AN-010 API Interface Specification

OmniPreSense radar sensors have an easy-to-use API to control their output. The simple commands can be used to configure the operation and output information provided by the sensor. Over time OmniPreSense will enhance the capabilities of its sensors by adding new features and functionality. These will come as new code versions which can be flashed to the board while keeping backwards compatibility.

Radar Sensor Types

OmniPreSense provides two different types of sensors, a Doppler radar sensor reporting motion, speed, and direction, and an FMCW radar sensor reporting range. The feature differences for each sensor is shown in Table 1. The following API commands pertain to both types of sensors except for special cases. In these cases, this document will call out the special command for either a Doppler (-A), FMCW (-B), or combination (-C) radar sensor.

Table 1. Radar Sensor Feature Matrix

Sensor	Type	Motion	Speed	Direction	Signal Magnitude	Range	FCC/IC Modular Approval	Detection Range (RCS = 10)
OPS241-A	Doppler	●	●	●	●			20-25m
OPS242-A	Doppler	●	●	●	●		●	20-25m
OPS243-A	Doppler	●	●	●	●		●	50-100m
OPS241-B	FMCW				●	●		15-20m
OPS243-C	FMCW & Doppler	●	●	●	●	●	● (pending)	50-60m

Terminal Control

A simple Command Terminal can be used to control the module operation with the API commands. Examples of simple but very useful Command Terminals are Tera Term and PuTTY. Both are free, open source terminal tools for the PC/Mac and embedded processors (Raspberry Pi, etc.) which can easily connect to a serial port and accept data over USB from the OmniPreSense module.

To begin using the OmniPreSense sensor, first download Tera Term or PuTTY onto your PC/Mac or embedded processor. With the OmniPreSense sensor plugged into the USB port of your system, start Tera Term or PuTTY. A configuration window such as Figure 1 or Figure 2 will appear. Tera Term can detect the active COM port (greyed out to right of Serial button if TCP/IP is selected). Select the Serial button and press OK. For PuTTY, you'll need to know which COM port is used, set its value, select the Serial button, and Open.

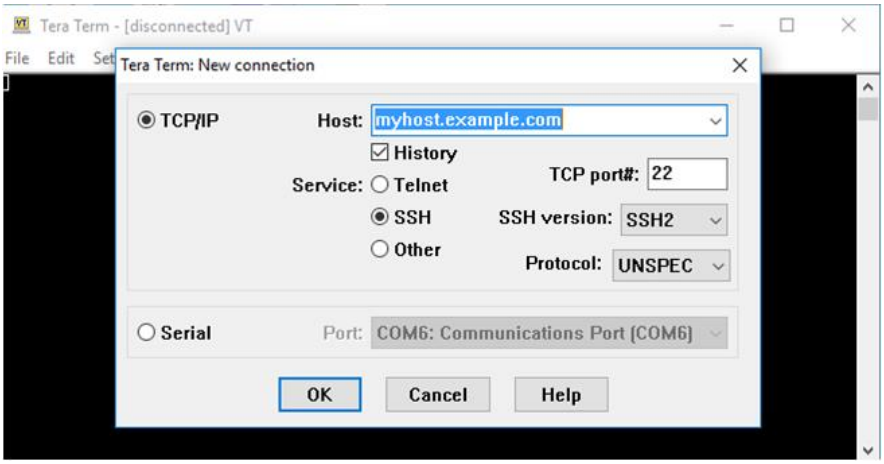

Figure 1. Tera Term Startup Menu

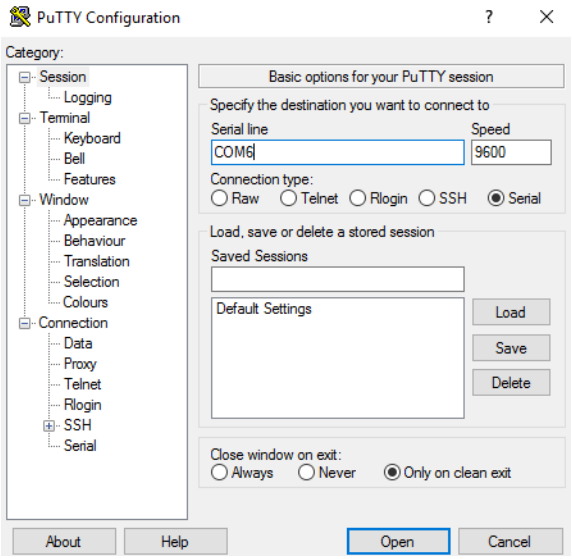

Figure 2. PuTTY Startup Menu

Once connected, the data reported by the sensor will start streaming to the terminal when an object either in motion appears (-A & -C Doppler radar sensors) or there are objects in the sensors field of view (-B and -C FMCW radar) to report the range. The default settings are shown in Table 2. If there is no object moving in front of the sensor or it's not pointing at any object, no data is reported or streamed to the terminal. A simple wave of the hand will show data like that shown in Figure 3. Any of the API commands can now be executed to change the output data or query the configuration.

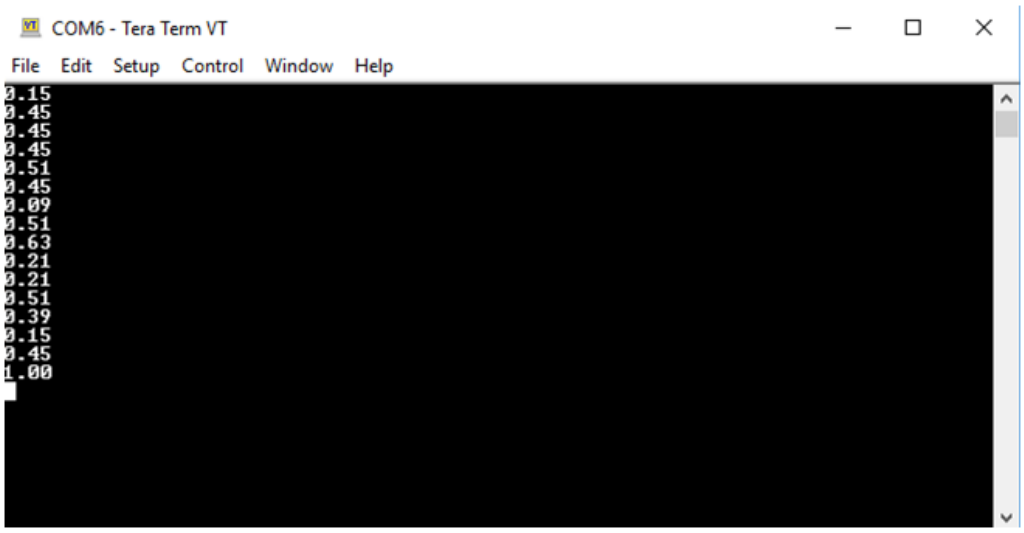

Figure 3. Streaming Data with Tera Term

Figure 4. Streaming Data with PuTTY

Default Settings

The default settings of the sensor are set to provide solid performance over a wide range of applications. Upon power-up the default settings are used, and operation begins. The user can configure the sensor for their application and save the settings as the new default settings (A! command). The default settings are listed in Table 2.

Table 2. Default Settings

API Command Description	API Command	Doppler (-A) Default Value	FMCW (-B) Default Value	Doppler & FMCW (-C) Default Value
Output Units	UM/uM	m/s	m	m/s, m
Data Precision	F2	2	1	1/1
Doppler Sampling Rate	SX	10,000	N/A	10,000
Doppler Sampling Buffer Size	S>	1024	N/A	512
Simple Motion Interrupt	IG	Off	Off	Off
Reported Speed Filter	R>n, R<n	Off	N/A	Off
Reported Direction Filter	R|	Off	N/A	Off
Peak Speed Averaging	K+	Off	N/A	Off
Reported Range Filter	r>n, r<n	N/A	Off	Off
Magnitude Filter	M>n, M<n (Doppler) or m>n, m<n (FMCW)	>10 (>20 for OPS243-A)	>150	>20
Human Readable Unix Time	OH	Off	Off	Off
JSON Output	OJ	Off	Off	Off
LED Control	OL	On	On	On
Magnitude Report	OM	Off	Off	Off
Number of Data Points per Report	On	1	1	1
Phase Data Output	OP, oP	N/A	N/A	Off
Raw Data Output	OR, oR	Off	Off	Off
Post FFT Data Output	OF, oF	Off	Off	Off
Speed or Range Report	OS/OD	On	On	On
Time Report	OT	Off	Off	Off
Output Units	OU	Off	Off	On
USB Overflow Watchdog	OZ	On	On	On
Sensor Power Mode	PA	Active	Active	Active
Power Level	PX	On	On	On
Speed/Range Resolution	X*n*	X1	x2	X1/x2
Cosine Error Correct	^*±n.n	0	0	0

Speed Operating Range (-A, -C)

The maximum speed reported is determined by the Sampling Frequency. For slow moving objects, a sample rate of 5,000 (SV command) is perfectly fine. The default setting of 10,000 (SX command) provides

a detectable speed of up to 31.1 m/s (69.5 mph) while 20,000 (S2 command) provides up to 62.2 m/s (139.1 mph). The resolution of the reported speed increases as the sample frequency goes down. The range of values is summarized in Table 3. The S=*nn*, with *nn* in ksps, can be used to set to any value with a maximum of 1,000ksps.

