

Customer Access Commands Manual for the RD-xx Family

Version E
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Support for RD-xx Rel 6.xx Standards and Rel 7.xx and later RD Standards

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1. Introduction

This document describes the external communications protocol for the RD-xx family for customer direct access. These commands are provided to the customer as-is with no implied warranty. The commands provided allow for identification of the connected device, reading instantaneous and accumulating metrics, gating the accumulating metrics, locking the current and voltage ranging relays and controlling the BNC ports functionality.

The commands described in this version of the document supports RD-20/21 versions 3.05 and later, RD-22 version 3.04 and later, and the RD-3x versions 6.00 and later. Although it is Radian's intention to support these commands with all future RD-xx products, there is no guarantee that the interface or commands may or may not change in the future.

1.1. RJ-45 Port Pinout (RD-2x family)

Signal	Description	RJ-45 Pin	DB9 Pin	Wire Color	Used by RD-xx
RTS	Request To Send	1	7	Blue	Yes
DTR	Data Terminal Ready	2	4	Orange	Yes
GND	Signal Ground	3	5	Black	Yes
TX	Data Transmit	4	3	Red	Yes
RX	Data Receive	5	2	Green	Yes
DCD	Data Carrier Detect	6	1	Yellow	No
DSR	Data Set Ready	7	6	Brown	No
CTS	Clear To Send	8	8	White	No
RI	Ring Indicator	N/C	9	Blank	No

1.2. DB-9 Port Pinout (RD-3x family)

Signal	Description	DB9 Pin	Used by RD-xx
RTS	Request To Send	7	Yes
DTR	Data Terminal Ready	4	Yes
GND	Signal Ground	5	Yes
TX	Data Transmit	3	Yes
RX	Data Receive	2	Yes
DCD	Data Carrier Detect	1	No
DSR	Data Set Ready	6	No
CTS	Clear To Send	8	No
RI	Ring Indicator	9	No

1.3. Communications Protocol

- Half duplex RS-232
- 57.6k Baud
- 1 start bit, 1 stop bit, no parity
- DTR line high
- After the RD has received a packet, an acknowledgment (ACK) is transmitted indicating the status of the packet. The time between the receipt of any packet by the RD-xx and the transmit of an ACK is typically less than 50 mS and worst-case 225 mS.
- The PC or other controlling device (host) operates as the master and the RD-xx operates as the slave.

1.4. Packet Format

A basic packet of information is described below. At least four bytes must be transmitted for a valid packet: Start, Packet Type, and Checksum. The Length and number of Data bytes is based on the packet type. For this document a number ending with an ‘h’ indicates the value is shown in hex format (i.e. 02h and A6h).

Start	Packet Type	Length	Data	Checksum
1 byte	1 byte	0 or 2 bytes	0 to 256 bytes	2 bytes

Start A single byte field used as a packet delimiter. This will be used to indicate the start of a valid packet. The lower four bits will indicate the ACK status of the packet (see below) the upper four bits indicate the phase the packet goes to (the Device Command Access or DCA).

Packet Type A single byte number representing the command requested with the given data.

Length A two byte number equal to the number of Data bytes that follow. Not all packet types require a length field.

Data 0 to 256 bytes of information for use with the Packet Type

Checksum A 16-bit sum of the Start, Packet Type, Length and all Data bytes.

1.5. Acknowledgements (ACK) and Device Command Accesses (DCA):

After receiving a packet from the host, the RD-xx will transmit an ACK indicating the status of that packet. The ACK code is located in the lower four bits of the Start byte. The upper four bits are the DCA.

The different types of ACKs are:

-ACK with no data:

Start	Packet Type	Checksum
A3h	1 byte	2 bytes

-ACK with data:

Start	Packet Type	Length	Data	Checksum
A6h	1 byte	2 bytes	0 to 256 bytes	2 bytes

-ACK with delay:

Start	Packet Type	Length	Data	Checksum
ACh	1 byte	2 bytes	Delay Time (2 bytes)	2 bytes

Delay Time is the amount of milliseconds after the response before the command actually takes effect. No further commands should be sent to the RD-xx until this time has elapsed.
This delay is needed in cases where the DSP must wait on slower memory devices such as I2C memory.

-ACK with error:

Start	Packet Type	Length	Data	Checksum
A9h	1 byte	2 bytes	Error code (2 bytes)	2 bytes

The different types of DCAs are (shown with ACK with data):

DCA	Phase
A6h	**[M]** Master (used for Total or Net access)
B6h	**[A]** Phase A
C6h	**[B]** Phase B
D6h	**[C]** Phase C

The packet descriptions given in chapter 2 will show which DCA's are valid for a given packet. DCA's that are not valid for a given packet are greyed out. Examples shown in the descriptions use a Master DCA but could be A, B, or C DCA for some packets. The DCA in the Start byte in the RD-xx's response will be the DCA sent in the command.

1.6. Communications Error Codes

Code	Error	Description
01h	Line Error	The UART has detected a Framing or a Break condition.
02h	Checksum Error	The transmitted Checksum is not equal to the calculated checksum.
03h	Timeout Error	The next byte in the current packet did not arrive within the 4 character time period.
04h	Invalid Start Byte Error	The first byte of the packet received by the RD was not equal to A6h.
05h	Length Error	The amount of data transmitted is larger than the receive buffer size in the RD or is greater than the Length indicated.
06h	Invalid Packet Type	Packet Type transmitted is not listed or supported by the RD.
07h	Invalid Start Address Error	The Start Address received by the RD does not exist.
08h	Invalid Range Error	The sum of the Start Address and the Range received by the RD exceeds the size of memory being accessed.
09h	Invalid Data Length Error	The amount of Data requested from the RD exceeds the size of the communications buffer
0Ah	Invalid Boundary Byte Error	The Starting Address received by the RD is not on a proper word boundary.
0Bh	Invalid Device Error	The device being accessed in the RD does not exist.
0Ch	Device Error	The device being accessed in the RD has had an error.
0Dh	Receive Register Overflow	The RD has received more data than it can process in a timely manner.
0Eh	Invalid Start Delimiter	The RD reported the start delimiter received was not valid
0Fh	Invalid Data Error	The data in the command cannot be processed by the RD.

10h	Internal Communications Error	A error occurred on the internal communications bus during RS-232 communications

1.7. Packet Types

The type of packets sent between the host and the RD-xx are listed below with a brief description.

Code	Packet	Description
00h	NOP	No-Operation
02h	Identification	Retrieve device identification data
03h	Reset RD-xx	Reset the programmable devices in the RD-xx (warm boot-up)
07h	Reset Metrics	Reset accumulating and min/max metrics data
08h	Start Accumulating Metrics	Begin to accumulate metrics
09h	Stop Accumulating Metrics	Stop a timed test and/or stops the accumulating metrics
0Ah	Start A Timed Accumulating Test	Begin accumulating metrics data for a time specified by the user in samples
0Bh	Lock/Unlock Relay Ranges	Lock/unlock selected voltage and current relays
0Ch	Trigger Waveform	Triggers a waveform capture in the RD-xx
0Dh	Read Instantaneous Metrics RD-2x format	Retrieve instantaneous metrics data from an RD-xx in RD-2x format
0Eh	Accumulated Waveform Data Read	Read the waveform data from the RD-xx
0Fh	Harmonic Data Read	Retrieve harmonic metric data from an RD-xx
16h	Read Accumulated Metrics RD-2x format	Retrieve accumulated metrics data from an RD-xx in RD-2x format
1Bh	Auto-Calibrate	Toggle between Full and Partial Auto-Calibration. Measurements are only available in Partial Auto-Calibration
1Dh	BNC Control	Change the functionality of the specified BNC port
20h	System Status	Retrieve the System Status from the RD-xx
21h	Minimum Metrics Data	Retrieve the minimum metrics data from

	Read	an RD-xx in RD-2x format
23h	Maximum Metrics Data Read	Retrieve the maximum metrics data from an RD-xx in RD-2x format
28h	Trigger Harmonic Analysis	Begin harmonic analysis on either the voltage or current axis
2Ch	Mode Change	Change between RMS and AVG
2Eh	Read Instantaneous Metrics RD-3x format	Retrieve instantaneous metrics data from an RD-xx in RD-3x format
2Fh	Read Accumulated Metrics RD-3x format	Retrieve accumulated metrics data from an RD-xx in RD-3x format

Packet Types (continued)

Code	Packet	Description
30h	Minimum Metrics Data Read	Retrieve the minimum metrics data from an RD-xx in RD-3x format
31h	Maximum Metrics Data Read	Retrieve the maximum metrics data from an RD-xx in RD-3x format
32h	Pulse Output Constant Change	Change the pulse output constant for a given Accumulating Metric
34h	Standard Test	Run a standard test on the RD-xx with the given parameters
39h	Meter Test	Run a meter test on the RD-xx with the given parameters

2. Packet Descriptions

2.1. [00h] NOP

Device	RS-712	RD-2x	RD-3x
Version Availabilty	4.13	2.02	6.00
Valid DCAs	**M**	**M**	**M** **A** **B** **C**

The NOP packet returns an ACK with no data. This command can be used for RS-232 diagnostics and troubleshooting.

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Checksum
A6h	00h	0000h	00A6h
1 byte	1 byte	2 bytes	2 bytes

With no errors, the response from the RD will be:

Start	Packet Type	Checksum
A3h	00h	00A3h
1 byte	1 byte	2 bytes

2.2. [02h] Identification

Device	RS-712	RD-2x	RD-3x
Version Availabilty	4.13	2.02	6.00
Valid DCAs	**M**	**M**	**M** A B C

The Identification packet returns information about the connected RD device so that it can be uniquely identified.

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Checksum
A6h	02h	0000h	00A8h
1 byte	1 byte	2 bytes	2 bytes

With no errors, the response from the RD will be:

Start	Packet Type	Length	Data	Checksum
A6h	02h	xxxxh	Model Number, Serial Number, Name, Version Number	xxxxh
1 byte	1 byte	2 bytes	45 bytes	2 bytes

The data returned from the RD-xx contains the model number, serial number, name and version number in ASCII with a comma delimiting each field. For example a response of “RD-21-472, 801234, Testing, 01.23.45” indicates the device is a model RD-21-472, the serial number is 801234, the device name is “Testing” and the software version is 01.23.45. The bytes in the Data field can contain NULL characters.

2.3. [03h] Reset RD-xx

Device	RS-712	RD-2x	RD-3x
Version Availabilty	4.13	2.02	6.00
Valid DCAs	**M**	**M**	**M** A B C

A Reset Metrics packet commands the RD-xx device to reinitialize all programmable devices and restart.

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Checksum
A6h	03h	0000h	00A9h
1 byte	1 byte	2 bytes	2 bytes

With no errors, the response from the RD will be:

Start	Packet Type	Length	Data	Checksum
ACh	03h	0002h	1194h	0156h
1 byte	1 byte	2 bytes	2 bytes	2 bytes

2.4. [07h] Reset Metrics

Device	RS-712	RD-2x	RD-3x
Version Availability	4.13	2.02	6.00
Valid DCAs	**M**	**M**	**M** **A** **B** **C**

A Reset Metrics packet commands the RD-xx device to clear the accumulating metrics registers and reset the minimum and maximum instantaneous metrics value.

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Data	Checksum
A6h	07h	0001h	Reset Code	00CDh
1 byte	1 byte	2 bytes	1 byte	2 bytes

Assuming no errors, the response from the RD will be:

Start	Packet Type	Checksum
A3h	07h	00AAh
1 byte	1 byte	2 bytes

Reset Code	Description
01h	Reset Waveform buffer to all zeros
02h	Reset Instantaneous Data
04h	Reset Instantaneous Min Data
08h	Reset Instantaneous Max Data
10h	Reset Accumulating Data

Any combination of these bits may be sent at any time during the normal operation of the RD-xx.

If a DCA with a Master access is sent, all metrics in all phases are reset. If an RD-device does not suuport
a Reset Code (i.e. RS-712 does not have Min, Max, or Accum Metrics), the RD-device will respond with an ack with error, INVALID DATA ERROR

2.5. [08h] Start Accumulating Metrics

Device	RS-712	RD-2x	RD-3x
Version Availability	4.13	2.02	6.00
Valid DCAs	M	**M**	**M** A B C

The Start Accumulating Metrics commands the RD to start the accumulators in one of 3 ways. The "Control Byte" field is used to define which method of gating to use.

The transmitted packet to the RD has the following format:

Start	**Packet Type**	**Length**	**Data**		**Checksum**
A6h	08h	0003h	Control Byte	Pulse Data	xxxxh
1 byte	1 byte	2 bytes	1 byte	2 bytes	2 bytes

The response from the RD-xx depends on the Control Byte sent:

Control Byte		Response	
00h	Control Byte Status Request	ACK_DATA	Returns the current status of the Control Byte in the device.
01h	Normal Gate Start	ACK_NODATA	The RD-xx shall immediately start accumulating metric data.
06h	Meter Gate Pulse Data = 0	ACK_DATA	Responds with the total number of pulses left in the currently running test (MSB first).
06h	Meter Gate Manual Mode Pulse Data < > 0	ACK_NODATA	Resets and begins accumulating metrics on the next pulse received and stop accumulating <Pulse Data> pulses later.
0Eh	Meter Gate Sensor mode	ACK_NODATA	Same as 06h but the RD-xx gating is in "sensor" mode instead of "manual" mode.

