INTERNATIONAL ROAD DYNAMICS INC.

Loop Signature Serial Protocol

INTERNATIONAL ROAD DYNAMICS INC.

QUALITY IN MOTION

Loop Signature Serial Protocol

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1 DOCUMENT OVERVIEW

1.1 POINTS OF CONTACT

For clarification of any material appearing in this manual or questions arising from the application/implementation of its content, please contact the Customer Service Hotline of International Road Dynamics Inc. at the numbers shown below.

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2 FRAME

2.1 MESSAGE FORMAT

All messages are transmitted within a frame with the following format:

Table 2-1 Message Format

Field	Byte	Bits	Value	Description
SOF	0	7:4	0xD	This nibble is fixed to indicate start of frame
		3:0	n	MSG length in number of bytes (0-15)
MSG	1 : n			This is the message
CRC	n + 1	15:8	**crc**	CCITT CRC16 checksum
	n + 2	7:0		

The 16 bit CRC of the frame is calculated using the CCITT algorithm with a 0x1021 truncated polynomial and an initial value of 0xFFFF. The pseudo code used to calculate the CRC is included below.

2.2 ISINC® CRC-16 CCITT PSEUDO CODE

iSINC CRC-16 CCITT Pseudo Code

```
crc = 0xFFFF
for ( number of data bytes )
{
    crc = (unsigned char)(crc >> 8) | (crc << 8)
    crc ^= data byte
    crc ^= (unsigned char)(crc & 0xff) >> 4
    crc ^= (crc << 8) << 4
    crc ^= ((crc & 0xff) << 4) << 1
}
```

3 MESSAGES (MSG)

3.1 IDENTIFIERS

The first 4 bytes of every message is the identifier (ID) which specifies the meaning of the remaining bytes. Identifiers are constructed as shown below:

Table 3-1 Message Identifiers

Field	Byte	Value	Description
Message Content	0 1 2	**mid**	Specify the meaning of included data bytes as per the definitions that follow
Message Source	3	**uid**	Unit Identification Number of the loop sensor that sent the message

A list of identifiers included in this document is given below:

Table 3-2 List of Identifiers

Identifier	Specification		Description
0x000800**XX**	3.2	Absolute Time Report	Reports absolute time in seconds since Thursday, 1 January 1970 (UNIX time) as determined by TGM **XX**
0x4C2800**XX**	3.3	Loop Activation Report	Reports time of activation/deactivation of loop sensor channels along with the current state of unchanged channels
0xCBE90A**XX**	3.4	Signature Sample Report	Reports three loop sensor samples along with the time they occurred as measured by LSM **XX**
0x8B4B06**XX**	3.5	Minima Detection Report	Reports localized minimum period for loop signature sample data along with the time it occurred as measured by LSM **XX**
0x8B4B05**XX**	3.6	Maxima Detection Report	Reports localized maximum period for loop signature sample data along with the time it occurred as measured by LSM **XX**

3.2 ABSOLUTE TIME REPORT

Reports absolute time in seconds since Thursday, 1 January 1970 (UNIX time). The message is issued once per second and successive time-stamped messages report time as an offset from this value:

Table 3-3 Identifiers: Absolute Time Report

Field	Byte	Bits	Value	Description
Identifier	0 1 2	8:31	**0x000800**	**Absolute Time Report**
	3	0:7	**uid**	Message Source
Absolute Time Stamp	4 5 6 7	0:31	t_{Abs}	Current time in seconds since Thursday, 1 January 1970 (UNIX time)

3.3 LOOP ACTIVATION REPORT

Reports time of activation/deactivation of loop sensor channels with an absolute timestamp offset in ¼ mS.

A bit-wise (1 channel per bit) representation of the state (1=on, 0=off) of each channel as of this report is included along with a mask indicating which channel(s) changed at time $\mathbf{t_1}$

Table 3-4 Identifiers: Loop Activation Report

Field	Byte	Bits	Value	Description
Identifier	0	8:31	**0x4C2800**	**Loop Activation Report**
	1			
	2			
	3	0:7	**uid**	Message Source
Time Stamp Offset	4	15	$\mathbf{f_{ps}}$	Previous Second Flag
		14:12	**n/a**	Reserved
		11:0	**to**	Absolute Time Offset for (De)Activation event(s) [¼ mS]
	5			
Channel Mask	6	0:7	**cm**	Bit-wise mask of channel(s) for which state changed at time $\mathbf{t_1}$ [b0=channel 0, b1= channel 1, etc.]
State Mask	7	0:7	**sm**	Bit-wise list of state(s) for each channel as of time $\mathbf{t_1}$

3.4 SIGNATURE SAMPLE REPORT

Reports three loop sensor samples along with the time they occurred.