Table 3. Maximum Operating Speeds

Sample Frequency	API Command	Maximum Speed (m/s)	Maximum Speed (mph)	Resolution* (m/s)	Resolution* (mph)
1,000	SI	3.1	7.0	0.006	0.014
5,000	SV	15.5	34.8	0.030	0.068
10,000	SX	31.1	69.5	0.061	0.136
20,000	S2	62.2	139.1	0.121	0.272
50,000	SL	155.4	347.7	0.304	0.679
100,000	SC	310.8	695.4	0.608	1.358
1,000,000	S=1000⏎	3,106.7	6,949.5	6.070	13.578

* 1024 buffer size, 512 buffer size accuracy will be twice these values, 256 four times, 128 eight times. OPS243-C uses default 512 buffer size for Doppler operation.

API Command Conventions

The API commands follow some basic conventions. Commands related to speed generally start with a capital letter such as O? or UC. Commands which related to range start with a small letter for the equivalent command. For example, use o? or uC for range.

Any command which assigns a number (ex. R>10) requires a carriage return (⏎) to complete the command. All other commands (ex. ??) take effect upon completion of command entry or the 2nd character of the command.

API Commands

The following are the API commands supported by the OPS241, OPS242, and OPS243. These commands can be sent by typing into the command terminal or by code to change settings on the sensor or control its operation. The commands provided include simple queries to fetch information about the sensor and its settings or write commands which control or change the operation of the sensor.

Module Information – returns information about the module and its setting.

Command	Name	R/W	Value
??	Module Information	Read	{"Product":"OPS242"} {"Version":"1.3.9"} {"SamplingRate":10000, "resolution":0.0607} {“SampleSize”:1024} {"Clock":"54"} {"Q2COUNT":"1149 (~22980 counts/sec) @t=37"} {"PowerMode":"Continuous"} {"Squelch":"100"} {“RequiredMinSpeed”:”0.000”}
?R	Reset Reason	Read	Provides the reason why sensor reset. {"ResetReason": "Status from bitmask", "Power On" : true, "Supply Watchdog" : true, "Power Validation" : true }
?Z	Speed Resolution	Read	{"SpeedResolution":0.1214, "SpeedUnit":"mps"}
?z	Range Resolution	Read	{"RangeResolution":0.3407, "RangeUnit":"m"}

Sensor Number/Label Name – returns model number, serial number, build date, or assigned label name of the sensor. The user assigns the label of their own choice. It can be any character and up to 15 characters are permitted. Set the sensor label with the L=s command where s is the desired string. Upon entering a label, use the save to persistent memory command (A!) to save it permanently. The serial number and build date uniquely identifies each sensor and is available from all sensors shipped after May 2020.

Command	Name	R/W	Value
?P	Sensor Part Number	Read	{"Product":"OPS241 FMCW"}
?N	Serial Number	Read	{"SerialNumber":"278270101"}
?D	Build Date	Read	{"MfgDate":"1925"}
L?	Sensor Label	Read	{"Label":"my example board"}
L=*s*	Sensor Label	Write	Write label to the sensor. *s* can be up to 15 characters long and any character.

Firmware Version/Board ID – returns current firmware version of the module. Firmware version consists of a major revision, minor revision, and patch revision in the form of xx.yy.zz.

Command	Name	R/W	Value
?V	Firmware Version Number	Read	{"Version":"1.3.9"}
?B	Firmware Build Number	Read	{"Build":"20181005_1335"}

Speed Output Units (-A, -C Doppler) – read or set the units for the velocity output. Units supported include m/s (default), cm/s, ft/s, km/hr, and miles per hour.

Command	Name	R/W	Value
U?	Current Velocity Units	Read	{"Units":"m-per-sec"}
UC	Centimeters per second	Write	{"Units":"cm-per-sec"}
UF	Feet per second	Write	{"Units":"ft-per-sec"}
UK	Kilometers per hour	Write	{"Units":"km-per-hr"}
UM	Meters per second	Write	{"Units":"m-per-sec"}
US	Miles per hour	Write	{"Units":"mph"} Calculations are based on the international mile (1,609.344 m per mile).

Range Output Units (-B, -C FMCW) – read or set the units for the range output. Units supported include meter (default), centimeter, feet, inch, and yards.

Command	Name	R/W	Value
u?	Current Range Units	Read	{"Units":"Value", "RangeUnit":"m"}
uM	Meters	Write	{"Units":"Value", "RangeUnit":"m"}
uC	Centimeters	Write	{"Units":"Value", "RangeUnit":"cm"}
uF	Feet	Write	{"Units":"Value", "RangeUnit":"ft"}
uI	Inch	Write	{"Units":"Value", "RangeUnit":"in"}
uY	Yards	Write	{"Units":"Value", "RangeUnit":"yd"}

Data Precision – set the number of decimal digits for the data reported.

Command	Name	R/W	Value
Fn	Decimal Places	Write	Set n to the number of decimal places to be reported. For example, setting to F2 will report 2 decimal places (ex. 10.35). F0 will provide the integer value only. Valid values of n are 0-5.
F?	Decimal Place Setting	Read	Query the number of decimal places set.

Sampling Rate/Buffer Size/Zero Padding (-A, -C Doppler) – set these values to control the sample rate of the module. This setting influences the output data and the rate at which the data is reported. The buffer size influences the report rate and resolution. A buffer size of 512 will have a report rate between 5-30Hz. The resolution becomes worse by a factor of two with a 512-buffer size versus 1024 (Figure 5) and worse again at 256 buffer size.

Zero padding can be used to improve the speed or range resolution without causing additional processing time and faster report rates. This controls the number of zeros to pad to the buffer size for FFT processing. As an example, X2 will pad 512 zeros to the default range processing FFT size of 512 and reduces the range resolution by ½ (~0.15 m). The improvement on resolution does not affect the report rate. The total FFT processing size of 2048 limits some combinations of X*n* and buffer size. For example, 1024 buffer size can only be used with X1 (1024 FFT, no padding) or X2 (2048 FFT, 2x padding) commands.

Command	Name	R/W	Notes
SI	1K samples/second	Write	
SV	5K samples/second	Write	
SX or S1	10K samples/second	Write	
S2	20K samples/second	Write	
SL	50K samples/second	Write	
SC	100K samples/second	Write	
S=*n*⏎	Configurable Sample Rate	Write	Set n to the sample rate in ksamples/second. For example, issue S=30⏎ for 30ksps sample rate. Max sample rate is 1,000ksps (1MHz).
S>	1024 buffer size	Write	1024 samples are collected before processing
S<	512 buffer size	Write	512 samples are collected before processing
S[	256 buffer size	Write	256 samples are collected before processing
S(	128 buffer size	Write	128 samples are collected before processing
X*n*⏎	Speed/Range Resolution Control	Write	Adjusts the speed or range resolution from the default value. n is value 1, 2, 4, or 8. Limits apply to usage with different buffer sizes, see Table 4 below. Default setting is X1/x1 with exception of OPS243-C which has X2/x2 set.
X=*n*⏎	Speed/Range Resolution Control	Write	Use for setting resolution with 16x values.