	Pulse Data < > 0		

For example:

To start the accumulators immediately: send the command A6 08 0003 01 0000 00B2.

To start the accumulators on the next BNC 1 gate input and run for 5 gates: send A6 08 0003 06 0005 00BC.

To get the number of remaining gates: send A6 08 0003 06 0000 00B7.

Start Accumulating Metrics (continued)

The response for the Normal Gate Start and Meter Gate with nonzero Pulse Data:

Start	Packet Type	Checksum
A3h	08h	00ABh
1 byte	1 byte	2 bytes

The response for the Control Byte Status Request:

Start	Packet Type	Length	Data	Checksum
A6h	08h	0001h	Control Byte Status	xxxxh
1 byte	1 byte	2 bytes	1 byte	2 bytes

The response for the Meter Gate with Pulse Data equal to zero case:

Start	Packet Type	Length	Data	Checksum
A6h	08h	0002h	Pulses Left in Test	xxxxh
1 byte	1 byte	2 bytes	2 bytes	2 bytes

<u>In Release 05.00.08 and 06.00.70 and later:</u>
If a command with a Normal Gate Start is sent, the RD-xx will turn off the external gate input until either a Reset Metrics [07h] or a Stop Accumulating Metrics [09h] command is sent or the unit is powered off then back on.

If a command with a Sensor Meter Test Start is sent, the RD-xx will allow the external gate input to be active only for the number of pulses sent (in the Pulse Data field) with the command. Other pulses after this will be ignored by the RD-xx.

The RD-xx will reactivate the external gate input after either a Reset Metrics [07h] or a Stop Accumulating Metrics [09h] command is sent or the unit is powered off then back on.

If a command with a Manual Meter Test Start is sent, the RD-xx will allow the external gate input to be active only for two pulses, start accumulating and stop accumulating. Other pulses after this will be ignored by the RD-xx.
The RD-xx will reactivate the external gate input after either a Reset Metrics [07h] or a Stop Accumulating Metrics [09h] command is sent or the unit is powered off then back on.

2.6. [09h] Stop Accumulating Metrics

Device	RS-712	RD-2x	RD-3x
Version Availability	4.13	2.02	6.00
Valid DCAs	M	**M**	**M** A B C

The Stop Gating Accumulating Metrics will immediately stop the accumulators.

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Checksum
A6h	09h	0000h	00AFh
1 byte	1 byte	2 bytes	2 bytes

Assuming no errors, the response from the RD will be:

Start	Packet Type	Checksum
A3h	09h	00ACh
1 byte	1 byte	2 bytes

2.7. [0Ah] Start a Timed Accumulating Test

Device	RS-712	RD-2x	RD-3x
Version Availability	4.13	2.02	6.00
Valid DCAs	M	**M**	**M** A B C

This command allows the RD to run a test a specific length of time.

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Data	Checksum
A6h	0Ah	0004h	Test Time (in samples)	xxxxh
1 byte	1 byte	2 bytes	4 bytes	2 bytes

The Test Time is in number of A/D samples. In a Rev. 4 or earlier unit, 23788.546 samples is approximately 1 second. In a Rev. 5 or later unit, 20119.225 samples is approximately 1 second. Setting the Test Time to a non-zero number will start the test immediately and run for the specified number of samples. Setting the Test Time to zero will return the amount of time left in the current test. If the return time is zero then the test (and accumulators) has stopped.

If the Test Time within the DATA section were a non-zero number, the response from the RD would be:

Start	Packet Type	Checksum
A3h	0Ah	00ADh
1 byte	1 byte	2 bytes

If the Test Time within the DATA section were equal to zero, the response from the RD would be:

Start	Packet Type	Length	Data	Checksum
A6h	0Ah	0004h	Test Time Left (in samples)	xxxxh
1 byte	1 byte	2 bytes	4 bytes	2 bytes

In Release 05.00.08 and 06.00.70 and later:
The RD-xx will deactivate it's external gate input during a timed accumulation. The RD-xx will reactivate the external gate input after either a Reset Metrics [07h] or a Stop Accumulating Metrics [09h] command is sent or the unit is powered off then back on.

2.8. [0Bh] Lock/unlock relay ranges

Device	RS-712	RD-2x	RD-3x
Version Availability	4.13	2.02	6.00
Valid DCAs	M	**M**	**M** **A** **B** **C**

Locking relays has the effect of limiting the RD-xx device from lowering the relay ranges. For protection of the device, the relays will still range to higher tap levels to keep from damaging the sensitive circuitry in the device. The accuracy of the measurement will be degraded for lower voltages and currents while locked to the higher relay ranges.

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Data		Checksum
A6h	0Bh	0003h	Control Byte	Relay Bits	xxxxh
1 byte	1 byte	2 bytes	1 byte	2 bytes	2 bytes

Assuming no errors, the response from an RD-2x will be:

Start	Packet Type	Length	Data		Checksum
A6h	0Bh	0003h	Control Byte	Relay Bits	xxxxh
1 byte	1 byte	2 bytes	1 byte	2 bytes	2 bytes

The response from an RD-3x will be:

Start	Packet Type	Length	Data						Check sum
A6h	0Bh	0009h	control byte A	relay bits A	control byte B	relay bits B	control byte C	relay bits C	xxxxh
1 byte	1 byte	2 bytes	1 byte	2 bytes	1 byte	2 bytes	1 byte	2 bytes	2 bytes

Control Byte bits 0, 1, 2 used for control of voltage relays

Value	Action
00h	Return status of voltage relays only (do not control)
04h	Unlock voltage relays
06h	Lock voltage relays at current setting
07h	Set and lock voltage relays

Control Byte bits 4, 5, 6 used for control of current relays

Value	Action
00h	Return status of current relays only (do not control)
40h	Unlock current relays
60h	Lock current relays at current setting
70h	Set and lock current relays

Lock/unlock relay ranges (continued)

Control Byte bits 3 and 7 used for control of clamp-on relay

Value	Action
00h	Return status of current relays only (do not control)
08h	Activate clamp disable relay
80h	Activate clamp enable relay
88h	Activate clamp enable and disable relays

Control Byte Response from the RD-xx

00h	Neither voltage nor current relays locked
02h	Voltage relay locked
20h	Current relay locked
22h	Both voltage and current relays locked

Relay Bits

CURRENT TAPS

200A and 120A Models:

0000h	all current relays open	
0808h	Minimum Spec - 0.0328A	Range
4008h	0.0320A - 0.0656A	Range
1008h	0.0640A - 0.1312A	Range
8008h	0.1280A - 0.2624A	Range
2008h	0.2560A - 0.5248A	Range
8010h	0.5120A - 1.0496A	Range
2010h	1.0240A - 2.0992A	Range
8020h	2.0480A - 4.1984A	Range
2020h	4.0960A - 8.3968A	Range
8040h	8.1920A - 16.7936A	Range
2040h	16.3840A - 33.5872A	Range
8080h	32.7680A - 67.1744A	Range
2080h	65.5360A - 200A	Range

Lock/unlock relay ranges (continued)

CURRENT TAPS
225A Models:

0000h	all current relays open	
0808h	Minimum Spec - 0.0349A	Range
4008h	0.0340A - 0.0697A	Range
1008h	0.0680A - 0.1394A	Range
8008h	0.1360A - 0.2788A	Range
2008h	0.2720A - 0.5576A	Range
8010h	0.5440A - 1.1152A	Range
2010h	1.0880A - 2.2304A	Range
8020h	2.1760A - 4.4608A	Range
2020h	4.3520A - 8.9216A	Range
8040h	8.7040A - 17.8432A	Range
2040h	17.4080A - 35.6864A	Range
8080h	34.8160A - 71.3728A	Range
2080h	69.6320A - 225A	Range

VOLTAGE TAPS (bits 0 through 2 of byte 2)

0000h	all voltage relays open
0001h	120V range
0002h	240V range
0004h	480V range

2.9. [0Ch] Trigger Waveform

Device	RS-712	RD-2x	RD-3x
Version Availability	N/A	2.02	7.03.40
Valid DCAs	**M**	**M**	**M** **A** **B** **C**

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Data	Checksum
A6h	0Ch	0001h	Control Word	xxxxh
1 byte	1 byte	2 bytes	1 byte	2 bytes

Assuming no errors, the response from an RD-xx will be:

Start	Packet Type	Length	Data			Check sum
A6h	0Ch	000Nh	Phase A Status	Phase B Status	Phase C Status	xxxxh
1 byte	1 byte	2 bytes	1 byte	1 byte	1 byte	2 bytes

A summary of the Control Word and Status for the Trigger Waveform command:

Control Word		Status	
0	Waveform Capture Status Requested	0	Waveform buffer not active
1	Stop Waveform Capture	1	Wavform buffer stopped; data available
2	Start Waveform Capture	2	Waveform buffer running; accumulating data

When a "Waveform Trigger" command has been sent, the software will always collects 800 voltage and 800 current samples, at a sampling frequency of 20119.225Hz. This data remains in DSP memory until the user issues another "Waveform Trigger" Command.

For RD-3x devices, if a DCA with a Master access is sent, the response will be the status of all three phases (Nh = 03h) –where phase A status would be the first byte, phase B status would be the second byte, and phase C would be the third byte. Otherwise, the response will be for the phase accessed (Nh = 01h).

2.10. [0Dh] Read Instantaneous Metrics; RD-2x format

Device	RS-712	RD-2x	RD-3x
Version Availability	4.13	2.02	6.00
Valid DCAs	**M**	**M**	**M** **A** **B** **C**

This command is for reading instantaneous metrics from RD-xx Standards in RD-2x format. The RD-xx will return all the metrics in the response in TI Floating-point format. See the section on converting the TI floating-point to IEEE format. Note that not all models support all instantaneous metrics.
In firmware versions 05.06.00 and 06.00.00 and later, metrics that are not supported will always return a value equal to the maximum TI floating point number (3.4028235E38).
This command is compatible with RD-3x devices.

The transmitted packet to the RD has the following format:

Type	**Start**	**Packet Type**	**Length**	**Data (See Table 1 Offset)**		**Set/clear Update Flag** (section 2.14)	**Checksum**
RD-3x	A6h	0Dh	0008h	0040h	00000014h	FFFDh	050Bh
RD-2x	A6h	0Dh	0008h	0024h	00000014h	FFFDh	02EFh
	1 byte	1 byte	2 bytes	2 bytes	4 bytes	2 bytes	2 bytes

With no errors, the response from the RD will be:

Start	**Packet Type**	**Length**	**Data**	**Checksum**
A6h	0Dh	0040h	Instantaneous Metrics in TI floating point format	xxxxh
1 byte	1 byte	2 bytes	64 bytes	2 bytes

The Instantaneous Metrics and their offsets are shown in Section 4.1, Table 1.

2.11. [0Eh] Accumulated Waveform Data Read

Device	RS-712	RD-2x	RD-3x
Version Availability	N/A	2.02	07.03.40
Valid DCAs	**M**	**M**	M **A** **B** **C**

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Data		Checksum
A6h	0Eh	0006h	Number of bytes to read	Waveform buffer offset to read from	xxxxh
1 byte	1 byte	2 bytes	2 byte	4 bytes	2 bytes

Assuming no errors, the response from an RD-xx will be:

Start	Packet Type	Length	Data	Checksum
A6h	0Eh	Nh	Waveform Data from specified offset	xxxxh
1 byte	1 byte	2 bytes	N bytes	2 bytes

More details on the Waveform Data can be found in Table 4. The Waveform Data is in 32 bit TI floating point format.

2.12. [0Fh] Read Harmonic Data

Device	RS-712	RD-2x	RD-3x
Version Availability	N/A	07.03.40	07.03.40
Valid DCAs	**M**	**M**	**M** **A** **B** **C**

This command is only available in RD-xx devices that have the harmonic option. If this command is sent to an RD that does not have the harmonic option, the RD-xx will return a communication error, ACK, INVALID_DEVICE.

This command can be used to read multiple harmonics after Triggering Harmonic Analysis using command 28h (see Section 2.17).

A Harmonics Data Read packet transmitted to the RD-xx will have the following format:

Start	Packet Type	Length	Data		Checksum
A6h	0Fh	0006h	Nh	Offset	xxxxh
1 byte	1 byte	2 bytes	2 bytes	4 bytes	2 bytes

Where N is the number of bytes, on 4 byte boundaries, to a maximum of 252 bytes. This allows the reading of 21 harmonics (magnitude, phase, and distortion) per command. More details on the data structure of the harmonics can be found in Table 3.

With no errors, the response from the RD will be:

Start	Packet Type	Length	Data	Checksum
A6h	0Fh	Nh	Harmonic Data from the specified Offset	xxxxh
1 byte	1 byte	2 bytes	N bytes	2 bytes

Where N is again on 4 byte boundaries. Each 4 byte group is in TI floating point format.

2.13. [16h] Read Accumulating Metrics; RD-2x format

Device	RS-712	RD-2x	RD-3x
Version Availability	4.13	2.02	6.00
Valid DCAs	M	**M**	**M** **A** **B** **C**

This command is for reading accumulating metrics from RD-xx Standards in RD-2x format. The RD-xx will return all the metrics in the response in TI Floating-point format. See the section on converting the TI floating-point to IEEE format. Note that not all models support all accumulating metrics.
In firmware versions 05.06.00 and 06.00.00 and later, metrics that are not supported will always return a value equal to the maximum TI floating point number (3.4028235E38).
This command is compatible with RD-3x devices.