Each message contains one 16 bit integer absolute sample of period in nanoseconds with an absolute timestamp offset in ¼ mS.

This is followed by two 12 bit 2's complement differential samples, each with a relative (successive) timestamp in mS:

Table 3-5 Identifiers: Signature Sample Report

Field	Byte	Bits	Value	Description
Identifier	0	8:31	**0xCBE90A**	**Signature Sample Report**
	1			
	2			
	3	0:7	**uid**	Message Source
Time Stamp Offset	4	15	$\mathbf{f_{ps}}$	Previous Second Flag
		14:12	**ch**	Channel Number [0-3]
		11:0	**to**	Absolute Time Offset for Sample 1 [¼ mS]
	5			
Sample 1	6	0:15	$\mathbf{v_1}$	Absolute Period for Sample 1 [nanoseconds]
	7			
Sample 2	8	15:12	$\mathbf{dt_2}$	Relative Time Offset for Sample 2 [mS]
		11:0	$\mathbf{dv_2}$	Relative Period Offset for Sample 2 [nanoseconds - 2's complement]
	9			

Sample 3	10	15:12	dt_3	Relative Time Offset for Sample 3 [mS]
	11	11:0	dv_3	Relative Period Offset for Sample [nanoseconds - 2's complement]

3.5 MINIMA DETECTION REPORT

Reports localized minimum period (in hundredths of % of baseline) for real-time loop signature sample data along with the time it occurred. Also reports the current absolute baseline period in nanoseconds that can be used with the minima value to calculate the absolute period.

Table 3-6 Identifiers: Minima Detection Report

Field	Byte	Bits	Value	Description
Identifier	0	8:31	**0x8B4B06**	**Minima Detection Report**
	1			
	2			
	3	0:7	**uid**	Message Source
Time Stamp Offset	4	15	f_{ps}	Previous Second Flag
		14:12		reserved
		11:0	**to**	Absolute Time Offset for minima event [¼ mS]
	5			
Channel Mask	6	0:7	**ch**	Channel Number [0-3]
Minima Value	7	0:15	v_1	Local minima detuning [hundredths of % of baseline]
	8			
Baseline Value	9	0:15	**bl**	Current baseline period [nanoseconds]
	10			

3.6 MAXIMA DETECTION REPORT

Reports localized maximum period (in hundredths of % of baseline) for real-time loop signature sample data along with the time it occurred. Also reports the current baseline period in nanoseconds that can be used with the maxima value to calculate the absolute period.

Table 3-7 Identifiers: Maxima Detection Report

Field	Byte	Bits	Value	Description
Identifier	0	8:31	**0x8B4B05**	**Maxima Detection Report**
	1			
	2			
	3	0:7	**uid**	Message Source
Time Stamp Offset	4	15	f_{ps}	Previous Second Flag
		14:12		reserved
		11:0	**to**	Absolute Time Offset for minima event [¼ mS]
	5			
Channel Mask	6	0:7	**ch**	Channel Number [0-3]
Maxima	7	0:15	v_1	

Value	8			Local maxima detuning [hundredths of % of baseline]
Baseline Value	9 10	0:15	**bl**	Current baseline period [nanoseconds]

4 EVENT TIMING

All data reports contain a "Time Stamp Offset" (**to**) field which represents the elapsed time since the last "Absolute Time Report" ($\mathbf{t_{abs}}$).

For single valued data reports, except as noted below, the absolute time of occurrence of the data ($\mathbf{t_1}$) is determined by:

$$\mathbf{t_1} = \mathbf{t_{abs}} + \mathbf{to}$$

For the special case of the "Signature Sample Report" there are three distinct samples ($\mathbf{v_1}$, $\mathbf{v_2}$, $\mathbf{v_3}$) reported. Absolute time of occurrence of the data ($\mathbf{t_1}$, $\mathbf{t_2}$, $\mathbf{t_3}$) is determined by:

$$\mathbf{t_1} = \mathbf{t_{abs}} + \mathbf{to}$$

$$\mathbf{t_2} = \mathbf{t_{abs}} + \mathbf{to} + \mathbf{dt_2}$$

$$\mathbf{t_3} = \mathbf{t_{abs}} + \mathbf{to} + \mathbf{dt_2} + \mathbf{dt_3}$$

Note :

It is possible for $\mathbf{t_{abs}}$ to be updated while one or more data reports are in transit. In this case **to** for the affected message should be referenced to the previous $\mathbf{t_{abs}}$. This is generally done by subtracting 1 second from the final value determined as above.