Table 4. Speed/Range Resolution Control

	Buffer Size							
Buffer Size	128		256		512		1024	
API Setting	Speed*	Range	Speed*	Range	Speed*	Range	Speed*	Range
X1/x1	0.49 m/s	0.62 m	0.24 m/s	0.62 m	0.12 m/s	0.62 m	0.06 m/s	0.62 m
X2/x2	0.24 m/s	0.31 m	0.12 m/s	0.31 m	0.06 m/s	0.31 m	0.03 m/s	N/A
X4/x4	0.12 m/s	0.16 m	0.06 m/s	0.16 m	0.03 m/s	N/A	N/A	N/A
X8/x8	0.06 m/s	0.08 m	0.03 m/s	N/A	N/A	N/A	N/A	N/A
X=16/x=16	0.03 m/s	0.04 m	N/A	N/A	N/A	N/A	N/A	N/A

* Assumes 10k sample rate for Doppler, OPS243-C speed resolutions are 2x these values

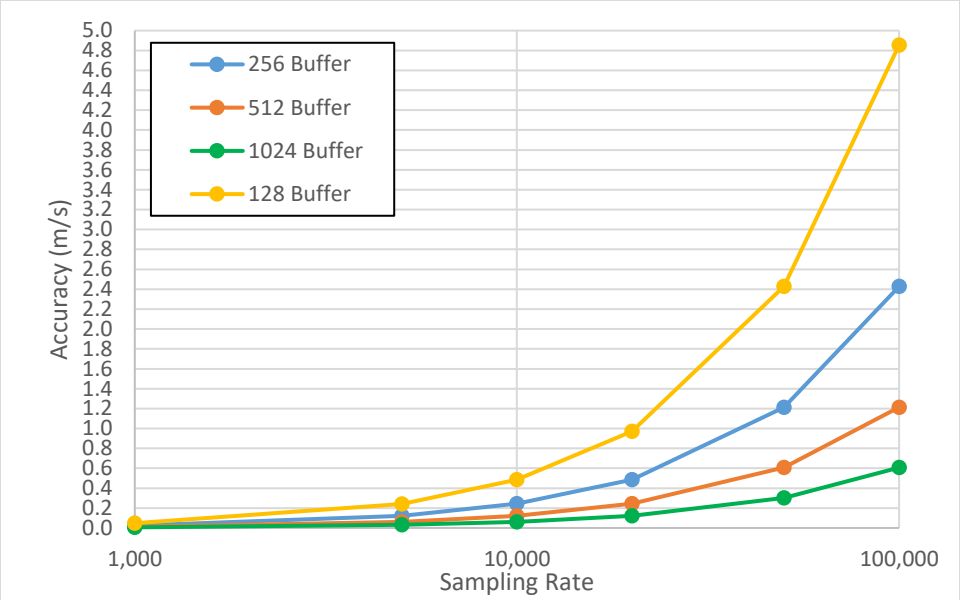

Figure 5. Doppler (-A) Buffer Size and Sampling Rate versus Resolution (no 0 padding)

Reported Speed/Range/Direction Filter – use these settings to set the range of data to report. Settings are available for either a minimum or maximum value below or above which data will not be reported. Commands are available to set speed, range, and direction of speed filters. These filters can be used to help set sensitivity levels of detection. This command requires a return (↵) after the number. Direction filter allows reporting only a single direction or both.

Speed averaging allows a means of filtering for the peak speed of an object. Some objects due to slight delays in signal path will have multiple speed reports. Enabling speed averaging (K+) filters out these additional reports and provides the primary speed of the object detected. The speed reported is the average of the three nearest detected speeds around the peak signal value.

Command	Name	R/W	Notes
R>n	Reported Minimum Speed Filter	Write	n is any number upon which no detected speeds below that number will be reported. R>0 resets to no limit. Doppler (-A, -C) radar only.
R<n	Reported Maximum Speed Filter	Write	n is any number upon which no detected speeds above that number will be reported. R<0 resets to no limit. Doppler (-A, -C) radar only.
r>n	Reported Range Filter	Write	n is any number upon which no detected range below that number will be reported. r>0 resets to no limit. FMCW (-B, -C) radar only.
r<n	Reported Range Filter	Write	n is any number upon which no detected range above that number will be reported. r<0 resets to no limit. FMCW (-B, -C) radar only.
R?	Report Current Speed Filter	Read	Reports current settings of the speed filter (-A, -C)
r?	Report Current Range Filter	Read	Reports current settings of the range filter (-B, -C)
R+	Inbound Only Direction	Write	Only reports inbound direction (-A, -C)
R-	Outbound Only Direction	Write	Only reports outbound direction (-A, -C)
R|	Clear Direction Control	Write	Reports both directions (-A, -C)
K+	Peak Speed Average Enable	Write	Enables speed averaging of peak detected values across the nearest two speeds detected. (-A, -C)
K-	Peak Speed Average Disable	Write	Speed averaging disabled (default)

Frequency Control (-A, -C Doppler) – use this setting to set the desired transmit frequency. Set *n* to a positive or negative number to set the frequency. T=0 is the default setting targeting 24.125GHz.

For the OPS241-A, OPS242-A, and OPS243-A, each increment steps approximately 18MHz. The programming steps are limited to 24.0 through 24.25GHz for the OPS242/OPS243 and up to 25.6GHz operation for the OPS241-A. The limits on *n* are -6 (24.0GHz) and 93 (25.6GHz) for the OPS241 and -2 (~24.0GHz) to 2 (~24.25GHz) for the OPS242-A/OPS243-A which has some guard banding to ensure it stays within the 24.0-24.25GHz ISM band.

The OPS243-C provides much finer frequency resolution control between 24.005 and 24.245GHz in 1MHz steps (0.004%). The default operation is at 24.005 (T=-120).

See Figure 6 for approximate values of n for each frequency. Depending on the spread between the current frequency and the newly set frequency, there may be a long settling time on the order of 5-10 seconds or longer based on the size of the jump in values. Writing ?F will provide the current transmitter output frequency.

Command	Name	R/W	Value
T=*n*	Frequency Setting	Write	T=0 is the default setting for 24.125GHz.
?F	Frequency Output	Read	Returns the output CW frequency of the transmitter in GHz for the OPS241-A, OPS242-A, and OPS243-A.
T?	Frequency Output	Read	Returns the output CW frequency of the transmitter in GHz for the OPS243-C.

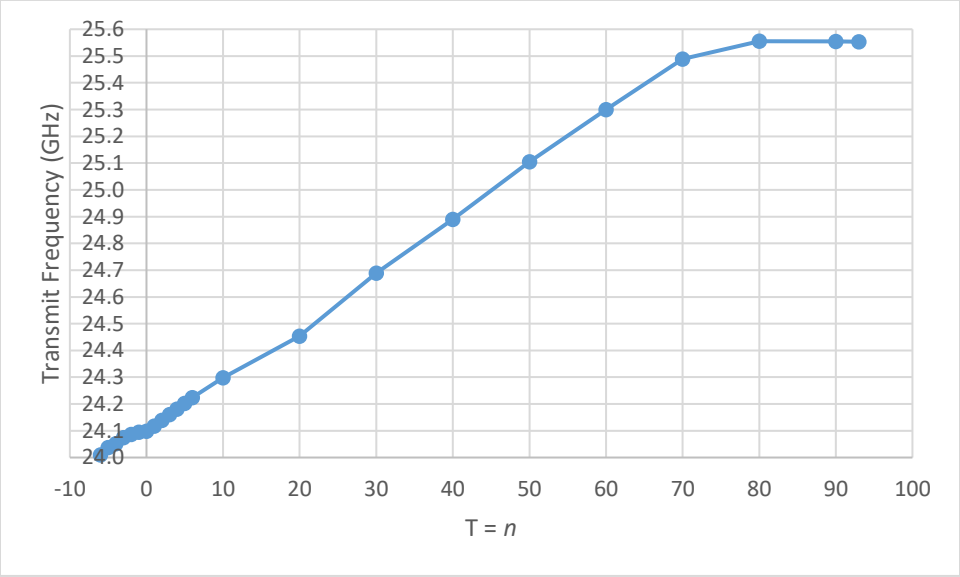

Figure 6. Frequency Setting T Values OPS241-A. OPS242-A and OPS243-A limited to 24.0-24.25