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Data		Checksum
			Bytes Returned	Offset	
A6h	16h	0006h	0020h	00000004h	00E6h
1 byte	1 byte	2 bytes	2 bytes	4 bytes	2 bytes

Assuming no errors, the response from the RD will be:

Start	Packet Type	Length	Data	Checksum
A6h	16h	0020h	Accumulating Metrics in TI floating point format	xxxxh
1 byte	1 byte	2 bytes	32 bytes	2 bytes

The Accumulating Metrics and their offsets are shown in Section 4.2, Table 2.

2.14. [1Bh] Auto-Calibrate

Device	RS-712	RD-2x	RD-3x			
Version Availabilty	4.13	4.00	6.00			
	M	**M**	**M**	**A**	**B**	**C**

An Auto Calibrate packet transmitted to the RD-xx (the **command**) will have the following format:

Start	**Packet Type**	**Length**	**Data**	**Checksum**
A6h	1bh	0001h	Calibrate Code	xxxxh
1 byte	1 byte	2 bytes	1 byte	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Start	**Packet Type**	**Length**	**Data**	**Checksum**
A6h	1bh	000Nh	Calibrate Status	xxxxh
1 byte	1 byte	2 bytes	N bytes	2 bytes

Calibration Code:	Description:
bit	
0	AutoCAL toggle bit The RD-2x will be in full AutoCAL mode if = 0. The RD-2x will be in partial AutoCAL mode if = 1.
8	Status request bit. The DSP returns the status of the bits mentioned above if = 1. The DSP updates the bits mentioned above and returns their status if = 0.

The Calibration Status is the current Calibration Code.

If a DCA with a Master access is sent, the response will be the status of all three devices (Nh = 03h). Otherwise, the response will be for the device accessed (Nh = 01h).

2.15. [1Dh] BNC Control

Device	RS-712	RD-2x	RD-3x
Version Availability	4.13	2.02	6.00
Valid DCAs	M	**M**	**M** A B C

BNC Control for the RD-2x

The BNC Control command for the RD-2x Standards allows setting the input and output functionality of the 3 BNC ports.

- Port 1 can be used as an input for gating the accumulators or as an output for pulses representing negative accumulating metrics.
- Port 2 is used for pulse output representing positive accumulating metrics data.
- Port 3 is used for controlling which device is used for the sync output for a 3-phase configuration. Phase A of the 3-phase configuration would be set to sync pulses out and Phase B and C would be set to sync pulses in.

The transmitted packet to the RD has the following format:

Start	**Packet Type**	**Length**	**Data**		**Checksum**
A6h	1Dh	0002h	BNC Code	BNC Data	xxxxh
1 byte	1 byte	2 bytes	1 byte	1 byte	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Start	**Packet Type**	**Length**	**Data**	**Checksum**
ACh	1Dh	0002h	000Ah	xxxxh
1 byte	1 byte	2 bytes	2 bytes	2 bytes

BNC Code	BNC Data
1	0 = Start/Stop/Clear Gating “Manual” mode
	1 = Clear-Start/Stop Gating “Manual” mode
	2 = Negative Pulses Out
	8 = Start/Stop/Clear Gating “Sensor” mode (Versions 4.21 and higher)
	9 = Clear-Start/Stop Gating “Sensor” mode (Versions 4.21 and higher)
2	Accumulating Metric Index (See Read Accumulating Metrics for RD-2x command Section 2.9)
3	0 = Three phase sync pulses out
	1 = Three phase sync pulses in

BNC Control (continued)

BNC Control for the RD-3x

The BNC Control command for the RD-3x Standards allows setting the functionality for Input Port 1 and Output Ports 1 through 3.

- Input Port 1 can be used as an input for gating the accumulators.
- Output Ports 1 through 3 are used for pulse outputs representing accumulating metrics data for a specific phase (A, B, C) or net value.

The transmitted packet to the RD has the following format:

Start	**Packet Type**	**Length**	**Data**			**Checksum**
A6h	1Dh	0003h	BNC Code	BNC Data	Phase Code	xxxxh
1 byte	1 byte	2 bytes	1 byte	1 byte	1 byte	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Start	**Packet Type**	**Length**	**Data**	**Checksum**
ACh	1Dh	0002h	000Ah	xxxxh
1 byte	1 byte	2 bytes	2 bytes	2 bytes

BNC Code	BNC Data	Phase Code
1 (Input Port)	0 = Start/Stop/Clear Gating "Manual" mode	Ignored for this BNC number
	1 = Clear-Start/Stop Gating "Manual" mode	
	8 = Start/Stop/Clear Gating "Sensor" mode (Versions 4.21 and higher)	
	9 = Clear-Start/Stop Gating "Sensor" mode (Versions 4.21 and higher)	
2 (Output Port)	Port 1 Accumulating Metric Index (See Read Accumulating Metrics packet, 16h, for the index list)	00h Pulse Output Phase A Fct 01h Pulse Output Phase B Fct 02h Pulse Output Phase C Fct 03h Pulse Output Master Fct
5 (Output Port)	Port 2 Accumulating Metric Index (See Read Accumulating Metrics packet, 16h, for the index list)	See Phase code for BNC code 2
6 (Output Port)	Port 3 Accumulating Metric Index (See Read Accumulating Metrics packet, 16h, for the index list)	See Phase code for BNC code 2

BNC Control (continued)

BNC Control for the RD-3x

The Phase Code is used with the Output Ports to specify which phase of the metric to pulse out. The Phase Codes are defined in the Set Pulse Output Constant Command.

Note: not all models support all accumulating metrics. Metrics that are not supported will not output any data. Attempts to set a pulse output related BNC to pulse out an accumulated metric that is not available will result in an INVALID DATA (0Fh) communications error.

"Manual" mode defines Input Port 1 to trigger on the falling edge of the signal and the Pickup port is not enabled. "Sensor" mode defines Port 1 to trigger on the rising edge of the signal and the Pickup port is enabled.

The default settings for the Pulse Outputs on an RD-3x are as follows:

Pulse Output	Accumulating Metric	Phase	Accumulating Metric for RD-3x models without VAR Hour and VA hour	Phase
1	Watt Hour	Totalized	Watt Hours	Totalized
2	VAR Hour	Totalized	Watt Hours	Phase A
3	VA Hour	Totalized	Watt Hours	Phase B

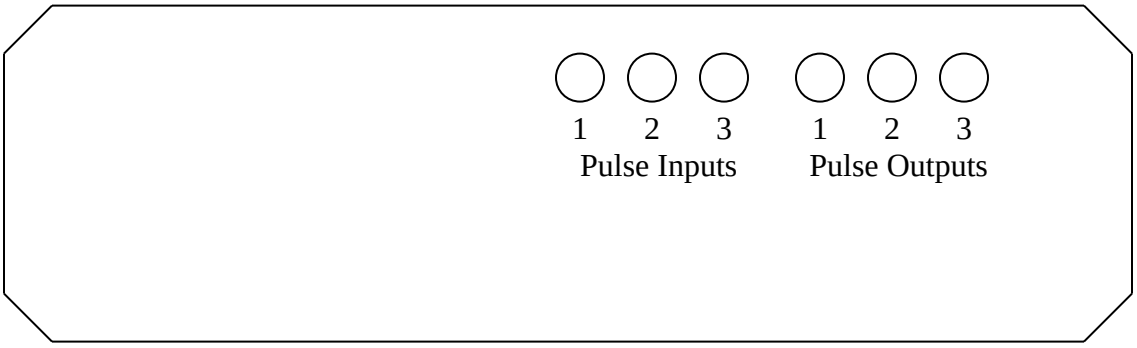

Figure 1 A Partial Outline of the Back Panel of an RD-3x

The default setting for the Pulse Inputs is; Pulse Inputs 1 and 2 disabled for gating, Pulse Input 3 enabled for gating. This allows all three phases to be gated by one signal.

2.16. [20h] System Status

Device	RS-712	RD-2x	RD-3x
Version Availabilty	4.13 **M**	4.20 **M**	6.00 **M** A B C

For a System Status, the packet sent to the RD-xx (the **command**) will be:

Start	Packet Type	Length	Data	Checksum
A6h	20h	0001h	Command	xxxxh
1 byte	1 byte	2 bytes	1 byte	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Start	Packet Type	Length	Data	Checksum
A6h	20h	000Nh	Status Specified by **Command** Data	xxxxh
1 byte	1 byte	2 bytes	N bytes	2 bytes

Command Data	**Descrip-tion**	**Response Data (beginning at the first byte in the DATA section, byte number 4)**						
00h avail vers. 2.02-5.99	Single Phase Status Req	Reserved (4 bytes)	Reserved (4 bytes)	Auto-Cal/ Misc Status (1 byte)	Update flags (6 bytes)	Status Indicators (1 byte)		
00h avail vers. 6.00-07.05.31	Status Summary	Reserved (1 byte)	Reserved (1 byte)	Auto-Cal/ Misc Indicator (1 byte)	Update flag (1 byte)	Status Indicators (1 byte)	Reserved (1byte)	Reserved (1 byte)
01h Reserved	Reserved	Reserved (4 bytes)	Reserved (4 bytes)	Reserved (4 bytes)	Reserved (4 bytes)			
02h Reserved	Reserved	Reserved (4 bytes)	Reserved (4 bytes)	Reserved (4 bytes)				
04h avail vers. 6.00-07.05.31	Auto Calibrate / Misc Status	Auto-Cal /Misc Status Phase A (1 byte)	Auto-Cal /Misc Status Phase B (1 byte)	Auto-Cal /Misc Status Phase C (1 byte)				
08h avail vers. 6.00-07.05.31	Update Flags	Update Flags Phase A (2 bytes)	Update Flags Phase B (2 bytes)	Update Flags Phase C (2 bytes)	Update Flags Master (2 bytes)			

System Status (continued)

Command Data	Descrip-tion	Response Data (beginning at the first byte in the DATA section, byte number 4)						
10h avail vers. 6.00-	Status Indicators	Status Indic. Phase A (1 byte)	Status Indic. Phase B (1 byte)	Status Indic. Phase C (1 byte)				
20h Reserved	Reserved	Reserved (4 bytes)	Reserved (4 bytes)	Reserved (4 bytes)				
40h Reserved	Reserved	Reserved (2 bytes)	Reserved (2 bytes)	Reserved (2 bytes)	Reserved (2 bytes)			

The Status Summary Response for RD-3x's has the following bit definitions for the bytes returned.

Bit 0	Bit 1	Bit 2	Bit 3
Phase A Error/ Update	Phase B Error/ Update	Phase C Error/ Update	Master Error/ Update

Command Data bits can be combined (or'd together) to receive multiple Status types.
The Data word responses will have the following definitions:

AutoCalibrate/ Misc Indicator

Bit:	Description:
0	This bit is set (1) if any of the following is detected: Pulse Output exceeded max limit. AutoCAL failure. CMSR value is maxed out. IMSR value is maxed out. VMSR value is maxed out. AMSR value is maxed out. Eboard unprogrammed Accum values at max.

AutoCalibrate/ Misc Status	Bit:	Description:
(avail. in rev 07.03.50)	0	Pulse Output exceeded max limit if set to one.
	1	AutoCAL failure if set to one.
	2	CMSR value is maxed out if set to one.
	3	IMSR value is maxed out if set to one.
	4	VMSR value is maxed out if set to one.
(avail. in rev 07.03.10)	5	AMSR value is maxed out if set to one.
(avail. in rev 07.03.10)	6	Eboard unprogrammed if set to one
(avail. in rev 07.03.50)	7	Accum values at max value if set to one.

Update Flags

Data byte offset:	Description:
0 - 1	Instantaneous Metric updated field (to indicate to external applications that new data is available)
2 - 3	Minimum Metric updated field (for external applications) -only available in versions 2.02 through 5.99
4 - 5	Maximum Metric updated field (for external applications) -only available in versions 2.02 through 5.99

Bit definition for any given update field:

Bit:	Description:	
	0, 2-15	Reserved
	1	Customer software has not read data since last update if set 1

Status Indicator Bits

Bit:	Description:
0	The RD-xx device/phase is in Three Phase Sync Sourcing mode if set to 1 otherwise, the RD-2x device is in Three Phase Sync Sensing mode.
1	If the RD-xx device/phase is in Three Phase Sync Sensing mode and this bit is set to 1, the RD-xx device is not receiving any Three Phase Sync Pulses.

2.17. [21h] Minimum Metrics Data Read

Device	RS-712	RD-2x	RD-3x			
Version	N/A	2.02	6.00			
Availabilty	M	**M**	**M**	**A**	**B**	**C**

This command is for reading the minimum instantaneous metrics from RD-xx Standards in RD-2x format. The RD-xx will return all the metrics in the response in TI Floating-point format. See the section on converting the TI floating-point to IEEE format. Note that not all models support all minimum instantaneous metrics.
In firmware versions 05.06.00 and 06.00.00 and later, metrics that are not supported will always return a value equal to the maximum TI floating point number (3.4028235E38).
This command is compatible with RD-3x devices.