Affected messages are tagged with "Previous Second Flag" ($\mathbf{f_{ps}}$) = 1.

5 DATA VALUES

Activation reports provide a bit-wise representation of the state of each channel as of time $\mathbf{t_1}$. Channels which changed at time $\mathbf{t_1}$ are masked in a similar manner

eg. **sm** = 0**b**00001010 indicates that channels 1 and 3 are currently on

eg. **cm** = 0**b**00000010 indicates that channel 1 just changed to active

There is no indication of when channel 3 became active in the above example, only that it is currently.

For single valued data reports the value is communicated in absolute terms and is given by $\mathbf{v_1}$ as noted for each message.

For the special case of the "Signature Sample Report" there are three distinct samples ($\mathbf{v_1}$, $\mathbf{v_2}$, $\mathbf{v_3}$) reported. Absolute values are determined by:

$\mathbf{v_1} = \mathbf{v_1}$

$\mathbf{v_2} = \mathbf{v_1} + \mathbf{dv_2}$

$\mathbf{v_3} = \mathbf{v_2} + \mathbf{dv_3}$

6 EXAMPLES

The following example serial data stream (shown on two lines to fit the page) is split into individual frames along the boundaries determined by the SOF character (in bold).

Frame 1	Frame 2	Frame 3

DA00080006574628 59A09E **DE**CBE90A06AF3E255CAFFCAFFE49A0 **DD**8B4B0506000602002025730 10B

DD8B4B0606005702001A25731B1F **DE**CBE90A0620162553A003A001E002 **D8**4C28000620160201

Frame 4	Frame 5	Frame 6

Figure 6-1 Serial Data Stream: Frames

Parsing of each data frame is detailed in the following tables:

Table 6-1 Serial Data: Frame 1

Frame 1	DA00080006574628 59A09E			
Value	**Field**	**Byte**	**Bits**	**Parse**
0xDA	SOF	0	7:4	0xD → start of frame
			3:0	0xA → Message length = 10 bytes
0x00	Identifier	1	8:31	0x000800 → **mid** = **Absolute Time Report**
0x08		2		
0x00		3		
0x06		4	0:7	0x06 → **uid** = Message source = UID 6
0x57	Absolute Time Stamp	5	0:32	0x57462859 → $\mathbf{t_{Abs}}$ = Wed, 25 May 2016 22:34:01 GMT
0x46		6		
0x28		7		
0x59		8		
0xA0	CRC	9	0:15	0xA09E → CCITT CRC16 checksum
0x9E		10		

Table 6-2 Serial Data: Frame 2

Frame 2	DECBE90A06AF3E255CAFFCAFFE49A0			
Value	**Field**	**Byte**	**Bits**	**Parse**
0xDE	SOF	0	7:4	(0xDE & 0xF0) >> 4 = 0xD → start of frame
			3:0	(0xDE & 0x0F) = 0xE → Message length = 14 bytes
0xCB	Identifier	1	8:31	0xCBE90A → **mid** =**Signature Sample Report**
0xE9		2		
0x0A		3		
0x06		4	0:7	0x06 → **uid** = Message source = UID 6
0xAF	Time Stamp Offset	5	15	(0xAF & 0x80) >> 7 = 1 → $\mathbf{f_{ps}}$ = True
			14:12	(0xAF & 0x70) >> 4 = 0x02 → **ch** = 2
			11:0	(0xAF3E & 0xFFF) = 0xF3E → **to** = 3902 = 975.5 mS
0x3E		6		
0x25	Sample 1	7	0:16	0x255C → $\mathbf{v_1}$ = 9564 nS
0x5C		8		
0xAF	Sample 2	9	15:12	(0xA0 & 0xF0) >> 4 = 0x0A → $\mathbf{dt_2}$ = 10 mS
			11:0	(0xAFFC & 0xFFF) = 0xFFC → $\mathbf{dv_2}$ = - 4 nS
0xFC		10		
0xAF	Sample 3	11	15:12	(0xA0 & 0xF0) >> 4 = 0x0A → $\mathbf{dt_3}$ = 10 mS
			11:0	(0xAFFE & 0xFFF) = 0xFFE → $\mathbf{dv_3}$ = -2 nS
0xFE		12		
0x49	CRC	13	0:16	0x49A0 → CCITT CRC16 checksum
0xA0		14		