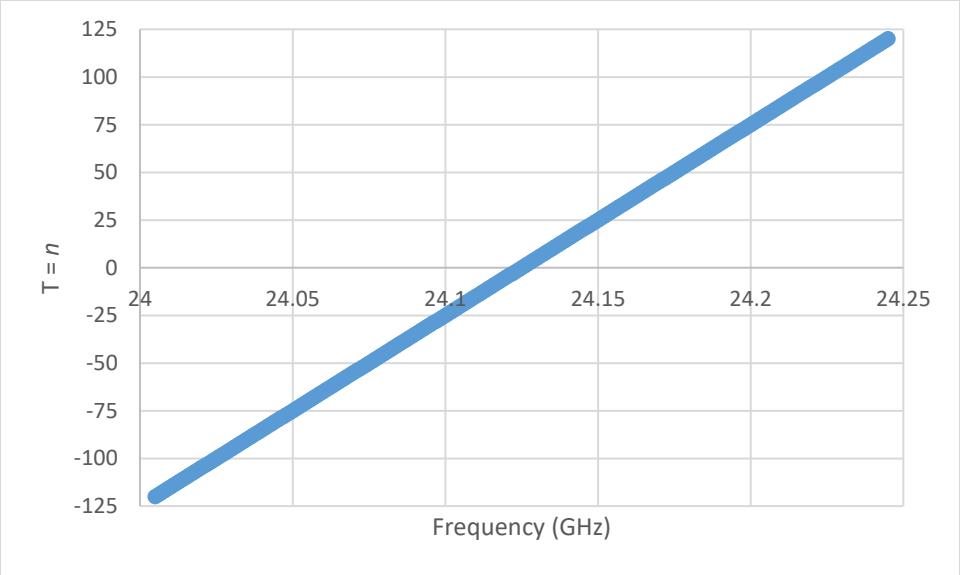

Figure 7. T Value versus Frequency Setting for OPS243-C

FMCW Chirp Control (-B, -C FMCW) – use these settings to adjust the FMCW chirp time and bandwidth on the OPS241-B and OPS243-C. Adjusting the buffer size, bandwidth, and FFT size changes the reported range resolution (see Table 5).

The OPS241-B and OPS243-C chirp time and bandwidth default settings are 1.6ms chirp time with a 990MHz ramp and a 512 buffer size sampled at 320kHz. The bandwidth can be set between 100-1,000MHz with the t=*n* command. The max frequency of the ramp cannot exceed 25GHz (starting frequency + ramp frequency). Use the t? command to see the current bandwidth and starting frequency. The t>n command is used to set the ramp start frequency (see Figure 8).

Changing the buffer size will automatically change the sampling rate to hold the chirp time constant at 1.6ms. However, if the buffer size is changed followed by the sample rate change (s=n command), the chirp time will adjust accordingly. For example, changing the buffer size from the default 512 to 256 (S[command) will automatically adjust the sample rate to 160kHz to keep a 1.6ms chirp time. Sending an s=256 (256kHz) will adjust the chirp time to 1.0ms (256 samples/256Ksps).

Command	Name	R/W	Value
t?	Chirp Bandwidth	Read	Returns the chirp bandwidth setting and the start and stop frequencies.
t=n	Chirp Bandwidth Setting	Write	Set the bandwidth for the OPS241-B between 100-1,000MHz. Default is 990MHz. *n* is value between 100 and 1,000 in MHz.
t>n	Chirp Ramp Start	Write	Sets the starting frequency for the chirp ramp in GHz between 24-24.9GHz. For example, t>24.01 will start the chirp ramp at 24.01GHz. The total chirp bandwidth ramp from the starting frequency must be less than or equal to 25GHz.
s?	Sample Rate	Read	Returns the current sample rate.
s=*n*	Sample Rate Setting	Write	Sets the sample rate. *n* is restricted for a chirp of between 1-3ms.

Table 5. Range Resolution for Different Chirp Settings (OPS241-B)

Bandwidth (MHz)	FFT Size	Buffer Size		
		128	256	512
150	X2	0.4997 m	0.4997 m	0.4997 m
	X4	0.2498 m	0.2498 m	N/A
	X8	0.1249 m	N/A	N/A
240	X2	0.3123 m	0.3123 m	0.3123 m
	X4	0.1561 m	0.1561 m	N/A
	X8	0.0781 m	N/A	N/A
990	X2	0.0757 m	0.0757 m	0.0757 m
	X4	0.0379 m	0.0379 m	N/A
	X8	0.0189 m	N/A	N/A

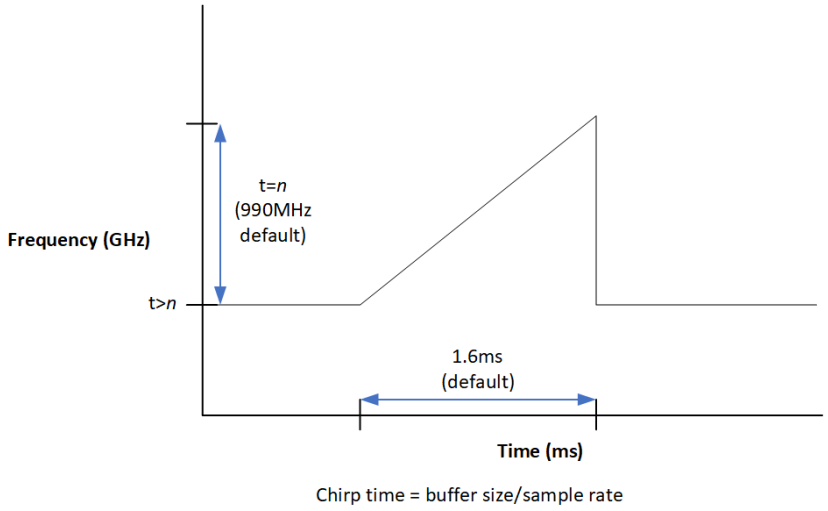

Figure 8. Chirp Time and Bandwidth for OPS241-B

Data Output – set to control the data output. In general, use capital O*x* for Doppler control and little o*x* for FMCW control.

Command	Name	R/W	Value
O?/o?	Output Settings	Write	Output current output settings for speed and range. Use O? for speed settings and o? for range settings.
OD	Range Report	Write	Turn range reporting on or off. Default operation range is reported. Use Od to turn it off and OD to turn it back on. FMCW (-B, -C) radar only.
OS	Speed Report	Write	Turn speed reporting on or off. Default operation speed is reported. Use Os to turn it off and OS to turn it back on. Doppler (-A, -C) radar only.
OB	Binary Output	Write	Outputs data in hex format to simplify communication. Data is output with the following format followed by the hex value of the speed or range: 0x01 = speed data 0x02 = range data 0x04 = magnitude of speed data 0x05 = magnitude of range data Speed data is signed integer and limited to ±128. Range data is unsigned and limited to 0-256. Magnitude information is not set on in default mode and should be set before turning on OB mode. Set Ob to turn off. OPS243 only.
OF	FFT Output On	Write	Results from the FFT processing of each buffer is sent. Data is output with json output format. For Doppler, use Of to turn FFT output off. For FMCW, use oF to turn on and of to turn off. For OPS243-C, either speed or range but not both can be output at the same time. It's not recommended to use OF with UART, especially at low baud rates.
OG	Object Sensor Light	Write	Enables White light when Object Sensor is enabled (IG) and an object is detected. Disable the light with Og. By default, the object sensor light is disabled.

The OB command provides a simpler communication in hex format. An example output is 023F0125. This translates to:

- 1st 0x02 = Range, value 0x3F = 63
- 2nd 0x01 = Speed, value 0x25 = 37

Make sure to set you units correctly so reported values stay within expected ranges.

Command	Name	R/W	Value
OC	Processing Light Activity	Write	Enables lights showing processing activity. Use OC for Doppler (-A, -C) and oC for FMCW (-B, -C) sensors. Disable the lights with Oc or oc. By default, the processing activity lights are disabled.
OH	Human Readable Date/Time	Write	Outputs the timestamp in a human readable manner based on the Unix Epoch time: Thu Jul 2 2020 14:56:39.368 GMT,"m",0.6. Set the time with the C=*n* command with accuracy of seconds (not milliseconds). Use Oh to turn off.
OJ	JSON Mode	Write	Turns on output to format data in JSON format. An example would output: {"speed":"0.06"}. Use Oj to turn off JSON mode.
OL	LED Control	Write	Turn the LEDs on (OL) or off (Ol). Turning off the LED's can save approximately 10mA of current consumption.
OM	Magnitude Report	Write	Turn on reporting of the magnitude associated with the speed. The magnitude is a measure of the size, distance, and reflectivity of the object detected. For Doppler, type Om to turn magnitude off. When turned on, magnitude information is reported before speed/range information. For FMCW, type oM to turn on and om to turn off.
ON	Detected Object	Write	Sensor determines if an object is present by looking for 2 consecutive speed reports. If met, the max speed detected is reported. If a faster speed is detected, additional speeds are reported. This lowers the number of speed reports for a given detected object. Use On to turn the mode off.
O*n* O=*n*	Number of Reports	Write	Define how many reports to provide. n is a number between 1 and 9 when using O*n*. To set up to 16 outputs, use O=*n*. The number *n* applies to magnitude and speed reports.
OP/oP	Phase Data	Write	Outputs phase information from the FFT processing for the OPS243-C. Use OP for speed and oP for range. Use Op or op to turn off.