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Data		Checksum
A6h	21h	0006h	0040h	00000014h	051Fh
1 byte	1 byte	2 bytes	2 bytes	4 bytes	2 bytes

With no errors, the response from the RD will be:

Start	Packet Type	Length	Data	Checksum
A6h	21h	0040h	Minimum Instantaneous Metrics in TI floating point format	xxxxh
1 byte	1 byte	2 bytes	64 bytes	2 bytes

The Minimum Instantaneous Metrics and their offsets are shown in Section 4.1, Table 1.

2.18. [23h] Maximum Metrics Data Read

Device	RS-712	RD-2x	RD-3x			
Version	N/A	2.02	6.00			
Availabilty	M	**M**	**M**	**A**	**B**	**C**

This command is for reading the maximum instantaneous metrics from RD-xx Standards in RD-2x format. The RD-xx will return all the metrics in the response in TI Floating-point format. See the section on converting the TI floating-point to IEEE format. Note that not all models support all instantaneous metrics.
In firmware versions 05.06.00 and 06.00.00 and later, metrics that are not supported will always return a value equal to the maximum TI floating point number (3.4028235E38).
This command is compatible with RD-3x devices.

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Data		Checksum
A6h	23h	0006h	0040h	00000014h	051Fh
1 byte	1 byte	2 bytes	2 bytes	4 bytes	2 bytes

With no errors, the response from the RD will be:

Start	Packet Type	Length	Data	Checksum
A6h	23h	0040h	Maximum Instantaneous Metrics in TI floating point format	xxxxh
1 byte	1 byte	2 bytes	64 bytes	2 bytes

The Maximum Instantaneous Metrics and their offsets are shown in Section 4.1, Table 1.

2.19. [28h] Trigger Harmonic Analysis

Device	RS-712	RD-2x	RD-3x			
Version	N/A	4.35	07.02.90			
Availabilty	M	**M**	**M**	**A**	**B**	**C**

This command is for starting a harmonic analysis for a specified harmonic and reading the harmonic results from RD-xx Standards. If the harmonic analysis is not complete, zeros will be returned for the harmonic data. The RD-xx will return the harmonic values in TI floating-point format. Note that Models that do not support harmonics will return an ACK with error; INVALID_DEVICE.

The transmitted packet to the RD has the following format:

Start	**Packet Type**	**Length**	**Data**				**Checksum**
x6h	28h	000Nh	Control Byte	Harmonic Number	Subharmonic Number	Base Harmonic	xxxxh
1 byte	1 byte	2 bytes	1 byte	1 byte	1 byte	1 byte	2 bytes

The Length, N, is equal to 2 for versions 07.03.70 and earlier. N can be equal to 4 in versions later than 07.03.70 to control the "Zooming" into an area of harmonic interest. The Subharmonic number is the "Zoom" factor and can be any integer number between 1 and 10. The Base harmonic is the integer offset into the harmonic indices. The total number and format of harmonic values read (see Section 4.3) remains the same but the "Harmonic order" can become a "Subharmonic" for any Subharmonic number other than 1.

With no errors, the response from the RD will be:

Start	**Packet Type**	**Length**	**Data**	**Checksum**
x6h	28h	002Ah	Harmonic Data	xxxxh
1 byte	1 byte	2 bytes	3 + (3 * 13) + M bytes	2 bytes

The Data in the response has the following format:

Data						
Status Phase A	Harmonics Phase A	Status Phase B	Harmonics Phase B	Status Phase C	Harmonics Phase C	Subharmonic Status
1 byte	13 bytes	1 byte	13 bytes	1 byte	13 bytes	M bytes

If a DCA with a Master access is sent, Data in the response is as shown above (Length = 2Ah) otherwise, Data in the response is for the device that is being accessed (Length = 0Eh).

Trigger Harmonic Analysis (continued)

For versions greater than 07.03.70, if the length of the Trigger Harmonic Analysis command includes Subharmonic information (N = 4), then the response will have the Subharmonic Status in order of Subharmonic Number then Base Harmonic where M = 2 for per phase DCA. If a DCA with a Master access is sent, M = 6. The response Packet Length for a Master access DCA would be 30h (2Ah + 06h). The response Packet Length for a per phase DCA would be 10h (0Eh + 02h).

For versions 4.35 through 5.99 (RD-2xs), the DATA in the response is always of length 00Nh = 1Ah (25 for harmonics + 1 status).

The Control Byte sent in the command is defined as follows:
The low nibble sets function. The high nibble selects between fixed fundamental frequency of 50 or 60 Hz if set to zero. If set to one a tracking fundamental algorithm is used that allows the fundamental to be a frequency other than 50 or 60 Hz

Value	Definition:
0	00h- Return status of harmonic analysis fixed fundamental (harmonic number field ignored)
1	01h- Return status of harmonic analysis fixed fundamental (harmonic number field ignored) Restart analysis if completed
2	02h- Trigger to start fixed fundamental voltage harmonic analysis on the requested harmonic number. If the harmonic number is 0 then stop harmonic analysis.
3	03h- Trigger to start fixed fundamental current harmonic analysis on the requested harmonic number. If the harmonic number is 0 then stop harmonic analysis.
16	10h- Return status of harmonic analysis tracking fundamental (harmonic number field ignored)
17	11h- Return status of harmonic analysis tracking fundamental (harmonic number field ignored) Restart analysis if completed
18	12h- Trigger to start tracking fundamental voltage harmonic analysis on the requested harmonic number. If the harmonic number is 0 then stop harmonic analysis.
19	13h- Trigger to start tracking fundamental current harmonic analysis on the requested harmonic number. If the harmonic number is 0 then stop harmonic analysis.

Trigger Harmonic Analysis (continued)

The Status byte returned in the response when the command was 0 is defined as follows:

Value	Definition:
0	Harmonic analysis is not being performed (Harmonic data is all zeros)
1	Harmonic analysis is in progress (Harmonic data is all zeros)
2	Voltage harmonic analysis is ready (Harmonic data contains results)
3	Current harmonic analysis is ready (Harmonic data contains results)

Whenever the command status is 1 and the response is status 2 or 3, the RD-xx will immediately begin to perform harmonic analysis on the same harmonic number and axis (voltage or current).

The Harmonics data consists of

For RD-xx versions 4.35 – 5.99:

Offset	Size	format	Definition:
00h	4	TI float	Amplitude of the fundamental (in volts or amps depending on Status value)
04h	4	TI float	Phase angle (in degrees) of the fundamental
08h	4	TI float	THD of the fundamental
0Ch	1	int	Harmonic analyzed
0Dh	4	TI float	Amplitude of the harmonic analyzed (in volts or amps depending on Status value)
11h	4	TI float	Phase angle (in degrees) of the harmonic analyzed
15h	4	TI float	THD of the harmonic analyzed

For RX-xx Versions 07.02.90 and greater:

Offset	Size	format	Definition:
00h	1	int	Harmonic analyzed
01h	4	TI float	Amplitude of the harmonic analyzed (in volts or amps depending on Status value)
05h	4	TI float	Phase angle (in degrees) of the harmonic analyzed
09h	4	TI float	Distortion of the harmonic analyzed. If the harmonic analyzed is the fundamental, this value represents the THD.

2.20. [2Ch] Measurement Modes

Device	RS-712	RD-2x	RD-3x
Version Availability	4.13	5.07	6.00
Valid DCAs	M	**M**	**M** A B C

The Measurement Mode command can be used to get or set the mode of the standard. This command will work for RD-2x Version 5.07 and greater and RD-30 Standards Version 6.00 and greater. RD-2x Standards prior to Version 5.07 will return an Invalid Packet Type error 06h. See the RD User Manual for a complete description of the Measurement Modes.

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Data		Checksum
A6h	2Ch	0004h	Measurement Mode	Mask Word	xxxxh
1 byte	1 byte	2 bytes	2 bytes	2 bytes	2 bytes

Assuming no errors, the response from the RD will be:

Start	Packet Type	Length	Data	Checksum
A6h	2Ch	0002h	Measurement Mode	xxxxh
1 byte	1 byte	2 bytes	2 bytes	2 bytes

To get the current Measurement Mode of the RD send the command with the Measurement Mode and Mask Word set to zeros: A6 2C 0004 0000 0000 0030

To set the Measurement Mode of the RD send the command with the Measurement Mode set based on the table below and set the Mask Word to 000Fh for an RD-3x or a 0001h for an RD-2x.

Measurement Mode Table

Code	Measurement Mode
0000h	Sets Mode to RMS
0001h	Sets Mode to AVG

Certain models of RD-2x/3x do not support Average (AVG) mode. RD-xx devices that do not support AVG mode will return and Invalid Data Error if requested to set to AVG mode.

2.21. [2Eh] Read Instantaneous Metrics; RD-3x format

Device	RS-712	RD-2x	RD-3x
Version Availability	N/A	N/A	6.00
Valid DCAs	M	M	**M** A B C

This command is for reading instantaneous metrics from RD-xx Standards in RD-3x format. The RD-3x will return the specific metric in TI Floating-point format for each phase, neutral and net values. See the section on converting the TI floating-point to IEEE format. The metric values will be based on the Measurement Mode setting (versions 06.00.17 and earlier). See the Measurement Mode command for getting and setting the mode. Note that not all models support all instantaneous metrics.
In firmware versions 06.00.00 and later, metrics that are not supported will always return a value equal to the maximum TI floating point number (3.4028235E38).

The transmitted packet to the RD has the following format:

Start	**Packet Type**	**Length**	**Data**		**Checksum**
A6h	2Eh	0004h	Metric Index	FFFDh	xxxxh
1 byte	1 byte	2 bytes	2 bytes	2 bytes	2 bytes

Assuming no errors, the response from the RD will be:

Start	**Packet Type**	**Length**	**Data**					**Check sum**
A6h	2Eh	0014h	Phase A	Phase B	Phase C	Net	Reserved	xxxxh
1 byte	1 byte	2 bytes	4 bytes	4 bytes	4 bytes	4 bytes	4 bytes	2 bytes

The response data is the Instantaneous Metric in TI floating-point format for phase A, phase B, phase C, Reserved, and net values.

The Instantaneous Metrics and their offsets are shown in Section 4.1, Table 1.

2.22. [2Fh] Read Accumulating Metrics; RD-3x format

Device	RS-712	RD-2x	RD-3x
Version Availability	N/A	N/A	6.00
Valid DCAs	M	M	**M** A B C

This command is for reading accumulating metrics from RD-xx Standards in RD-3x format. The RD-3x will return the specific metric in TI Floating-point format for each phase, neutral and net values. See the section on converting the TI floating-point to IEEE format. The metric values will be based on the Measurement Mode setting (versions 06.00.17 and earlier). See the Measurement Mode command for getting and setting the mode. Note that not all models support all accumulating metrics.
In firmware versions and 06.00.00 and later, metrics that are not supported will always return a value equal to the maximum TI floating point number (3.4028235E38).

The transmitted packet to the RD has the following format:

Start	Packet Type	Length	Data	Checksum
A6h	2Fh	0002h	Accumulating Metric Index	xxxxh
1 byte	1 byte	2 bytes	2 bytes	2 bytes

Assuming no errors, the response from the RD will be:

Start	Packet Type	Length	Data					Check sum
A6h	2Fh	0014h	Phase A	Phase B	Phase C	Net	Reserved	xxxxh
1 byte	1 byte	2 bytes	4 bytes	4 bytes	4 bytes	4 bytes	4 bytes	2 bytes

The Accumulating Metrics and their offsets are shown in Section 4.2, Table 2.

2.23. [30h] All Minimum Metrics Request

Device	RS-712	RD-2x	RD-3x
Version Availabilty	N/A M	2.02 M	6.00 **M** A B C

This command is for reading minimum instantaneous metrics from RD-xx Standards in RD-3x format. The RD-3x will return the specific metric in TI Floating-point format for each phase, neutral and net values. See the section on converting the TI floating-point to IEEE format. The metric values will be based on the Measurement Mode setting (versions 06.00.17 and earlier). See the Measurement Mode command for getting and setting the mode. Note that not all models support all instantaneous metrics.
In firmware versions and 06.00.00 and later, metrics that are not supported will always return a value equal to the maximum TI floating point number (3.4028235E38).

The transmitted packet to the RD has the following format:

Start	**Packet Type**	**Length**	**Data**	**Checksum**
A6h	30h	0002h	Metric Index	xxxxh
1 byte	1 byte	2 bytes	2 bytes	2 bytes

Assuming no errors, the response from the RD will be:

Start	**Packet Type**	**Length**	**Data**					**Check sum**
A6h	30h	0014h	Phase A	Phase B	Phase C	Net	Reserved	xxxxh
1 byte	1 byte	2 bytes	4 bytes	4 bytes	4 bytes	4 bytes	4 bytes	2 bytes

The response data is the Minimum Instantaneous Metric in TI floating-point format for phase A, phase B, phase C, neutral, and net values.

The Minimum Instantaneous Metrics and their offsets are shown in Section 4.1, Table 1.

2.24. [31h] All Maximum Metrics Data Request

Device	RS-712	RD-2x	RD-3x
Version Availabilty	N/A M	2.02 M	6.00 **M** A B C

This command is for reading maximum instantaneous metrics from RD-xx Standards in RD-3x format. The RD-3x will return the specific metric in TI Floating-point format for each phase, neutral and net values. See the section on converting the TI floating-point to IEEE format. The metric values will be based on the Measurement Mode setting (versions 06.00.17 and earlier). See the Measurement Mode command for getting and setting the mode. Note that not all models support all instantaneous metrics.
In firmware versions and 06.00.00 and later, metrics that are not supported will always return a value equal to the maximum TI floating point number (3.4028235E38).