Table 6-3 Serial Data: Frame 3

Frame 3	DD8B4B0506000602002025730 10B			
Value	**Field**	**Byte**	**Bits**	**Parse**
0xDD	SOF	0	7:4	(0xDD & 0xF0) >> 4 = 0xD → start of frame
			3:0	(0xDD & 0x0F) = 0xD → Message length = 13 bytes
0x8B	Identifier	1	8:31	0x8B4B05 → **mid** = **Maxima Detection Report**
0x4B		2		
0x05		3		
0x06		4	0:7	0x06 → **uid** = Message source = UID 6
0x00	Time Stamp Offset	5	15	(0x0F & 0x80) >> 4 = 0 → $\mathbf{f_{ps}}$ = False
			14:12	reserved
			11:0	(0x0006 & 0xFFF) = 0x6 → **to** = 6 = 1.5 mS
0x06		6		
0x02	Channel Mask	7	0:7	0x02 → **ch** = 2
0x00	Maxima Value	8	0:16	0x0020 → $\mathbf{v_1}$ = 32 = 0.0032
0x20		9		
0x25	Baseline Value	10	0:16	0x2573 → **bl** = 9587 nS
0x73		11		
0x01	CRC	12	0:16	0x10B → CCITT CRC16 checksum
0x0B		13		

Table 6-4 Serial Data: Frame 4

Frame 4	DD8B4B0606005702001A25731B1F			
Value	**Field**	**Byte**	**Bits**	**Parse**
0xDD	SOF	0	7:4	(0xDD & 0xF0) >> 4 = 0xD → start of frame
			3:0	(0xDD & 0x0F) = 0xD → Message length = 13 bytes
0x8B	Identifier	1	8:31	0x8B4B06 → **mid** = **Minima Detection Report**
0x4B		2		
0x06		3		
0x06		4	0:7	0x06 → **uid** = Message source = UID 6
0x00	Time Stamp Offset	5	15	(0x0F & 0x80) >> 4 = 0 → $\mathbf{f_{ps}}$ = False
			14:12	reserved
			11:0	(0x0057 & 0xFFF) = 0x57 → **to** = 6 = 21.75 mS
0x57		6		
0x02	Channel Mask	7	0:7	0x02 → **ch** = 2
0x00	Maxima Value	8	0:16	0x001A → $\mathbf{v_1}$ = 26 = 0.0026
0x1A		9		
0x25	Baseline Value	10	0:16	0x2573 → **bl** = 9587 nS
0x73		11		
0x1B	CRC	12	0:16	0x1B1F → CCITT CRC16 checksum
0x1F		13		

Table 6-5 Serial Data: Frame 5

Frame 5	DECBE90A0620162553A003A001E002			
Value	**Field**	**Byte**	**Bits**	**Parse**
0xDE	SOF	0	7:4	(0xDE & 0xF0) >> 4 = 0xD → start of frame
			3:0	(0xDE & 0x0F) = 0xE → Message length = 14 bytes
0xCB	Identifier	1	8:31	0xCBE90A → **mid** =**Signature Sample Report**
0xE9		2		
0x0A		3		
0x06		4	0:7	0x06 → **uid** = Message source = UID 6
0x20	Time Stamp Offset	5	15	(0x20 & 0x80) >> 7 = 0 → $\mathbf{f_{ps}}$ = False
			14:12	(0x20 & 0x70) >> 4 = 0x02 → **ch** = 2
			11:0	(0x2016 & 0xFFF) = 0x016 → **to** = 22 = 5.5 mS
0x16		6		
0x25	Sample 1	7	0:16	0x2553 → $\mathbf{v_1}$ = 9555 nS
0x53		8		
0xA0	Sample 2	9	15:12	(0xA0 & 0xF0) >> 4 = 0x0A → $\mathbf{dt_2}$ = 10 mS
			11:0	(0xA003 & 0xFFF) = 0x003 → $\mathbf{dv_2}$ = + 3 nS
0x03		10		
0xA0	Sample 3	11	15:12	(0xA0 & 0xF0) >> 4 = 0x0A → $\mathbf{dt_3}$ = 10 mS
			11:0	(0xA001 & 0xFFF) = 0x001 → $\mathbf{dv_3}$ = + 1 nS
0x01		12		
0xE0	CRC	13	0:16	0xE002 → CCITT CRC16 checksum
0x02		14		