Command	Name	R/W	Value
OR	Raw ADC Output On	Write	I and Q output buffers from the ADC will be sent. Data output will alternate between the I and then Q buffer. For Doppler, Or turns off raw ADC reporting. For FMCW, use oR to turn on and or to turn off. For OPS243-C, either speed or range but not both can be output at the same time. It is not recommended to use OR with UART, especially at low baud rates.
OT	Time Report	Write	Turn the time report on. Time is reported as the seconds and milliseconds since the last reboot or power on. For example, 137.429, 3.6 is read as 137 seconds and 429 milliseconds with a speed of 3.6 m/s. If magnitude is turned on, the data is provided as time, magnitude, speed. Use Ot to turn off.
OU	Units Report	Write	Report the current unit setting with each report. Default units is turned on. Use Ou to turn off for Doppler. Type oU to turn units report on and ou to turn it off for FMCW.
OV	Largest Report Order	Write	Changes the default order of the speed or range reported from largest signal magnitude first to largest speed/range value first. Use OV for speed and oV for range. Use Ov or ov to return to ordering by signal magnitude (Ov for OPS241-B).
O/	Smallest Report Order	Write	Changes the default order of the speed or range reported from based on largest signal magnitude first to smallest speed/range first. Use O/ for speed and o/ for range (O/ for OPS241-B).
OY	Range AND Speed Filter	Write	Set OY on to filter on the range AND speed report. Only speeds detected while an object is present between the range filter settings will be reported. Use Oy or oy to turn off.

Command	Name	R/W	Value
OZ	USB Buffer Watchdog Timer Control	Write	Use this command to have the watchdog timer ignore the USB buffer overflow flag. This may be useful for some Linux systems which are not consuming the data from the sensor. Use Oz command to return to default mode of looking at the flag.
BZ BL BS BC BT BV	Blank Data Reporting	Write	If measured data does not meet filtering criteria, sensor will report out a character with every sampling interval. BZ will report zero value. BL will report blank lines. BS will report a space. BC will report with a comma. BT will report a timestamp. Use BV to turn off. B? will report the current setting.

Cosine Error Correction – set the cosine error angle and the reported speed will be adjusted by the correct factor. The Cosine Error causes the sensor to report speed values less than actual based on the cosine of the angle the object makes with the sensor. See AN-11 Cosine Error Adjustment for more details.

The Cosine Error Correction can be applied separately to inbound and outbound traffic. In a typical traffic mounting applications, the inbound and outbound lanes are separated by a distance (ex. 3-5m/10-16 ft.) which means one lane will be closer to the sensor and have a shallower angle or smaller cosine error. Objects in the other lane will be seen at a higher angle and larger cosine error. Use the ^/+*n.n* command for objects inbound to the sensor and ^/-*n.n* for objects outbound with *n.n* being the angle made by the sensor to the object. The acceptable angle is from 0 to 89˚. Default configuration does not have any cosine error correction applied. As an example, a cosine error of 30˚ would increase all speed reports by a factor of 1.15 (1.15 = 1/cos(30˚)).

Command	Name	R/W	Value
^/+n.n	Inbound Cosine Error Correction	Write	Set to the angle the inbound object makes with the sensor.
^/-n.n	Outbound Cosine Error Correction	Write	Set to the angle the outbound object makes with the sensor.

UART Control – set to control the UART interface. The default configuration is 8-bits, no parity, 19,200 baud rate, and 1 stop bit. The OPS241, OPS242, and OPS243 will start reporting out on the UART immediately after power on. If the USB is enumerated, the UART reporting will be shut off and data will be reported out USB. It's not recommended to use OF with UART, especially at low baud rates.

Command	Name	R/W	Value
I?	Query Baud Rate	Read	Outputs current baud rate and oversampling setting.
In	Baud Rate	Write	Set n to values 1, 2, 3, 4, or 5 based on desired baud rate. I1 = 9,600 I2 = 19,200 (default) I3 = 57,600 I4 = 115,200 I5 = 230,400
IS	RS-232/UART Interface Selection	Write	OPS243-C rev D boards only. Starting with rev D boards, both UART and RS-232 are available on the same sensor. UART is the default communication over the J3 header. Use IS command to set the communication out the RS-232 pins on the J3 header. Use persistent memory command (A!) to save RS-232 as the default communication upon power-up. Use Is command to change back to UART interface. Note, starting with revision D2 of the OPS243, a mechanical jumper is used to select UART or RS-232 interface output. See the detailed datasheet for the configuration.

Simple Object Detection Interrupt – a simple output which trips if an object in motion or object in range is detected. The signal is toggled on the interrupt pin (pin 3, J8 on OPS242; pin 6, J5 OPS241; pin 3, J3 on OPS243). For the Doppler (-A, -C) radar sensors, the pin is high when no motion is present and low when motion is detected. For the FMCW (-B, -C) radar sensors, the pin is high when no object is in the detected region and set low when and object is detected in the detection region. For Doppler (-A, -C) radar sensors the interrupt can be filtered on speed (R>n, R<n), signal magnitude (M>n, M<n), and direction (R+, R-, R|). For FMCW (-B, -C) radar sensors, the interrupt can be filtered on range (r>n, r<n) and signal magnitude (m>n, m<n). Figure 9 shows how filtering can allow detection for certain objects and mask out others.

Command	Name	R/W	Value
IG	Object Detection Interrupt	Write	Turn object detection interrupt on. Use "Ig" to turn off.

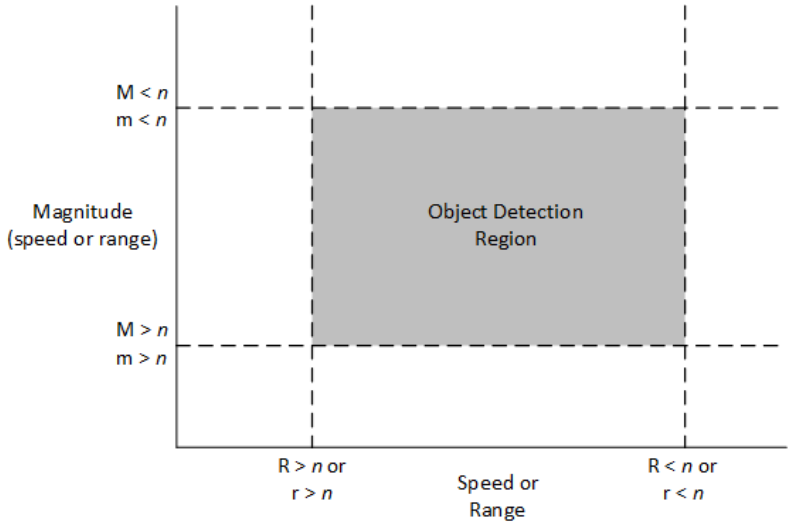

Figure 9. Speed, Range and Magnitude Filtering

Simple Counter – counts objects which meet the speed/range and signal magnitude filtering settings. The counter will count the number of objects over time which meet the filtering settings for speed/range and signal magnitude. The count is not reported but can be queried with the N? command. The count can be reset with the N! command. A count is triggered if 2 or more consecutive reports meet the threshold limits. Once detected, the object is set to be counted until 4 reports missing the threshold limits are seen. The value to start a count (default 2) can be set with the N>*n* command. The value to end a count (default 4) can be set with the N<*n* command. To start a new count, clear the running count with the N! command. The maximum number of objects that can be counted is 4,294,967,295.

Command	Name	R/W	Value
N?	Query Count	Read	Reports number of objects counted. {"DetectedObjectCount":3}
N!	Reset Count	Write	Resets the number of objects in counter. {"DetectedObjectCount":0}
N>*n*	Count Start Threshold	Write	{"MotionSignal":"Status", "CountToPass":2, "CountToFail":4}
N<*n*	Count End Threshold	Write	{"MotionSignal":"Status", "CountToPass":2, "CountToFail":3}
N#	Query Count without Reset	Write	{"DetectedObjectCount":4}
N@	Query Count Settings	Write	{"MotionSignalCountToPass":2, "MotionSignalCountToFail":4}

Clock – set to control the reporting of the time. The time is measured in seconds/milliseconds from power on of the module. Use the OT command to report the time in seconds and milliseconds. When the module is put in low power state (PI), the clock will continue counting. If you wish for the module to provide "the real time", then set it to "the Unix Epoch time" (see wikipedia.org/wiki/Unix_time). Note if using the Unix time, only use a value with accuracy to seconds, not with milliseconds. The largest input value for C is 4294967295. Use the OH command to report the time in a human readable format.