The transmitted packet to the RD has the following format:

Start	**Packet Type**	**Length**	**Data**	**Checksum**
A6h	31h	0002h	Metric Index	xxxxh
1 byte	1 byte	2 bytes	2 bytes	2 bytes

Assuming no errors, the response from the RD will be:

Start	**Packet Type**	**Length**	**Data**					**Check sum**
A6h	31h	0014h	Phase A	Phase B	Phase C	Net	Reserved	xxxxh
1 byte	1 byte	2 bytes	4 bytes	4 bytes	4 bytes	4 bytes	4 bytes	2 bytes

The response data is the Maximum Instantaneous Metric in TI floating-point format for phase A, phase B, phase C, neutral, and net values.

The Maximum Instantaneous Metrics and their offsets are shown in Section 4.1, Table 1.

2.25. [32h] Set Pulse Output Constant

Device	RS-712	RD-2x	RD-3x
Version Availability	4.13	5.06	6.00
Valid DCAs	M	**M**	**M** A B C

The Set Pulse Output Constant command is only available in Versions 5.06 and greater. This allows setting the pulse output constant for a specific accumulating metric. The Pulse Output Constant should be in TI floating point format.

The transmitted packet to the RD device has the following format:

Start	Packet Type	Length	Data			Checksum
A6h	32h	0007h	Metric Index	Status	Pulse Output Constant	xxxxh
1 byte	1 byte	2 bytes	2 bytes	1 byte	4 bytes	2 bytes

Assuming no errors, for a 00h in the "Status" field, the response from the RD will be:

Start	Packet Type	Checksum
A3h	32h	00D5h
1 byte	1 byte	2 bytes

For a 01h in the "Status" field, the reponse from the RD will be:

Start	Packet Type	Length	Data	Checksum
A3h	32h	0004h	Pulse Output Constant of given Metric Index	xxxxh
1 byte	1 byte	2 bytes	4 bytes	2 bytes

The Accumulating Metric Index Table is shown in the Read Accumulating Metrics commands (section 2.13).

2.26. [34h] Standard Test

Device	RS-712	RD-2x	RD-3x
Version Availability	N/A	07.00.00	07.01.10
Valid DCAs	M	**M**	**M** A B C

The transmitted packet to an RD-2x device has the following format:

Start	**Packet Type**	**Length**	**Data**				**Checksum**
A6h	34h	000Ah	Test Fct	Control	Duration	Pulse Constant	xxxxh
1 byte	1 byte	2 bytes	1 byte	1 byte	4 bytes	4 bytes	2 bytes

The "Test Fct" is the index of the accumulating function for the Standard Test. See Table 2 for details on the accumulating function indices. If an accumulating function is not supported by the RD-xx model, an ACK_ERROR with INVALID_DATA will occur.

The "Duration" is an unsigned 32-bit integer number representing either the Time in samples for the Standard Test or the Number of Pulses Counted for the Standard Test.

The "Pulse Constant" is a 32 bit TI floating point number representing the pulse constant to be used for the Standard Test.

The "Control" byte is described below:

Bit	Description
0	RD-xx returns status if this bit is 0, otherwise it starts a Standard Test For the correct status information to be returned, the original parameters that were sent to initiate the Standard Test must be sent.
1	Testing Non-Radian Standard if equal to 0, otherwise testing a Radian Standard
2	Time-based test if equal to 0, otherwise Pulse-based test
3-7	Reserved

Standard Test (continued)

The transmitted packet to an RD-3x device has the following format:

Start	**Packet Type**	**Length**	**Data**					**Check sum**
A6h	34h	000Bh	Test Fct	Control	Duration	Pulse Constant	Test Phase	xxxxh
1 byte	1 byte	2 bytes	1 byte	1 byte	4 bytes	4 bytes	1 byte	2 bytes

The “Test Fct” is the index of the accumulating function for the Standard Test. See Table 2 for details on the accumulating function indices. If an accumulating function is not supported by the RD-xx model, an ACK_ERROR with INVALID_DATA will occur.

The “Duration” is an unsigned 32-bit integer number representing either the Time in samples for the Standard Test or the Number of Pulses Counted for the Standard Test.

The “Pulse Constant” is a 32 bit TI floating point number representing the pulse constant to be used for the Standard Test.

The “Test Phase” is the phase of the RD-3x that is to perform the Standard Test.

The “Control” byte is described below:

Bit	Description
0	RD-xx returns status if this bit is 0, otherwise it starts a Standard Test For the correct status information to be returned, the original parameters that were sent to initiate the Standard Test must be sent.
1	Testing Non-Radian Standard if equal to 0, otherwise testing a Radian Standard
2	Time-based test if equal to 0, otherwise Pulse-based test
3	Totalized form of Test Function to be used for Standard Test if this bit is 1, otherwise the per phase form of the Test Function is used
4-7	Reserved

Standard Test (continued)

Assuming no errors, the response from a RD-xx will be:

Start	**Packet Type**	**Length**	**Data**								**Check sum**
A6h	34h	001Ah	Test Fct	Control	Duration	% Err	% Reg	Pulse Constant	Accum Metric	Pulse Count	xxxxh
1 byte	1 byte	2 bytes	1 byte	1 byte	4 bytes	4 bytes	4 bytes	4 bytes	4 bytes	4 bytes	2 bytes

The “Duration” in the response will be the number of samples or pulses left in the test.
% Err (Error), % Reg (Registration), and Accum Metric are 4 bytes values in TI floating point format. The % Err and % Reg values are returned as the maximum TI floating point number (3.4028235E38) until the test is complete.
“Pulse Count” is the number of pulses read during the standard test and is represented as a 32bit unsigned integer.

To Abort any Standard Test, a test must be started with a Duration of zero. Not restarting a Standard Test with a Duration of zero will not change the gating registers back to their default states.

2.27. [39h] Meter Test

Device	RS-712	RD-2x	RD-3x
Version Availability	4.13	5.06	6.00
Valid DCAs	M	**M**	**M** A B C

The transmitted packet to an RD-2x device has the following format:

Start	**Packet Type**	**Length**	**Data**								**Check sum**
A6h	39h	0010h	Test Fct	Control	Duration	Kh	Meter Elements	Current Elements	Revs	Pulses/Rev	xxxxh
1 byte	1 byte	2 bytes	1 byte	1 byte	4 bytes	4 bytes	1 byte	1 byte	2 bytes	2 bytes	2 bytes

Data Bytes	Description
1	Test Fct; The index of the accumulating function for the Meter Test. (see Table 2 for details) If an accumulating function is not supported by the RD-xx model, an ACK_ERROR with INVALID_DATA will be returned.
2	Control; For the correct status information to be returned, the original parameters that were sent to initiate the Meter Test must be sent.

Bit	Description
0	Return status if 0, Start Meter test if 1
1	Pulse-based Sensor Meter test 0
2	Time-based Sensor Meter test 1
	Pulse-based Manual Meter test 2
	Demand Meter test 3
3-7	Reserved for future use

3-6	Duration; 32 bit integer number representing

Pulse-based Sensor Meter test	Field ignored for this test.
Time-based Sensor Meter test	Duration of Meter test in samples
Pulse-based Manual Meter test	Field ignored for this test.
Demand Meter test	Duration of Meter test in samples

7-10	Kh; 32 bit TI floating point number

Pulse-based Sensor Meter test	Kh factor
Time-based Sensor Meter test	Kh factor
Pulse-based Manual Meter test	Kh factor
Demand Meter test	Demand Meter reading

11	Meter elements; The index into the array of meter elements 0-3. The meter elements are 3.0, 2.5, 2.0, and 1.0 respectively.

Meter Test (continued)

Data Bytes	Description
12	Current elements; The index into the array of current elements 0-2. The current elements are 1, 2, or 3 respectively.
13-14	Revs; The number of revolutions for the Meter during the test. It is only necessary to transmit this field when doing a Sensor or Manual Meter test (reducing the packet length by 2 bytes otherwise).
15-16	Pulses/Rev; The number of pulses per revolution for the Meter during the test. It is only necessary to transmit this field when doing a Sensor Meter test (reducing the packet length by 2 bytes otherwise).

The transmitted packet to an RD-3x device has the following format:

Start	**Packet Type**	**Length**	**Data**									**Check sum**
A6h	39h	0011h	Test Fct	Control	Duration	Kh	Meter elements	Current Inputs	Test Phase	Revs	Pulses/ Rev	xxxxh
1 byte	1 byte	2 bytes	1 byte	1 byte	4 bytes	4 bytes	1 byte	1 byte	1 byte	2 bytes	2 bytes	2 bytes

The areas within the Data field for the RD-3x command have the same definition as for the RD-2x command with the following exceptions.

The “Control” byte is described below:

Bit	Description		
0	Return status if 0, Start Meter test if 1		
1	Pulse-based Sensor Meter test	0	
2	Time-based Sensor Meter test	1	
	Pulse-based Manual Meter test	2	
	Demand Meter test	3	
3	Totalized form of Test Function to be used for Meter test if 1. Per phase form of Test Function to be used for Meter test if 0.		
4-7	Reserved for future use		

For the correct status information to be returned, the original parameters that were sent to initiate the Meter Test must be sent.

Meter Test (continued)

The "Test Phase" is the phase of the RD-3x that is to perform the Meter Test.

Test Phase	Value
A	0
B	1
C	2

Assuming no errors, the response from a RD-xx will be:

Start	**Packet Type**	**Length**	**Data**							**Check sum**
A6h	39h	0016h	Test Fct	Control	% Err	% Reg	Accum Metric	Duration Left	Pulse Count	xxxxh
1 byte	1 byte	2 bytes	1 byte	1 byte	4 bytes	4 bytes	4 bytes	4 bytes	4 bytes	2 bytes

% Err (Error), % Reg (Registration), and Accum Metric are 4 bytes values in TI floating point format. The % Err and % Reg values are returned as the maximum TI floating point number (3.4028235E38) until the test is complete. "Duration Left" and "Pulses Counted" are both 32 bit unsigned integers. "Duration Left" represents either the number of pulses left in a Meter test for Pulse-based testing or the number of samples left for Time-based or Demand Meter testing. "Pulses Counted" is the number of pulses that the RD-xx has detected during a Time-based Meter test. "Pulses Counted" is not returned for Pulse-based meter testing or Demand Meter Testing.

To abort any Meter Test, a test must be started with a duration of zero. Not restarting a Standard Test with a duration of zero will not change the gating registers back to their default states.

2.28. [3Ah] ANALOG SENSE TEST

Communications Delay Timeout: 50 mS
An Analog Sense Test packet transmitted to the RD-xx (the **command**) will have the following format:

Device	RS-712	RD-2x	RD-3x
Version Availabilty	N/A M	7.04.00 **M**	7.04.00 M A B **C**

Start	**Packet Type**	**Length**	**Data**						**Check sum**
x6h	3Ah	0006h	Test Fct	Control	Analog Sense Factor	Type	Input	Offset	xxxxh
1 byte	1 byte	2 bytes	1 byte	1 byte	4 bytes	4 bytes	4 bytes	4 bytes	2 bytes

where "x6h" is either A6h for an RD-2x or D6h for an RD-3x.

The "Control" byte is described below:

Bit	Description
0	Return status if 0, Apply transmitted parameters if 1
1-7	Reserved for future use

The Test Fct field is the index of the Instantaneous Metric to perform the Analog Sense test on. Only Volts, Amps, Watts, VA, VAR, and Frequency can be used to perform an Analog Sense test.
Table 2 has a listing of these metrics and their indices. Metrics not listed here will result in an error
if sent.

The Analog Sense Factor is in 32 bit TI floating point format.

The "Type" field is the transducer type (0 = 0 mA, 1 = 4mA, or 2 = 12m A).

The "Input" field is the input reference (if three phase) : 0 = Phase A, 1 = Phase B, 2 = Phase c, 3 = Totalized.

The "Offset" field is a generic offset applied to the transducer output, a 32 bit TI floating point format.

The equation defining the tranducer output is:

$T = Analog\_Sense\_Factor * (I_{Input} - Type) + Offset$

The **response** from the RD-xx for this packet could be;
An ACK_NODATA if bit 0 of Control is equal to 1, otherwise, an ACK_DATA with the following data format:

Start	**Packet Type**	**Length**	**Data**						**Check sum**
x6h	3Ah	0015h	Test Fct	Analog Sense Factor	Referene Value	DUT Value	DIF Value	%Err	xxxxh
1 byte	1 byte	2 bytes	1 byte	4 bytes	4 bytes	4 bytes	4 bytes	4 bytes	2 bytes

Analog Sense Factor, Reference Value, DUT Value, DIF Value, and % Err are 4 byte values in TI floating point format. Analog Sense Factor and Test Fct in the response are the same as the transmitted. Reference Value is the value of the metric from the RD-xx. DUT value is the measurement, scaled by the Analog Sense Factor, from the
Device Under Test via the Analog Sense input BNC3. DIF is the difference between the Reference and DUT values. % Err is the percentage error of the DUT value with respect to the Reference Value.