Table 6-6 Serial Data: Frame 6

Frame 6	**D8**4C28000620160201			
Value	**Field**	**Byte**	**Bits**	**Parse**
0xD8	SOF	0	7:4	(0xDE & 0xF0) >> 4 = 0xD → start of frame
			3:0	(0xDE & 0x0F) = 0x8 → Message length = 8 bytes
0x4C	Identifier	1	8:31	0x4C2800 → **mid** =**Loop Activation Report**
0x28		2		
0x00		3		
0x06		4	0:7	0x06 → **uid** = Message source = UID 6
0x20	Time Stamp Offset	5	15	(0x20 & 0x80) >> 7 = 0 → $\mathbf{f_{ps}}$ = False
			14:12	reserved
			11:0	(0x2016 & 0xFFF) = 0x016 → **to** = 22 = 5.5 mS
0x16		6		
0x02	Channel Mask	7	0:7	**cm** = 0x02 → Channel 2 just changed
0x01	State Mask	8	0:7	**sm** = 0x01 → Channel 2 is off; Channel 1 is on

A summary of data points collected is detailed below. For convenience absolute time is not shown. Time can be considered as relative to $\mathbf{t_{Abs}}$ = Wed, 25 May 2016 22:34:01 GMT as collected in Frame 1**.**

Table 6-7 Data Points

Time (S)	Period (nS)	Source	Calculation	Note
- 0.0245	9564	Frame 2	$\mathbf{t_1 = t_{abs} + to - 1}$ $\mathbf{v_1 = v_1}$	-1 offset to time since $\mathbf{f_{ps}}$ = 1 (True)
- 0.0145	9560		$\mathbf{t_2 = t_{abs} + to + dt_2 - 1}$ $\mathbf{v_2 = v_1 + dv_2}$	
- 0.0045	9558		$\mathbf{t_3 = t_{abs} + to + dt_2 + dt_3 - 1}$ $\mathbf{v_3 = v_2 + dv_3}$	
0.0015	9556	Frame 3	$\mathbf{t_1 = t_{abs} + to - 1}$ $\mathbf{av_1 = bl - (bl \times v_1)}$	Absolute value obtained using baseline and detune value sent. Sense of (Min/Max) is with respect to frequency and is counter-intuitive as sent
0.02175	9562	Frame 4	$\mathbf{t_1 = t_{abs} + to - 1}$ $\mathbf{av_1 = bl - (bl \times v_1)}$	Absolute value obtained using baseline and detune value sent. Sense of (Min/Max) is with respect to frequency and is counter-intuitive as sent
0.0055	9555	Frame 5	$\mathbf{t_1 = t_{abs} + to}$ $\mathbf{v_1 = v_1}$	Packet is sent once all 3 data points are collected. Since Min/Max frames contain only one point ordering can be
0.0155	9558		$\mathbf{t_2 = t_{abs} + to + dt_2}$ $\mathbf{v_2 = v_1 + dv_2}$	
0.0255	9559		$\mathbf{t_3 = t_{abs} + to + dt_2 + dt_3}$ $\mathbf{v_3 = v_2 + dv_3}$	

The following graph depicts the data obtained from the sample stream:

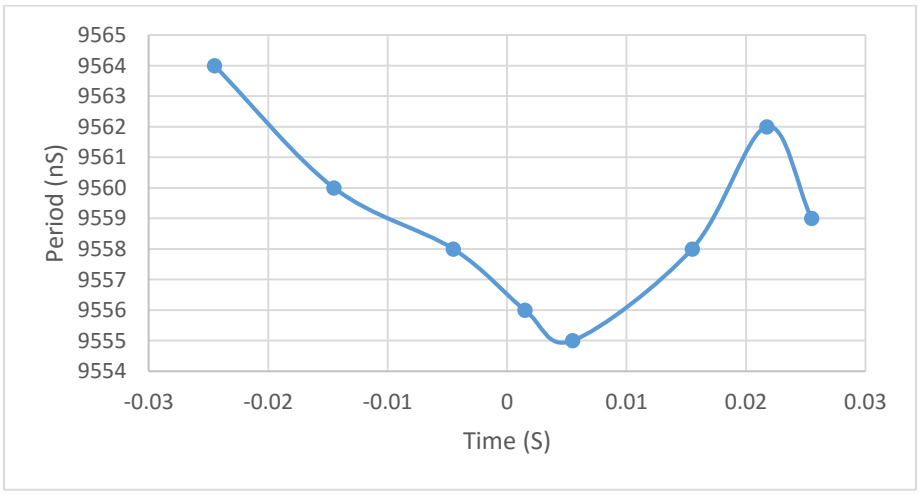

Figure 6-2 Sample Stream Graph

7 PARAMETERS

The serial interface operates with the following parameters:

Baud Rate:	***57600***
Data Bits:	***8***
Parity:	***none***
Stop Bits:	***1***
Flow Control:	***none***

APPENDICES

Appendix A LIST OF TABLES AND FIGURES

A.1 LIST OF TABLES

A.2 LIST OF FIGURES