Command	Name	R/W	Value
C?	Query Time	Read	Ex. {"Clock":"50"} reports 50 seconds since power on.
C=n	Set Time	Write	Reset the clock start time. For example, n = 10 will start the clock at 10 seconds and then continue counting.
CZ=xxx+n	Set Local Time	Write	Set the local time relative to GMT time. Set Unix time first and then use the CZ setting for your local time zone. For example, San Jose, CA is Pacific Standard Time (PST). Command would be CZ=PST+5. The +5 is the offset from GMT. Then set human readable timestamp (OH command) and a timestamp would report: Wed Mar 15 2023 20:05:21.613 =PST,0.06

Module/Transmit Power – set to control the operating mode (PA, PI, PP) or the transmit power. The typical maximum transmit power is 9 dB. Reducing the transmit power does not reduce the overall power consumption of the module. Note that the detection range will decrease with decreased transmit power.

Command	Name	R/W	Value
P?	Active Power State	Read	Reports current power state.
PA	Active Power Mode	Write	Normal operating mode.
PI	Idle Power Mode	Write	No activity, waits for Active Power command. The RF is powered down for further power savings.
PP	Single Pulse	Write	Use to capture and process a single report. Set to PI mode first to use.
P7 or PN	Min Power	Write	Transmit is set at -9 dB below max power.
P6	Transmit Power Control	Write	Transmit is set at -6 dB below max power.
P5	Transmit Power Control	Write	Transmit is set at -4 dB below max power.
P4	Transmit Power Control	Write	Transmit is set at -2.5 dB below max power.
P3 or PD	Mid Power	Write	Transmit is set at -1.4 dB below max power.
P2	Transmit Power Control	Write	Transmit is set at -0.8 dB below max power.
P1	Transmit Power Control	Write	Transmit is set at -0.4 dB below max power.
P0 or PX	Max Power	Write	Transmit power is set at its maximum value with maximum range. PX has additional "overdrive" of 0.2 dB when utilized.
PW	WiFi Power Control	Write	Pw turns WiFi power off and WiFi no longer active or connected. Set PW to turn on.
P!	System Reset	Write	Full system reset including the clock.

Short Duty Cycle Control – set to control duty cycle operation under 1 second. The time set is the amount of time the sensor will delay between outputting the last report and starting the next report.

Command	Name	R/W	Value
W?	Current Delay time	Read	
W0	0 delay between reports	Write	
WI	1ms delay	Write	
WV	5ms delay	Write	
WX	10ms delay	Write	
WL	50ms delay	Write	
WC	100ms delay	Write	
WD	500ms delay	Write	
WM	1000ms delay	Write	
Wn	n*100ms delay	Write	$0 \leq n \leq 9$
W=n	n*1ms delay	Write	$0 \leq n \leq 172{,}800{,}000$

Long Duty Cycle Control – set to control the duty cycle operation greater than or equal to 1 second. The time set is the amount of time the module will sleep between transmit/receive pulses and processing. For settings longer than 1 second, the RF will be powered off to save power. In this manner, lower power operation may be achieved. The below Z commands are not applicable to the OPS243. Use Hibernate mode instead.

Command	Name	R/W	Value
Z?	Current sleep setting	Read	
Z0	Sleep 0 Second	Write	Use to set back to normal operation.
ZI	Sleep 1 Second	Write	
ZV	Sleep 5 seconds	Write	
ZX	Sleep 10 seconds	Write	
ZL	Sleep 50 seconds	Write	
ZC	Sleep 100 seconds	Write	
Z2	Sleep 200 seconds	Write	
Zn	Sleep n*100 seconds	Write	$0 \leq n \leq 9$
Z=n	Set Sleep Time	Write	Set the amount of time to sleep between data processing. Ex., n = 5 would set the module to sleep for 5 seconds (RF powered off) between a transmit/receive pulse and processing. $0 \leq n \leq 4{,}294{,}967$

Magnitude Control – provides control over the sensitivity of the module to detect moving objects. Low numbers are most sensitive, high numbers are least sensitive.

Command	Name	R/W	Value
M?	Current speed magnitude setting	Read	Doppler (-A, -C) radar only.
m?	Current range magnitude setting	Read	FMCW (-B, -C) radar only.
M>n	Low Speed Magnitude Filter	Write	n is any number upon which no detected magnitudes below that number will be reported. M>0 resets to no limit. Doppler (-A, -C) radar only.
M<n	High Speed Magnitude Filter	Write	n is any number upon which no detected magnitudes above that number will be reported. M<0 resets to no limit. Doppler (-A, -C) radar only.
m>n	Low Range Magnitude Filter	Write	n is any number upon which no detected magnitudes below that number will be reported. m>0 resets to no limit. FMCW (-B, -C) radar only.
m<n	High Range Magnitude Filter	Write	n is any number upon which no detected magnitudes above that number will be reported. m<0 resets to no limit. FMCW (-B, -C) radar only.

Cosine Error Correction – provides ability to automatically correct for cosine error if the angle is known. The reported speed will be adjusted by the cosine of the angle provided. As an example, a cosine angle setting of 30˚ will increase the reported speed by 1.15 ($velocity_{reported} = velocity_{measured}/\cos(30^{\circ})$).

Command	Name	R/W	Value
^/+n.n	Inbound Cosine Error Correction	Write	Set n.n to the angle the sensor makes with inbound objects.
^/-n.n	Outbound Cosine Error Correction	Write	Set n.n to the angle the sensor makes with inbound objects.

Speed/Range Alerts – provides a method to send alert messages if speeds or ranges are above or below a threshold level for OPS243. The alert is output on GPIO pins and as an output message. The OPS243 datasheet for description of the GPIO pin usage.

Command	Name	R/W	Value
Y? or y?	Alert and Averaging Setting	Read	Reports current alert settings for speed alerts (Y?) on OPS243-A. For OPS243-C, y? reports range, speed alert and and averaging settings.
Y<n.n	High Speed Alert Setting	Write	Set this value for high-speed alerts. Any speeds detected above this value will trigger an alert on P4.1_GPIO (pin 2, J3 header) and output an alert message.
Y>n.n	Low Speed Alert Setting	Write	Set this value for low-speed alerts. Any speeds detected below this value will trigger an alert signal on P4.0_GPIO (pin 1, J3 header) and output an alert message. If no value is set, P4.0_GPIO reflects the active data sampling time (active low).
Y<n.n	High Range Alert Setting	Write	Set this value for high-range alerts. Any range detected above this value will trigger an alert on P4.1_GPIO (pin 2, J3 header) and output an alert message.
y>n.n	Low Range Alert Setting	Write	Set this value for low-range alerts. Any range detected below this value will trigger an alert on P4.0_GPIO (pin 1, J3 header) and output an alert message.

