * 1.13 - 46.8$. Note that the temperature resolution is more than one degree, but can be made finer by oversampling and decimating. Also, due to the IC used, the absolute accuracy of the temperature is poor (~ 3 degrees tolerance). The accelerometer data in the X and Y direction are sampled at 8Hz and represented in 2's complement with a single byte in the range from $-2g$ to $+2g$. The accelerometer data in the z-axis has the same representation as the other 2 axes, but is sampled at 32Hz, thus it has 4 times the data as the other directions. The ADC, temperature, and accelerometer data have error correction applied if the data received was corrupted by the wireless link. How much error correction is applied is encoded in the least significant 2 bits of the first ADC sample. If the 2 bits equal 0, then there was no wireless data corruption and no error correction was applied. If the 2 bits equal 3, then the wireless corruption was high, and the ADC data has been blanked, the temperature and accelerometer data are extrapolated from previous samples. Intermediate values describe the level of error correction applied. Note that this information should be removed from the ADC first sample if the true ADC value is desired. If it is left in, it is acceptable as it should be below the noise floor. The ED is the lowest 7 bits of the last byte and gives the received level in a range of 0-84 with units of dB.

Sub-DataCode	TimeStamp	PDN	Misc.	ADC	Temp.	AccX	AccY	AccZ	ED
(1)	(6)	(1)	(1)	(128/124)	(1)	(1)	(1)	(4)	(1)

Unified Controller Related DataCode 0x10 Payload Descriptions

1. **No Sub-DataCode:** Unified controller status. Device Serial Number (DSN) is 5 bytes that uniquely identifies the unified controller. This is a serial number programmed during production and is read MSB to LSB. The timestamp is 6 bytes starting with the MSB currently in the device. The timestamp is the number of ticks of a 4096Hz clock/counter from a reference date and time of September 28, 2012 08:00:00.000. 6 bytes follow that hold the ASCII values for "OPIUCD". This allows recognition of this device to be a unified controller. Two bytes indicating the Firmware (FW) version follows. The Mode is 1 byte indicating the mode the unified controller is in. Normal operation has the unified controller in mode 0 most of the time. PDNs are 8 bytes representing the eight Paired Device Numbers, or devices, that are paired with this unified controller. Although there is room for eight paired devices, it is not recommended to have more than 4. These should fill the first 4 slots. The ZigBee channel, 1 byte, indicates the zigbee channel the unified controller is using to receive data from devices. The uSD byte indicates the status of the uSD slot on the unified controller. If the unified controller is disabling the power of the device in the uSD slot, the 3rd LSB will be 0. If the unified controller is enabling the power of the device in the uSD slot, the 3rd LSB will be 1. If the unified controller detects a TrueSense device in the uSD slot, then the 2nd LSB will be 1, or 0 if there is

no detected TrueSense device in the slot. If the unified controller detects a memory module in the uSD slot, then the LSB will be 1, or 0 if there is no detected memory module. It is possible that these 3 bits are all one since we allow a tandem configuration with TrueSense plugged into the Memory module. It is impossible to have the 3rd bit low with the first bit high because TrueSense, if it is in the slot will be shutoff and thus unrecognizable to the unified controller. The Chrgr byte indicates 1 or 0 if the charger IC on the unified controller is actively charging (either the unified controller battery, or the truesense battery if it is plugged in). The PDN0-7 Info represents settings of the paired devices during pairing. These include the sensor (TrueSense) DSN, firmware version, ZigBee Channel, RF output power, RF transmit mode, RF timeout value, and memory module write.

DSN	TimeStamp	"OPIUCD"	FW	Mode	PDNs	ZigBee Ch.	uSD	Chrgr.	PDN0-7 Info
(5)	(6)	(6)	(2)	(1)	(8)	(1)	(1)	(1)	(8*12)

2. **Sub-DataCode 0x11:** Wireless channel information. ZigBee Signal Sense is one byte that has the value of either 1 or 0. A value of 1 indicates that a signal with zigbee-like characteristics was detected and a value of 0 indicates no zigbee-like signal was detected. The Energy Detection Value is the last byte and gives the received level in a range of 0-84 with units of dB.