2.29. [3Dh] Power Quality Start/Stop/Status

Device	RD-2x	RD-3x
Version Availability	7.05.30	7.05.30
Valid DCAs	**M**	**M** **A** **B** **C**

The packet transmitted to the RD-xx (**Power Quality Start**) will have the following format:

Start	Packet Type	Length	Control Field	Data	Checksum
A6h	3Dh	0025h	0x01	9 (floats) PQ Thresholds	xxxxh
1 byte	1 byte	2 bytes	1 Byte	36 bytes	2 bytes

The threshold definitions are as follows:

Bytes	Thresholds	Typical Value
0-3	Sag Trigger	108.0 Volts
4-7	Swell Trigger	126.0 Volts
8-11	Voltage Transient Trigger	200.0 Volts
12-15	Noise Trigger	1.5 Volts
16-19	Voltage %THD Trigger	5.0 % THD
20-23	Frequency Trigger	2.0 Hz
24-27	3-Phase Imballanced Trigger	2.0 Volts
28-31	Current Transicent Trigger	10.0 Amps
32-35	Current %THD Trigger	20.0 % THD

The packet being sent from the RD-xx (the **response**) would be:

Start	Packet Type	Checksum
A3h	3Dh	00E0h
1 byte	1 byte	2 bytes

The packet transmitted to the RD-xx (**Power Quality Stop Command**) will have the following format:

Start	Packet Type	Length	Control Field	Checksum
A6h	3Dh	0001h	0h	00E4h
1 byte	1 byte	2 bytes	1 byte	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Start	Packet Type	Checksum
A3h	3Dh	00E0h
1 byte	1 byte	2 bytes

The packet transmitted to the RD-xx (**Power Quality Status Command**) will have the following format:

Start	Packet Type	Length	Control Field	Checksum
A6h	3Dh	0001h	2h	00E6h
1 byte	1 byte	2 bytes	1 byte	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Start	Packet Type	Length	Status	Checksum
A3h	3Dh	0001h	0x00 – 0xFF	xxxxh
1 byte	1 byte	2 bytes	1 byte	2 bytes

If the returned status is 0xFF no event data is available. If the return status is not 0xFF, then a power quality event has occurred and event data is available. The index into the Power Quality event data fifo is returned in the status field of the status message. To return the data associated with this Power Quality event fifo entry, send the Power Quality Data message as defined below.

2.30. [3Eh] Power Quality Data

Device	RD-2x	RD-3x
Version Availability	7.05.30	7.05.30
Valid DCAs	**M**	**M** **A** **B** **C**

The packet transmitted to the RD-xx (**Power Quality Data**) will have the following format:

Start	Packet Type	Length	Event Fifo Index	Offset (bytes)	Length (bytes)	Checksum
A6h	3Eh	0005h	00h – 3Fh	Fifo offset	Tx Length	xxxxh
1 byte	1 byte	2 bytes	1 Byte	2 bytes	2 Bytes	2 bytes

The messsage field definitions are as follows:

Field	Definition
Event Fifo	Event Index returned from Power Quality Status

Field	Definition
Index	Message
Offset	Offset (in bytes) into an event data buffer entry
Length	Length (in bytes) of event data to transfer

The packet being sent from the RD-xx (the **response**) would be:

Start	**Packet Type**	**Length**	**Event Data**	**Checksum**
A6h	3Eh	XXXXh	waveform	xxxxh
1 byte	1 byte	2 bytes	N Bytes	2 bytes

The event data definitions are as follows:

Bytes	Description	Data Type
0-3	Event Type 1 – Sag 2 – Swell 3 – Voltage Transient 4 – Noise 5 – Voltage %THD 6 – Frequency 7 – Imbalanced 8 – Current Transient 9 – Current % THD	(Integer)
4-7	Time Stamp Time in seconds since start of Power Quality algorithm.	(float)
8-11	Duration Time in seconds of the duration of the detected event.	(float)
12-15	Magnitude 1 – RMS Voltage 2 – RMS Voltage 3 – RMS Voltage 4 – STD of Voltage Residual 5 – %THD 6 – Hz 7 – 3-phase Voltage Envelope Ratio	(float)

Bytes	Description	Data Type
	8 – RMS Current 9 – %THD	
16-1416	Waveform (350 samples) 1 – Instantaneous Voltage Envelope. 2 – Instantaneous Voltage Envelope. 3 – Instantaneous Voltage Envelope. 4 – STD of Voltage Residual over STD window at each instant t. 5 – %THD voltage computed over harmonic time window at each instant t. 6 – Instantaneous Frequency. 7 – Instantaneous 3-phase voltage envelope ratio. 8 – Instantaneous Current Envelope. 9 - %THD current computed over harmonic time window at each instant t.	(float)

2.31. [3FH] Meter Emulation/Service Selection

Device	RD-2x	RD-3x
Version Availability	7.05.30	7.05.30
Valid DCAs	**M**	**M** **A** **B** **C**

Meter Emulation allows the user to perform a general complex linear transformation on the three phases of input potential and current. This complex linear transformation is defined as follows:

$$V'_1 = C_{11}* V_1 + C_{12}*V_2 + C_{13}*V_3$$
$$V'_2 = C_{21}* V_1 + C_{22}*V_2 + C_{23}*V_3$$
$$V'_3 = C_{31}* V_1 + C_{23}*V_2 + C_{33}*V_3$$

$$A'_1 = K_{11}* A_1 + K_{12}*A_2 + K_{13}*A_3$$
$$A'_2 = K_{21}* A_1 + K_{22}*A_2 + K_{23}*A_3$$
$$A'_3 = K_{31}* A_1 + K_{23}*A_2 + K_{33}*A_3$$

Where (V1,V2,V3) is the RD-3X's complex three phase potential, and (A1,A2,A3) it's complex three phase current. C being the 3x3 complex coefficient matrix for the potential transformation, and K the 3x3 complex coefficient matrix for the current transformation. (V'1, V'2, V'3) the transformed complex three phase potential, and. (A'1, A'2, A'3) the transformed three phase current.

There are two Meter Emulation control messages that can be sent to the RD.
Start meter emulation, which also contains the coefficients of the potential and current transformations. Stop meter emulation, which does not contain any data content.

The packet transmitted to the RD-xx (**the Start Emulation Command**) will have the following format:

Start	**Packet Type**	**Length**	**Data**		**Checksum**
A6h	3Fh	0091h	Control	**Coefficient Data**	xxxxh
1 byte	1 byte	2 bytes	01h	144 bytes	2 bytes

The order of the coefficient data is as follows:

Bytes	Coefficient	Z-Coil Example	Form 2S Example	Delta Example
0-3	Real(C_{11})	1	0.5	1
4-7	Real(C_{12})	0	0	-1
8-11	Real(C_{13})	0	0	0
12-15	Imag(C_{11})	0	0	0
16-19	Imag(C_{12})	0	0	0
20-23	Imag(C_{13})	0	0	0
24-27	Real(C_{21})	1	0	0
28-31	Real(C_{22})	0	0	0
32-35	Real(C_{23})	1	0	0
36-39	Imag(C_{21})	0	0	0
40-43	Imag(C_{22})	0	0	0
44-47	Imag(C_{23})	0	0	0
48-51	Real(C_{31})	0	0	0
52-55	Real(C_{32})	0	0	-1
56-59	Real(C_{33})	1	0	1

Bytes	Coefficient	Z-Coil Example	Form 2S Example	Delta Example
60-63	Imag(C_{31})	0	0.5	0
64-67	Imag(C_{32})	0	0	0
68-71	Imag(C_{33})	0	0	0
72-75	Real(K_{11})	1	1	0
76-79	Real(K_{12})	0	0	0
80-83	Real(K_{13})	0	0	0
84-87	Imag(K_{11})	0	0	1
88-91	Imag(K_{12})	0	0	0
92-95	Imag(K_{13})	0	0	0
96-99	Real(K_{21})	0	0	1
100-103	Real(K_{22})	-1	0	0
104-107	Real(K_{23})	0	0	0
108-111	Imag(K_{21})	0	0	0
112-115	Imag(K_{22})	0	0	0
116-119	Imag(K_{23})	0	0	0
120-123	Real(K_{31})	0	0	0
124-127	Real(K_{32})	0	0	0
128-131	Real(K_{33})	1	1	0
132-135	Imag(K_{31})	0	0	1
136-139	Imag(K_{32})	0	0	0
140-143	Imag(K_{33})	0	0	0

The packet being sent from the RD-xx (the **response**) would be:

Start	**Packet Type**	**Checksum**
A3h	3Fh	00E2h
1 byte	1 byte	2 bytes

The packet transmitted to the RD-xx (**the Stop Emulation Command**) will have the following format:

Start	**Packet Type**	**Length**	**Data**	**Checksum**
A6h	3Fh	0001h	0h	xxxxh
1 byte	1 byte	2 bytes	1 byte	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Start	Packet Type	Checksum
A3h	3Fh	00E2h
1 byte	1 byte	2 bytes

Example 1: Z-Coil, form 6

$$V'_1 = C_{11}* V_1 + C_{12}*V_2 + C_{13}*V_3 \text{ ---------- } V'_1 = 1* V_1 + 0*V_2 + 0*V_3$$
$$V'_2 = C_{21}* V_1 + C_{22}*V_2 + C_{23}*V_3 \text{ ---------- } V'_2 = 1* V_1 + 0*V_2 + 1*V_3$$
$$V'_3 = C_{31}* V_1 + C_{32}*V_2 + C_{33}*V_3 \text{ ---------- } V'_3 = 0* V_1 + 0*V_2 + 1*V_3$$

$$A'_1 = K_{11}* A_1 + K_{12}*A_2 + K_{13}*A_3 \text{ ---------- } A'_1 = 1* A_1 + 0*A_2 + 0*A_3$$
$$A'_2 = K_{21}* A_1 + K_{22}*A_2 + K_{23}*A_3 \text{ ---------- } A'_2 = 0* A_1 + -1*A_2 + 0*A_3$$
$$A'_3 = K_{31}* A_1 + K_{32}*A_2 + K_{33}*A_3 \text{ ---------- } A'_3 = 0* A_1 + 0*A_2 + 1*A_3$$

2.32. [40h] Flicker Meter Start/Stop

Device	RD-2x	RD-3x
Version Availability	7.05.30	7.05.30
Valid DCAs	**M**	**M** **A** **B** **C**

The packet transmitted to the RD-xx (**Flicker Meter Start**) will have the following format:

Start	Packet Type	Length	Control Field	PST Measurement Window	Number of PSTs to Average	Checksum
A6h	40h	0004h	0x01	0-3		xxxxh
1 byte	1 byte	2 bytes	1 Byte	1 Byte	2 Bytes	2 bytes

PST Measurement Window is defined as:
0 = 1 min
1 = 5 min
2 = 10 min
3 = 15 min

The packet being sent from the RD-xx (the **response**) would be:

Start	Packet Type	Checksum
A3h	40h	00E3h
1 byte	1 byte	2 bytes

The packet transmitted to the RD-xx (**Flicker Meter Stop**) will have the following format:

Start	Packet	Length	Control Field	Checksum

	Type			
A6h	40h	0001h	0h	00E7h
1 byte	1 byte	2 bytes	1 byte	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Start	Packet Type	Checksum
A3h	40h	00E3h
1 byte	1 byte	2 bytes

2.33. [41h] Flicker Meter Data

Device	RD-2x	RD-3x
Version Availability	7.05.30	7.05.30
Valid DCAs	**M**	**M** **A** **B** **C**

The packet transmitted to the RD-xx (**Flicker Meter Data**) will have the following format:

Start	Packet Type	Length	Data Option	Checksum
A6h	41h	0001h	0-4	xxxxh
1 byte	1 byte	2 bytes	1 Byte	2 bytes

The data option definitions is as follows:
0 - Send current Pst and Plt to user
1 - Demodulated Amplitude
2 - Instant Flicker level
3 - PDF
4 - CPDF

The packet being sent from the RD-xx (the **response option 0**) would be:

Start	Packet Type	Length	Stale Flag	Pst	Plt	Checksum
A6h	41h	9h	0 old/1 new	TI Float	TI Float	xxxxh
1 byte	1 byte	2 bytes	1 byte	4 bytes	4 bytes	2 bytes

The packet being sent from the RD-xx (the **response option 1-4**) would be:

Start	Packet Type	Length	Stale Flag	Data Option (1-4) (Waveform)	Checksum
A6h	41h	253h	0 old/1 new	TI Float	xxxxh
1 byte	1 byte	2 bytes	1 byte	252 bytes	2 bytes

2.34. [42h] Change VAR Type

Device	RD-2x	RD-3x
Version Availability	7.05.30	7.06.00
Valid DCAs	**M**	**M** **A** **B** **C**

The packet transmitted to the RD-xx (**Change VAR Type**) will have the following format:

Start	Packet Type	Length	VAR Type	Checksum
A6h	42h	0001h	0 – 5	xxxxh
1 byte	1 byte	2 bytes	1 Byte	2 bytes

VAR Type is defined as:

0 = Voltage 90 Degree Shifted

$$VAR_i = \frac{1}{kT}\int_{\tau}^{\tau+kT}\left(I_i V_i\left(t+90°\right)\right)dt \qquad \text{and} \qquad \text{net } VARh = \sum_{i=1}^{3} VARh_i$$

1 = Integral VAR

$$VAR_i = \frac{\omega}{kT}\int_{\tau}^{\tau+kT} I_i\left[\int V_i\,dt\right]dt \quad \text{and} \quad \text{net } VARh = \sum_{i=1}^{3} VARh_i$$

2 = Integral VAR 50 Hz

$$VAR_i = \frac{2\pi 50}{kT}\int_{\tau}^{\tau+kT} I_i\left[\int V_i\,dt\right]dt \qquad \text{and} \qquad \text{net } VARh = \sum_{i=1}^{3} VARh_i$$

3 = Integral VAR 60 Hz

$$VAR_i = \frac{2\pi 60}{kT}\int_{\tau}^{\tau+kT} I_i\left[\int V_i dt\right]dt \qquad \text{and} \qquad \text{net } VARh = \sum_{i=1}^{3} VARh_i$$

4 = RMS VAR

$$\| V_i \| = \sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} V_i{}^2 dt} \qquad \text{and} \qquad \| I_i \| = \sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} I_i{}^2 dt}$$

$$WATT_i = \frac{1}{kT}\int_{\tau}^{\tau+kT} V_i I_i dt \qquad \text{and} \qquad VA_i = \| V_i \| \cdot \| I_i \|$$

$$VAR_i = \sqrt{VA_i^2 - WATT_i{}^2} \qquad \text{and} \qquad \text{net } VARh = \sum_{i=1}^{3} VARh_i$$

5 = Fundamental VAR

$$\| \tilde{V}_i \| = \sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} \tilde{V}_i{}^2 dt} \qquad \text{and} \qquad \| \tilde{I}_i \| = \sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} \tilde{I}_i{}^2 dt}$$

$$VAR_i = \| \tilde{V}i \| \cdot \| \tilde{I}_i \| \sin(\theta_i) \qquad \text{and} \qquad \text{net } VAR = \sum_{i=1}^{3} VAR_i$$

TERMINOLOGY USED

Index "i" represents the i^{th} phase in the poly-phase network.