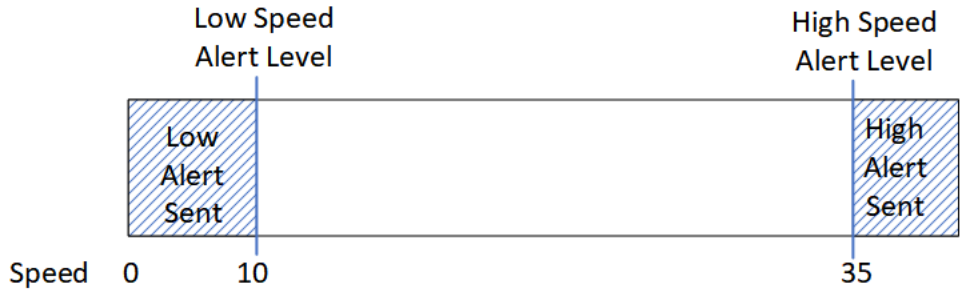

Figure 10. Speed Alert Settings with Example Speeds

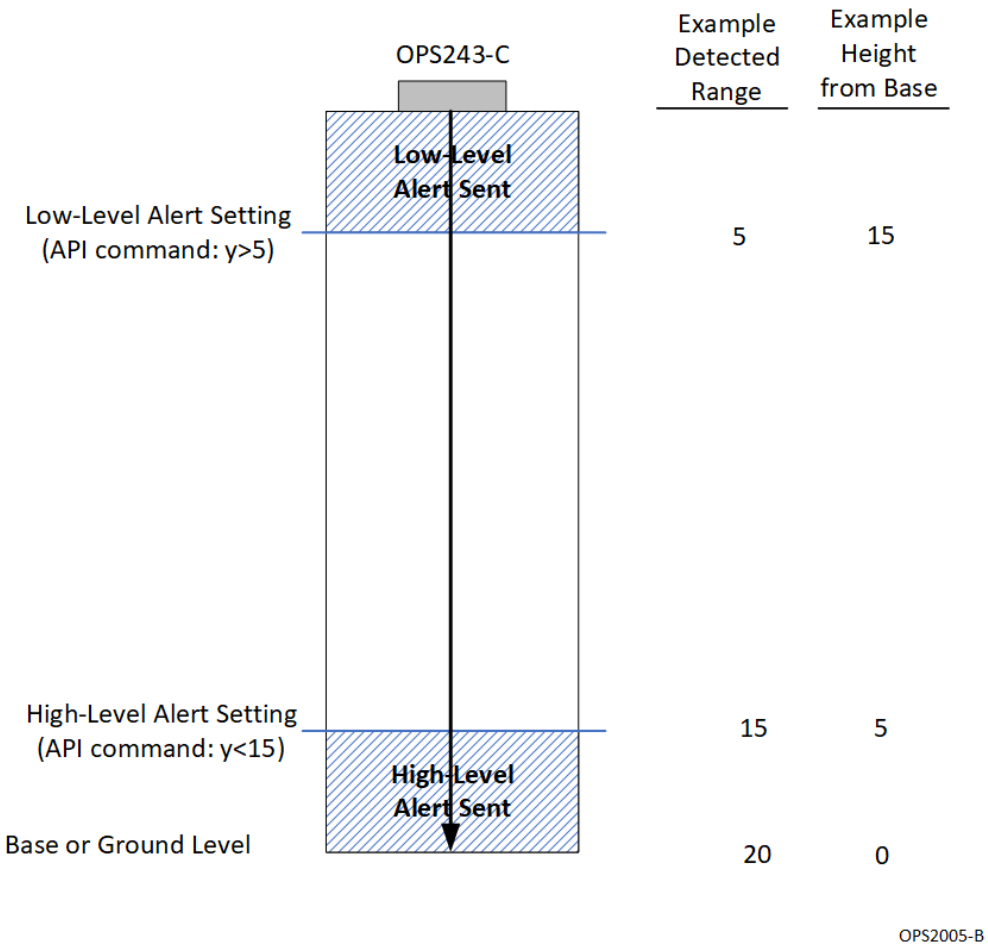

Figure 11. Range Alert Settings with Examples

Speed/Range Averaging (OPS243) – provides a means of averaging over set time periods to ensure properly reported data. Example usages are for water height monitoring. Data is averaged over a set time period and delays between reports can be set.

Command	Name	R/W	Value
y+	Enable Range Averaging	Write	Set to turn on range averaging. Issue y- to disable.
yp*n*	Range Averaging Time Period	Write	Set this value, *n*, for the length in seconds that the sensor should average over. Default value is 5.
yd*n*	Time Period between Range Averaging	Write	Set this value, *n*, for the length in seconds that the sensor will wait before starting a new averaging. Default is 300 seconds (5 minutes).
Y+	Enable Speed Averaging	Write	Set to turn on speed averaging or moving average. Issue Y- to disable.
Yp*n*	Speed Averaging Time Period	Write	Set this value, *n*, for the length in seconds that the sensor should average over. Default value is 5. Set this value to 0 to enable moving average.
Yd*n*	Time Period between Speed Averaging	Write	Set this value, *n*, for the length in seconds that the sensor will wait before starting a new averaging. Default is 300 seconds (5 minutes).
Ym*n*	Moving Average Number of Points	Write	Sets the number of speed reports to use in the moving average (ex. 5, max 20).

Persistent Memory – saves current configuration into flash memory and is retained even if power is removed. To ensure proper saving of the data into flash it's recommended to wait 1 second before issuing any additional commands to the sensor after issuing the A! and AX commands.

Command	Name	R/W	Value
A!	Save Configuration	Write	Saves current configuration settings in flash memory. Upon power loss or recycling power, the saved configurations will be used as the default.
A?	Persistent Memory Settings	Write	Reports the current settings for persistent memory.
A.	Read Settings	Write	Read the current flash settings.
AX	Reset Flash Settings	Write	Will overwrite current saved settings and return to the factory default settings.

Hibernate Mode (OPS243 only) – enables very low power (~100-250mW) duty cycle mode for battery-based applications. In Hibernate mode, the sensor shuts down internal power to the processor and RF for a time period set by the Z=*n* command. After time *n*, the sensor powers up, pulses a signal, processes the data and makes that data available. If filter values are set on speed (R>, R<), signal magnitude (M>, M<), or direction (R+, R-), the sensor will check to see if the processed data meets any of the threshold values and if so, will stay in active mode. It will continue in this manner until data does not meet the threshold settings at which time the sensor will stay active for Z>*n* seconds before entering back into Hibernate mode. Figure 12 shows graphically this process.

Command	Name	R/W	Value
Z+	Hibernate On	Write	Turns Hibernate mode on.
Z-	Hibernate Off	Write	Turns Hibernate mode off. Note the command
Z?	Hibernate Status	Write	Reports status of Hibernate mode
Z=*n*	Hibernate Time	Write	Set value of *n* to the time in seconds for the sensor to hibernate between pulses. Ex., Z=1 will hibernate for 1 second. The values for *n* should be whole numbers. Default value is 1 second.
Z>*n*	Hibernate Delay	Write	Set value of *n* to the time in seconds to delay going into hibernate mode after active pulsing. The default time is 0.5 second. The value of *n* is a floating point. For example, use Z>1.5 to set the delay to 1.5 seconds. Longer delay times will increase the active time and reduce power savings. The response message reports in ms (ex. 3 seconds reports as {"HibernateDelayMsec":3000})

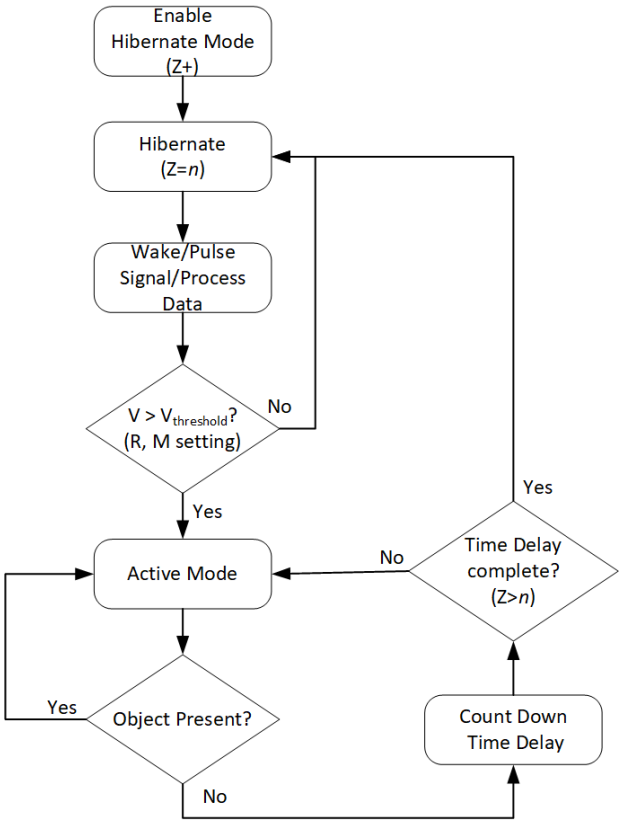

Figure 12. Hibernate Mode Operation

Appendix

Table 6. OPS241-A/OPS242-A Doppler Radar Feature versus Code Version Matrix

Feature	V1.3.1	V1.3.2	V1.3.3	V1.3.4-V1.3.9	V1.4.0	Notes
Module Information	•	•	•	•	•	
Module Part Number	•	•	•	•	•	
Firmware Version	•	•	•	•	•	
Firmware Build	•	•	•	•	•	
Speed Output Units	•	•	•	•	•	
Data Precision	•	•	•	•	•	
Sampling Rate	•	•	•	•	•	
Buffer Size	•	•	•	•	•	
Reported Speed Filter	•	•	•	•	•	
Reported Direction Filter	•	•	•	•	•	
Frequency Control	•	•	•	•	•	OPS242 limited to 24-24.25GHz
Frequency Reporting	•	•	•	•	•	
256 Buffer Size	•	•	•	•	•	
LED Control	•	•	•	•	•	
Number Reports	•	•	•	•	•	
Magnitude Report	•	•	•	•	•	
Speed Report	•	•	•	•	•	
Time Report	•	•	•	•	•	
Zero Reporting	•	•	•	•	•	
Timing Report	•	•	•	•	•	
Module Power	•	•	•	•	•	
Transmit Power	•	•	•	•	•	
Duty Cycle Control	•	•	•	•	•	
Debug Modes	•	•	•	•	•	
UART Interface	•	•	•	•	•	
Maximum Speed	•	•	•	•	•	
Motion Interrupt	•	•	•	•	•	
Min/Max Magnitude Filter	•	•	•	•	•	
Watchdog Timer	•	•	•	•	•	
Persistent Memory		•	•	•	•	
System Reset		•	•	•	•	
Simple Counter				•	•	
Serial Number, Mnfr Date, and Custom Label					•	
Buster OS USB driver fix					•	Raspberry Pi 4
Peak Speed Average					•	
Zero Padding FFT control					•	