Sub-DataCode	ZigBee Signal Sense	Energy Detection Value
(1)	(1)	(1)

3. **Sub-DataCode 0x21:** Events/Tags information. Tags are created from pushing the buttons on the unified controller. The unified controller can save up to 100 events which can all be contained in this payload. Tag0 Timestamp is 6 bytes starting with the MSB recording the time the button was pressed for the first tag. The timestamp is the number of ticks of a 4096Hz clock/counter from a reference date and time of September 28, 2012 08:00:00.000. Tag0 Type is a single byte indicating which button was pressed. Following tags, if they exist, follow the same format. It is possible that no tags exist in which case Tag0 and following Tag information will not exist.

Sub-DataCode	Tag0 Timestamp	Tag0 Type	...	TagN Timestamp	TagN Type
(1)	(6)	(1)	...	(6)	(1)

Relax Device Related DataCodes 0x14 Payload Descriptions (Relax only)

1. **Sub-DataCode 0x01:** Saved Relax State Data. This data contains Relax state information: beginning timestamp (6 bytes, high MSB first, unsigned), accumulated score (4 bytes, MSB first, unsigned), and number of packets used to calculate score (4 bytes, MSB first, unsigned).

Sub-DataCode	Timestamp	Accumulated Score	Packets Used
(1)	(6)	(4)	(4)

2. **Sub-DataCode 0x05:** Relax State threshold and offsets used. This data contains parameters used for determining Relax state.

Sub-DataCode		10 parameters, 2 bytes each
(1)		(20)

3. **Sub-DataCode 0x06:** Relax State threshold and offsets to set. This data contains parameters to be used for determining Relax state.

Sub-DataCode		10 parameters, 2 bytes each
(1)		(20)

4. **Sub-DataCode 0x22:** 64 point FFT data. This data contains the calculated FFT data of the ADC signal on the last packet received (64 data samples in each packet). Due to symmetry of the FFT of real signals, only half of the FFT data is sent. Only magnitude is sent, and each data point is represented by an unsigned 2 bytes. The lowest frequency magnitude is sent first and increasing frequency values are sent subsequently.

Sub-DataCode		32 frequency magnitudes, 2 bytes each
(1)		(64)

Sensor Device Related DataCode 0x20 Payload Descriptions

1. **Sub-DataCode 0x01:** TrueSense Status. This data contains information related to the TrueSense device plugged into the uSD slot. In it is the TrueSense Device Serial Number (DSN), Real-time clock value (RTC), Firmware Version (FW), assigned Paired Device Number (PDN), ZigBee channel, RF transmit mode, RF transmit power, Memory Module write setting, and RF transmit timeout value. The DSN is 5 byte serial number with the MSB coming first which is programmed at the factory at production. RTC is a 5 byte value indicating the number of ticks of a 512Hz clock/counter from a reference date and time of September 28, 2012 08:00:00.000. The FW is 2 bytes indicating the firmware version of the device. The PDN is an assigned number in a single byte that the device can be recognized as by other devices. The ZB Ch. is a single byte indicating the ZigBee channel used. RFTX Mode is a single byte indicating the RF transmit mode the sensor is in. RFTX Pwr is a single byte indicating the RF transmit power. MM Wr. is a single byte indicating if the sensor should write to a memory module that is attached to it. RFTX Tout is a single byte indicating the RF transmit timeout value. The sensor will stop sending RF signals with data after the timeout value has been reached.

Sub-DataCode		DSN		RTC		FW		PDN		ZB Ch.		RFTX Mode		RFTX Pwr		MM Wr.		RFTX Tout
(1)		(5)		(5)		(2)		(1)		(1)		(1)		(1)		(1)		(1)

Memory Module Related DataCode 0x2A Payload Descriptions

1. **Sub-DataCode 0x02:** 5 packets of interpreted data read out from the memory module. It is essentially five of the interpreted packets (DataCode = 0x01, Sub-DataCode = 0x01), stripped on the sub-datacode and prepended with a byte indicating the length of each packet. If the length byte is zero, then the data for that packet doesn't exist meaning that no data exists in the memory module.

Sub-DataCode	Pkt0 Len.	Pkt0 Payload	...	Pkt4 Len.	Pkt4 Payload
(1)	(1)	(0, 140, or 144)	...	(1)	(0, 140, or 144)