$\tilde{V}_i$ = Potential component fundamental (1^{st} harmonic order)

$\tilde{I}_i$ = Current component fundamental (1^{st} harmonic order)

V_i = Generalized potential waveform (fundamental and all harmonics).

I_i = Generalized current waveform (fundamental and all harmonics).

θ_i = Phase angle between the potential and current.

Δt = VAR-hour and VA-hour integration interval.

T = Fundamental period.

k = Number of fundamental periods.

ω = Fundamental frequency = $2\pi f_0$, where f_0 is the fundamental.

τ = Start time of integration.

|| || = Generally represents the norm of the wave function: 1-norm (Average) or 2-norm RMS

The packet being sent from the RD-xx (the **response**) would be:

Start	Packet Type	Checksum
A3h	42h	00E5h
1 byte	1 byte	2 bytes

2.35. [43h] Change Integration Time

Device	RD-2x	RD-3x
Version Availability	7.06.00	7.06.00
Valid DCAs	**M**	**M** **A** **B** **C**

The packet transmitted to the RD-xx (**Change Integration Time**) will have the following format:

Start	Packet Type	Length	Integration	Checksum
A6h	43h	0001h	0 – 2FFh	xxxxh
1 byte	1 byte	2 bytes	1 Byte	2 bytes

Integration Time is an integer which represents multiples of ½ second reporting intervals. To compute the new reporting interval the equation would be: Reporting Interval = (Integration + 1)*0.5 seconds.

The packet being sent from the RD-xx (the **response**) would be:

Start	Packet Type	Checksum
A3h	43h	00E6h
1 byte	1 byte	2 bytes

2.36. [44H] Clamp-On Port Disable/Enable

Device	RD-2x	RD-3x
Version Availability	7.06.00	7.06.00
Valid DCAs	**M**	**M** A B C

The packet transmitted to the RD-xx (**Clamp-On Port Disable/Enable**) will have the following format:

Start	Packet Type	Length	Data	Checksum
A6h	44h	0001h	xxh	xxxxh
1 byte	1 byte	2 bytes	1 byte	2 bytes

The areas within the Data field for the RD-3x command have the same definition as for the RD-2x command with the following exceptions.

The “Data” byte is described below:

Bit	Description	
0	Disable	0
	Enable	1
1	N/A	

The packet being sent from the RD-xx (the **response**) would be: ACK with no data

Start	Packet Type	Checksum
A6h	44h	xxxxh
1 byte	1 byte	2 bytes

2.37. [50h] Change Fundamental Frequency

Device	RD-2x	RD-3x
Version Availability	7.06.00	7.06.00
Valid DCAs	**M**	**M** A B C

The packet transmitted to the RD-xx (**Change Fundamental Frequency**) will have the following format:

Start	Packet Type	Length	Fundamental Frequency	Checksum
A6h	50h	0004h	25-400 Hz (TI Float)	xxxxh
1 byte	1 byte	2 bytes	4 Bytes	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Start	Packet Type	Checksum
A3h	50h	00E5h
1 byte	1 byte	2 bytes

2.38. [72h] Burden Tester – Burden Test

Device	RD-2x	RD-3x
Version Availability	7.07.00	7.07.00
Valid DCAs	**M**	**M** A B C

The function of this message is to initiate a burden test in the RD-xx.

The packet transmitted to the RD-xx (**Burden Test - *Stop State***) will have the following format:

Phase	Start	Packet Type	Length	Data	Checksum
RD-2x	A6h	72h	0001h	00h	0119h
RD-3x: A	B6h	72h	0001h	00h	0129h
RD-3x: B	C6h	72h	0001h	00h	0139h
RD-3x: C	D6h	72h	0001h	00h	0149h
	1 byte	1 byte	2 bytes	1 byte	2 bytes

The packet transmitted to the RD-xx (**Burden Test - *Start State***) will have the following format:

Phase	Start	Packet Type	Length	Data Byte1	Data Byte2	Checksum
RD-2x	A6h	72h	0002h	01h	Mask	xxxxh
RD-3x: A	B6h	72h	0002h	01h	Mask	xxxxh
RD-3x: B	C6h	72h	0002h	01h	Mask	xxxxh
RD-3x: C	D6h	72h	0002h	01h	Mask	xxxxh
	1 byte	1 byte	2 bytes	1 of 2 bytes	2 of 2 bytes	2 bytes

Mask 8 bits (Binary Coding)	Burden Value (ohms)
00000000	0.0
00000001	0.1
00000010	0.2
00000100	0.5
00001000	1.0
00010000	2.0
00100000	4.0
01000000	8.0

Note: To measure perform measurements over all burden values the Mask Code would be 7Fh

The packet being sent from the RD-xx (the **response**) would be:

Phase	Start	Packet Type	Checksum
RD-2x	A3h	72h	0112h
RD-3x: A	B3h	72h	0122h
RD-3x: B	C3h	72h	0132h
RD-3x: C	D3h	72h	0142h
	1 byte	1 byte	2 bytes

2.39. [73h] Burden Tester - Demagnitization

Device	RD-2x	RD-3x
Version Availability	7.07.00	7.07.00
Valid DCAs	**M**	**M** A B C

The function of this message is to initiate a demagnitization of transformer core in the RD-xx.

The packet transmitted to the RD-xx (**Demagnitization**) will have the following format:

Phase	Start	Packet Type	Length	Checksum
RD-2x	A6h	73h	0000h	0119h
RD-3x: A	B6h	73h	0000h	0129h
RD-3x: B	C6h	73h	0000h	0139h
RD-3x: C	D6h	73h	0000h	0149h
	1 byte	1 byte	2 bytes	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Phase	Start	Packet Type	Checksum
RD-2x	A3h	73h	0116h
RD-3x: A	B3h	73h	0126h
RD-3x: B	C3h	73h	0136h
RD-3x: C	D3h	73h	0146h
	1 byte	1 byte	2 bytes

2.40. [74h] Burden Tester – Status

Device	RD-2x	RD-3x
Version Availability	7.07.00	7.07.00
Valid DCAs	**M**	**M** A B C

The function of this message is to determine the burden hardware & testing state.

The packet transmitted to the RD-xx (**Status**) will have the following format:

Phase	Start	Packet Type	Length	Checksum
RD-2x	A6h	74h	0000h	011Ah
RD-3x: A	B6h	74h	0000h	012Ah
RD-3x: B	C6h	74h	0000h	013Ah
RD-3x: C	D6h	74h	0000h	014Ah
	1 byte	1 byte	2 bytes	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Phase	Start	Packet Type	Length	Data Byte1	Data Byte2	Data Byte3	Checksum
RD-2x	A6h	74h	0003h	Status	Temperature	Clamp/Fan	xxxxh
RD-3x: A	B6h	74h	0003h	Status	Temperature	Clamp/Fan	xxxxh
RD-3x: B	C6h	74h	0003h	Status	Temperature	Clamp/Fan	xxxxh
RD-3x: C	D6h	74h	0003h	Status	Temperature	Clamp/Fan	xxxxh
	1 byte	1 byte	2 bytes	1 of 3 bytes	2 of 3 bytes	3 of 3 bytes	2 bytes

Note: Temperature is in degress C with 1 degree increments (range: +-128 degrees C).

Status 8 bits (Binary Coding)	Indication
00000000	No Burden Tester Connected
00000001	Over Temperature Detected
00000010	Over Burden Detected
00000100	Process Busy
00001000	Burden Tester Cooling
00010000	Burden Tester Connected
00100000	Resister Failure
01000000	Test Complete
10000000	Continuity Failure

Clamp/Fan 8 bits (Binary Coding)	Indication
00000001	Clamp Connected = 1
00000010	Fan on = 1
00000100 – 10000000	NOT USED

2.41. [75h] Burden Tester – Burden Test Results

Device	RD-2x	RD-3x
Version Availability	7.07.00	7.07.00
Valid DCAs	**M**	**M** A B C

The function of this message is to retreive the “current measurement” data for the last burden test executed.

The packet transmitted to the RD-xx (**Burden Test Results**) will have the following format:

Phase	Start	Packet Type	Length	Checksum
RD-2x	A6h	75h	0000h	011Bh
RD-3x: A	B6h	75h	0000h	012Bh
RD-3x: B	C6h	75h	0000h	013Bh
RD-3x: C	D6h	75h	0000h	014Bh
	1 byte	1 byte	2 bytes	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Phase	Start	Packet Type	Length	Data (4 Bytes / Measurement)	Checksum
RD-2x	A6h	75h	0020h	Current at ith Burden	xxxxh
RD-3x: A	B6h	75h	0020h	Current at ith Burden	xxxxh
RD-3x: B	C6h	75h	0020h	Current at ith Burden	xxxxh
RD-3x: C	D6h	75h	0020h	Current at ith Burden	xxxxh
	1 byte	1 byte	2 bytes	32 Bytes (4 x 8 measurements)	2 bytes

Data Word (4 Bytes)	Curent Measure at Burden Value (ohms)
0	0.0
1	0.1
2	0.2
3	0.5
4	1.0
5	2.0
6	4.0
7	8.0

2.42. [79h] Standard / Meter Test Status – Type2

Device	RD-2x	RD-3x
Version Availability	7.07.00	7.07.00
Valid DCAs	**M**	**M** A B C

The function of this message is to retreive the last individual metrics (phase A,B,C) measured during a test in which a totalized metric was measured (phase A + B + C).

The packet transmitted to the RD-xx (**Standard/Meter Test Status – Type2**) will have the following format:

Phase	Start	Packet Type	Length	Checksum
RD-2x	A6h	79h	0000h	011Fh
RD-3x: A	B6h	79h	0000h	012Fh
RD-3x: B	C6h	79h	0000h	013Fh
RD-3x: C	D6h	79h	0000h	014Fh
	1 byte	1 byte	2 bytes	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Phase	Start	Packet Type	Length	Data (4 Bytes / Metric)	Checksum
RD-2x	A6h	79h	000Ch	Metric for A,B,C	xxxxh
RD-3x: A	B6h	79h	000Ch	Metric for A,B,C	xxxxh
RD-3x: B	C6h	79h	000Ch	Metric for A,B,C	xxxxh
RD-3x: C	D6h	79h	000Ch	Metric for A,B,C	xxxxh
	1 byte	1 byte	2 bytes	12 bytes	2 bytes

2.43. [7Bh] Burden Tester – Phase Measurement Test Results

Device	RD-2x	RD-3x
Version Availability	7.07.00	7.07.00
Valid DCAs	**M**	**M** A B C

The function of this message is to retreive the "phase measurement" data for the last burden test executed.