Table 7. OPS241-B FMCW Radar Feature versus Code Version Matrix

Feature	V1.0.0	V1.0.5	V1.0.6	Notes
Module Information	•	•	•	
Module Part Number	•	•	•	
Firmware Version	•	•	•	
Firmware Build	•	•	•	
Range Output Units	•	•	•	
Data Precision	•	•	•	
Range & Magnitude Filter	•	•	•	
Automatic Calibration		•	•	
Chirp Time Control			•	Use sample rate and buffer size changes
Bandwidth Control			•	
Serial Number, Mnfr Date, and Custom Label			•	

Table 8. OPS243-A Doppler Radar Feature versus Code Version Matrix

Feature	V1.1.5	V1.1.6	V1.1.7	V1.1.8	V1.1.9	V1.2.0	Notes
Persistent Memory	●	●	●	●	●	●	
System Reset	●	●	●	●	●	●	
Simple Counter	●	●	●	●	●	●	
Hibernate Mode	●	●	●	●	●	●	
Serial Number, Mnfr Date, and Custom Label	●	●	●	●	●	●	
Build Date	●	●	●	●	●	●	
Sensor Label	●	●	●	●	●	●	
Raspberry Pi Buster USB driver fix	●	●	●	●	●	●	
Peak Speed Average	●	●	●	●	●	●	
Speed Resolution Control	●	●	●	●	●	●	
Human Readable Unix Timestamp	●	●	●	●	●	●	
Persistent Memory Report	●	●	●	●	●	●	
Radar Sign Mode	●	●	●	●	●	●	
Enhanced RS-232 Robustness	●	●	●	●	●	●	
2048 FFT Size	●	●	●	●	●	●	
USB Buffer Overflow Ignore (OZ)	●	●	●	●	●	●	Made default on v1.1.5
Binary Output	●	●	●	●	●	●	
GPIO Output for ADC Sampling	●	●	●	●	●	●	
UART Robustness	●	●	●	●	●	●	
Rev D2 Board Support		●	●	●	●	●	Larger processor
Cosine Error Adjust		●	●	●	●	●	Inbound and outbound
USB Modulo 64 Fix		●	●	●	●	●	
Fix USB JSON Extraneous Null			●	●	●	●	
CZ Local Time Zone Setting				●	●	●	
PP Requires PI First				●	●	●	
Wn Time Limit Implemented				●	●	●	
Speed Alert Setting					●	●	
Speed Averaging						●	
Speed Moving Average						●	
Increased Sample Rate						●	
WiFi Power Control						●	

Table 9. OPS243-C FMCW & Doppler Radar Feature versus Code Version Matrix

Feature	V1.1.9	V1.2.0	V1.2.1	V1.2.2	V1.2.3	V1.2.4	Notes
Hibernate Mode	•	•	•	•	•	•	
Serial Number, Mnfr Date, and Custom Label	•	•	•	•	•	•	
Raspberry Pi Buster USB driver fix	•	•	•	•	•	•	
Peak Speed Average	•	•	•	•	•	•	
Human Readable Unix Timestamp	•	•	•	•	•	•	
Persistent Memory Report	•	•	•	•	•	•	
Range Resolution Control	•	•	•	•	•	•	
Phase Data Output	•	•	•	•	•	•	
Radar Sign mode	•	•	•	•	•	•	
Enhanced RS-232 Robustness	•	•	•	•	•	•	
2048 FFT Size	•	•	•	•	•	•	
16 Max Output Reports	•	•	•	•	•	•	
Binary Output	•	•	•	•	•	•	
RS-232/UART Output Select	•	•	•	•	•	•	Functional on rev. D boards only
Range AND Speed Filter	•	•	•	•	•	•	
UART Robustness	•	•	•	•	•	•	
Rev D2 Board Support	•	•	•	•	•	•	
USB Buffer Overflow Ignore (OZ)	•	•	•	•	•	•	
USB Modulo 64 Fix	•	•	•	•	•	•	
Cosine Error Adjust		•	•	•	•	•	Inbound and outbound
Fix USB JSON Extraneous Null			•	•	•	•	
CZ Local Time Zone Setting				•	•	•	
PP Requires PI First				•	•	•	
Wn Time Limit Implemented				•	•	•	
Speed Alert Setting					•	•	
Range Alert Setting					•	•	
Speed Averaging					•	•	
Range Averaging					•	•	
Speed Moving Average						•	
Increased Sample Rate						•	
WiFi Power Control						•	

Table 10. Persistent Memory Command Support

Command	Code
Buffer Size	S), S[, S<, S>
Baud Rate	I*n*
Cosine Error Correction	^/+n.n, ^/-n.n
Sample Rate	SI, SV, SX, S1, S2, SL, SC,
Blank Data Reporting	BZ, BL, BS, BC, BT, BV
Transmit Power Level	P7, PN, P6, P5, P4, P3, PD, P2, P1, P0, PX
Decimal Places	F*n*
Output Units	UC, UF, UK, UM, US, uM, uC, uF, uI, uY
Min/Max Speed	R>*n*, R<*n*
Peak Detect	K+, K-
Direction	R+, R-
Min/Max Magnitude	M>*n*, M<*n*, m>*n*, m<*n*
Object Detection Interrupt	IG
Count Start/End Threshold	N>*n*, N<*n*
USB Overflow Watchdog Ignore	OZ, Oz
Range AND Speed	OY, Oy
RS-232 or UART Output	IS, Is
Short Duty Cycle Control	W0, WI, WV, WX, WL, WC, WD, WM
Hibernate	Z+, Z-, Z=*n*, Z>*n*
Sensor Label	User defined label (L=*s*)

The above commands are available for saving in persistent memory with the A! command. See the full listing of the settings with the A? command.

Revision History

Version	Date	Description
A	Apr. 19, 2017	Initial release.
Y	June 6, 2023	Added changes incorporated in V1.1.5 (OPS243-A) • UART robustness enhancement • Set USB Tx ignore watchdog (OZ) as default on Added changes incorporated in V1.1.6 (OPS243-A) • Support for rev D2 board using larger memory processor • Cosine error adjustment for inbound/outbound directions • Fixed issue with USB output when text string is modulo 64 Added changes incorporated in V1.1.8 (OPS243-A) • CZ command to set local time zone • Clarified PP requires PI be set first • Changed limit of W=n to 172,800,000 ms Added changes incorporated in V1.1.9 (OPS243-A) • Added high/low speed Alert message support Added changes incorporated in V1.1.9 (OPS243-C) • UART robustness enhancement • Set USB Tx ignore watchdog (OZ) as default on • Fixed issue with USB output when text string is modulo 64 Added changes incorporated in V1.2.0 (OPS243-C) • Cosine error adjustment for inbound/outbound directions Added changes incorporated in V1.2.1 (OPS243-C) • Fixed USB JSON extraneous Null character issue Added changes incorporated in V1.2.2 (OPS243-C) • CZ command to set local time zone • Clarified PP requires PI be set first • Changed limit of W=n to 172,800,000 ms Added changes incorporated in V1.2.3 (OPS243-C) • Added high/low speed Alert message support • Added high/low range Alert message support • Added speed averaging • Added range averaging
Z	November 28, 2023	Added changes incorporated in V1.2.0 (OPS243-A) • Added speed averaging (Y+) • Added moving average (Ym*n*) • Added power control on WiFi module (PW/Pw command) • Increased max sampling rate to 1,000ksps (ex. S=1000⏎) Added changes incorporated in V1.2.4 (OPS243-C) • Added moving average (Ym*n*) • Added power control on WiFi module (PW/Pw command) • Increased max sampling rate to 1,000ksps (ex. S=1000⏎)