The packet transmitted to the RD-xx (**Phase Measurement Test Results**) will have the following format:

Phase	Start	Packet Type	Length	Checksum
RD-2x	A6h	7Bh	0000h	0121h
RD-3x: A	B6h	7Bh	0000h	0131h
RD-3x: B	C6h	7Bh	0000h	0141h
RD-3x: C	D6h	7Bh	0000h	0151h
	1 byte	1 byte	2 bytes	2 bytes

The packet being sent from the RD-xx (the **response**) would be:

Phase	Start	Packet Type	Length	Data (4 Bytes / Measurement)	Checksum
RD-2x	A6h	75h	0020h	Phase at ith Burden	xxxxh
RD-3x: A	B6h	75h	0020h	Phase at ith Burden	xxxxh
RD-3x: B	C6h	75h	0020h	Phase at ith Burden	xxxxh
RD-3x: C	D6h	75h	0020h	Phase at ith Burden	xxxxh
	1 byte	1 byte	2 bytes	32 Bytes (4 x 8 measurements)	2 bytes

Data Word (4 Bytes)	Phase Measure at Burden Value (ohms)
0	0.0
1	0.1
2	0.2
3	0.5
4	1.0
5	2.0
6	4.0
7	8.0

2.44. [7Ch] RD-3x Metric Read – Vector, Volt, Amp

Device	RD-3x
Version Availability	7.06.00
Valid DCAs	**M** A B C

The packet transmitted to the RD-3x (**RD-3x Metric Read – Vector, Volt, Amp**) will have the following format:

Start	Packet Type	Length	Checksum
A6h	7ch	0000h	xxxxh
1 byte	1 byte	2 bytes	2 bytes

The packet being sent from the RD-3x (the **response**) would be:

Start	Packet Type	Length	Data	Checksum
A6h	7Ch	0054h	Vector, Volt, Amp Metrics in TI floating point format	xxxxh
1 byte	1 byte	2 bytes	84 bytes	2 bytes

The Vector, Volt, Amp Metrics and their offsets are shown in Section 4.2, Table 2.1.

3. Sample Code

3.1. Checksum calculating

```
unsigned int CalculateChecksum(char *data, int size)
{
  unsigned int checksum = 0;

  for (int index = 0 ; index < size; index++)
    checksum += ( (unsigned int)data[index] ) & 0xff;

  return checksum & 0xffff;
}
```

3.2. Float Point Format on the RD

The TMS320VC33 Digital Signal Processor used in the RD-xx uses a different format than IEEE to represent floating point numbers. The DSP uses an 8-bit exponent, 1-bit for sign, and a 23-bit mantissa. The IEEE format uses 1-bit for sign, an 8-bit exponent, and a 23-bit mantissa.

The DSP format:

Bits 31 24	23	22 0
Exponent	Sign	Mantissa

The IEEE format:

Bits 31	30 23	22 0
Sign	Exponent	Mantissa

The DSP *exponent* is expressed in twos-complement format. A special case occurs when the *exponent* = -128. In this case the number is interpreted as 0, independent of the value of the *sign* and *mantissa*. Normally a number is treated as zero when the *mantissa* is zero. The *mantissa* is expressed in twos-complement form, with the binary point after the most significant non-sign bit. Since this bit is the complement of the *sign* bit, it is not included; the *mantissa* actually has 24 bits. The *sign* bit when set indicates a negative value.

The IEEE *exponent* is expressed in an offset-by-127 format. (The actual *exponent* is exponent-127.) The *mantissa* has 23 bits. When set, the *sign* bit indicates a negative value.

For a more information on converting between these two types of floating point formats, consult the Texas Instruments TMS320C3X General-Purpose Applications User's Guide under the section titled *IEEE/TMS320C3X Floating-Point Format Conversion*.

A possible routine to handle the conversion from the DSP floating-point format to the IEEE floating point format is shown on the following pages.

3.3. Floating Point Conversion Routines

```
//-------------------------------------------------------------------------------------
//  Copyright, ©, 2000-2004  Radian Research, Inc.
//  References:     TMS320C3x User's Guide 1997
//                  5.4.1  Converting IEEE Format to 2s-Complement
//                  TMS320C3x Floating-Point Format
//
//  Note:           1)      These Routines assume Single Precision (32-bit)
//                          floating point numbers with conversion done on
//                          a PC.
//                  2)      De-normalized numbers are numbers such as +0 or -0.
//                  3)      Not-a-Number (NaN) are numbers such as +infinity
//                          or -infinity.
//                  4)      These routines convert bytes to TI float and TI
//                          float to bytes.
//-------------------------------------------------------------------------------------

float DDeviceMemStructs::bytesToFloatTMS320(char *data)
{
  byte* pByte = (byte*)data;

  // Check for special cases
  if ((pByte[0] == 0x80) || (pByte[0] == 0x81))
  {
     // 2s-complement 0 maps to 0
     // 2s-complement number too small for IEEE numbers
     return(0.0);
  }

  if ((pByte[0] == 0x7f) && (pByte[1] == 0x7f) && (pByte[2] == 0xff) && (pByte[3] == 0xff))
    return(FLT_MAX);

  // Get the mantissa from the data array
  // DSP uses 23 bit LSB mantissa
  unsigned long mantissa = (((unsigned long)data[1] & 0x7f) << 16) |
                           (((unsigned long)data[2] & 0xff) << 8) |
                           ((unsigned long)data[3] & 0xff);

  // True if negative values
  bool negMantissa = (data[1] & 0x80) != 0;  // Sign in msb of 2nd byte

  if (((byte)data[0] == 0x7f) && negMantissa && (mantissa == 0))
  {
    // most negitave 2s-complement numbers to smallest negative IEEE
    return(FLT_MAX * -1);
  }

  // Get the exponent from the data array
  unsigned long value;
  unsigned long exponent = (unsigned char)(data[0] & 0xff);  // DSP uses MSB 8 bit 2's compliment exponent
```

Floating Point Conversion Routines (continued)

```
  if (negMantissa == false)
  {
    // positive 2s-complement number to positive IEEE number.
    value = (((exponent + 0x7F) << 23) | mantissa) & 0x7fffffff;
  }
  else if (mantissa != 0)
  {
    // negative 2s-complement numbers with no zero fractions to same IEEE number.
    value = ((~mantissa) + 1) & 0x7fffff;
    value |= 0x80000000 | ((exponent + 0x7f) << 23);
  }
  else
  {
    // negative 2s-complement numbers with a 0 fraction.
    value = 0x80000000 | ((exponent + 0x80) << 23);
  }

  // Convert to float w/o modifying bits
  float ret;
  memcpy(&ret, &value, 4);

  if ((ret > MAXSAFEVALUE) || (ret < MINSAFEVALUE))
  {
    ret = SAFEVALUE;
  }
  return(ret);
}
```

Floating Point Conversion Routines (continued)

```
void DDeviceMemStructs::floatToBytesTMS320(float value, char *data)
{
  unsigned long uValue;
  unsigned long mantissa;
  unsigned long exponent;
  bool negMantissa; // True if negative values

  memcpy(&uValue, &value, 4);  // Convert from float w/o modifying bits

  exponent = (uValue >> 23) & 0xff;
  mantissa = uValue & 0x7fffff;
  negMantissa = (uValue & 0x80000000) != 0;

  // Special cases
  if (exponent == 0xff)  // NAN
  {
    exponent = 0x7f;
    mantissa = negMantissa ? 0 : 0x7fffff; // negative / positive infinity
  }
  else if (exponent == 0)  // denormalized numbers
  {
    exponent = 0x80;
    negMantissa = false;
    mantissa = 0;
  }
  else
  {
    if (negMantissa)  // Negative number
    {
      if (mantissa)
      {
        mantissa = ~mantissa + 1;  // convert to 2's compliment
        exponent -= 0x7f;
      }
      else
        exponent -= 0x80;
    }
    else
      exponent -= 0x7f;
  }
  // Pack number into bytes
  data[0] = (char)exponent;
  data[1] = (char)((mantissa >> 16) & 0x7f);
  if (negMantissa)
    data[1] |= (char)0x80;
  data[2] = (char)((mantissa >> 8) & 0xff);
  data[3] = (char)(mantissa & 0xff);
}
```

4. Appendices

4.1. TABLE 1: Instantaneous Metrics Table

The Instantaneous Metrics and their offsets are shown below (Indices 11 through 15 are available in Rel. 06.00.41 and later).

Index	Offset	Metric
0	14h	Volts (V)
1	18h	Amps (A)
2	1Ch	Watt (W)
3	20h	Volt-Amps (VA)
4	24h	VAR
5	28h	Frequency (Hz)
6	2Ch	degrees Phase (oP)
7	30h	Power Factor (PF)
8	34h	Analog Sense (ASn)
9	38h	Delta Phase (doP)
10	3Ch	Delta Volts (dV)
11	40h	Delta Watts (dW)
12	44h	Delta VA (dVA)
13	48h	Delta VAR (dVAR)
14	4Ch	Cross-connected Delta VAR (xdVAR)
15	50h	Cross-connected Wye VAR (xyVAR)

4.2. TABLE 2: Accumulated Metrics Table

The Accumulated Metrics and their offsets are shown below (Index 12 and indices 14 through 25 are available in Rel. 06.00.41 and later).

Index	Offset	Metric
0	04h	Watt Hours (Wh)
1	08h	VAR Hours (VARh)
2	0Ch	Q Metric Hours (Qh)
3	10h	Volt-Amp Hours (VAh)
4	14h	Volt Hours (Vh)
5	18h	Amp Hours (Ah)
6	1Ch	Volt Squared Hours (V2h)
7	20h	Amp Squared Hours (A2h)
8	24h	Watt Hours Plus (Wh+)
9	28h	Watt Hours Minus (Wh-)
10	2Ch	VAR Hours Plus (VARh+)
11	30h	VAR Hours Minus (VARh-)
12	34h	Delta Watt Hours (dWh)
13	38h	Accumulated time (t)
14	3Ch	Delta VA Hours (dVAh)
15	40h	Delta VAR Hours (dVARh)
16	44h	Cross-Connected Delta VAR Hours (xdVARh)
17	48h	Cross-Connected Wye VAR Hours (xyVARh)
18	4Ch	Delta Watt Hours Positive (dWh+)
19	50h	Delta Watt Hours Negative (dWh-)
20	54h	Delta VAR Hours Positive (dVARh+)
21	58h	Delta VAR Hours Negative (dVARh-)
22	5Ch	Cross-Connected Delta VAR Hours Positive(xdVARh+)
23	60h	Cross-Connected Delta VAR Hours Negative(xdVARh-)
24	64h	Cross-Connected Wye VAR Hours Positive(xyVARh+)
25	68h	Cross-Connected Wye VAR Hours Positive(xyVARh-)

4.2.1. TABLE 2.1: Vector, Volt, Amp Metrics Table

The Vector, Volt, Amp Metrics are shown below.

Index	Metric
0	Angle <Va,Vb> (deg)
1	Angle <Va,Vc> (deg)
2	Angle <Va,Ia> (deg)
3	Angle <Va,Ib> (deg)
4	Angle <Va,Ic> (deg)
5	Angle <Vb,Vc> (deg)
6	Angle <Vb,Ia> (deg)
7	Angle <Vb,Ib> (deg)
8	Angle <Vb,Ic> (deg)
9	Angle <Vc,Ia> (deg)
10	Angle <Vc,Ib> (deg)
11	Angle <Vc,Ic> (deg)
12	Angle <Ia,Ib> (deg)
13	Angle <Ia,Ic> (deg)
14	Angle <Ib,Ic> (deg)
15	Va (Volts RMS)
16	Ia (Amps RMS)
17	Vb (Volts RMS)
18	Ib (Amps RMS)
19	Vc (Volts RMS)
20	Ic (Amps RMS)

4.3. TABLE 3: Harmonic Data Table

These values are read from RD-xx DSP internal memory.

CAUTION: The DSP address sent is the actual offset in the table divided by 4 (All objects in memory are stored with 32-bits per address).

For RD-2x Versions 2.02-5.99, and RD-2x/3x Versions 07.03.40 and greater:

Offset	Length (in bytes)	Format	Description
00h	4	TI float (4 bytes)	Amplitude Harmonic order 1
04h	4	TI float (4 bytes)	Phase Harmonic order 1
08h	4	TI float (4 bytes)	THD
0Ch	4	TI float (4 bytes)	Amplitude Harmonic order 2
10h	4	TI float (4 bytes)	Phase Harmonic order 2
14h	4	TI float (4 bytes)	Distortion
18h	4	TI float (4 bytes)	Amplitude Harmonic order 3
1Ch	4	TI float (4 bytes)	Phase Harmonic order 3
20h	4	TI float (4 bytes)	Distortion
O	o	O	O
O	o	O	O
24Ch	4	TI float (4 bytes)	Amplitude Harmonic order 50
250h	4	TI float (4 bytes)	Phase Harmonic order 50
254h	4	TI float (4 bytes)	Distortion

4.4. TABLE 4: Waveform Data Table

NOTE: These values are read from RD-xx DSP internal memory. The samples are stored every A/D Sample Period.

CAUTION: The DSP address sent is the actual offset in the table divided by 4 (All objects in memory are stored with 32-bits per address).

Offset	Length (in bytes)	Format	Description
00h	4	TI float (4 bytes)	Voltage Sample (t)
04h	4	TI float (4 bytes)	Voltage Sample (t + 1)
08h	4	TI float (4 bytes)	Voltage Sample (t + 2)
O	o	O	O
O	o	O	O
(N/2 – 4)h	4	TI float (4 bytes)	Voltage Sample (t + N/2)
(N/2)h	4	TI float (4 bytes)	Current Sample (t)
(N/2 + 4)h	4	TI float (4 bytes)	Current Sample (t + 1)
(N/2 + 8)h	4	TI float (4 bytes)	Current Sample (t + 2)
O	o	O	O
O	o	O	O
(N – 4)h	4	TI float (4 bytes)	Current Sample (t + N/2)

Where t is the current sample, t – 1 is the next sample, and N is the size of the Waveform Capture memory block.