

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.

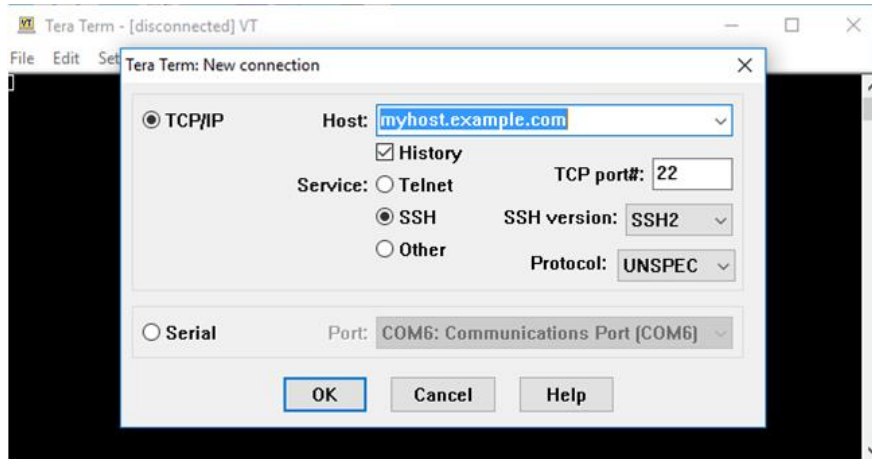


Figure 1. Tera Term Startup Menu

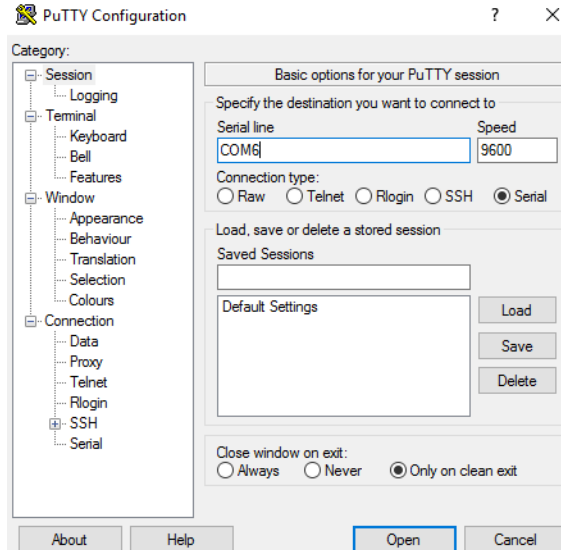


Figure 2. PuTTY Startup Menu

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.

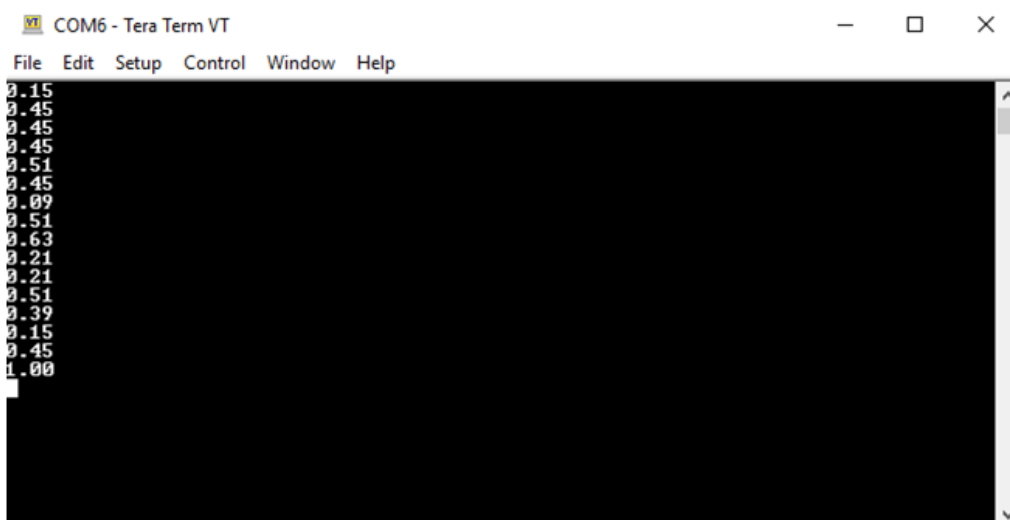


Figure 3. Streaming Data with Tera Term



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 |
| Sensor Power Mode | PA | Active | Active | Active |
| Power Level | PX | On | On | On |
| Speed/Range Resolution | Xn | X1 | x2 | X1/x2 |

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.

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 |

* 1024 buffer size, 512 buffer size accuracy will be twice these values, 256 four times, 128 eight times. OPS243-C uses 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 } |

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 therefore supporting fast 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 Xn 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> | 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 |
| Xn | 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 set. |

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 |

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

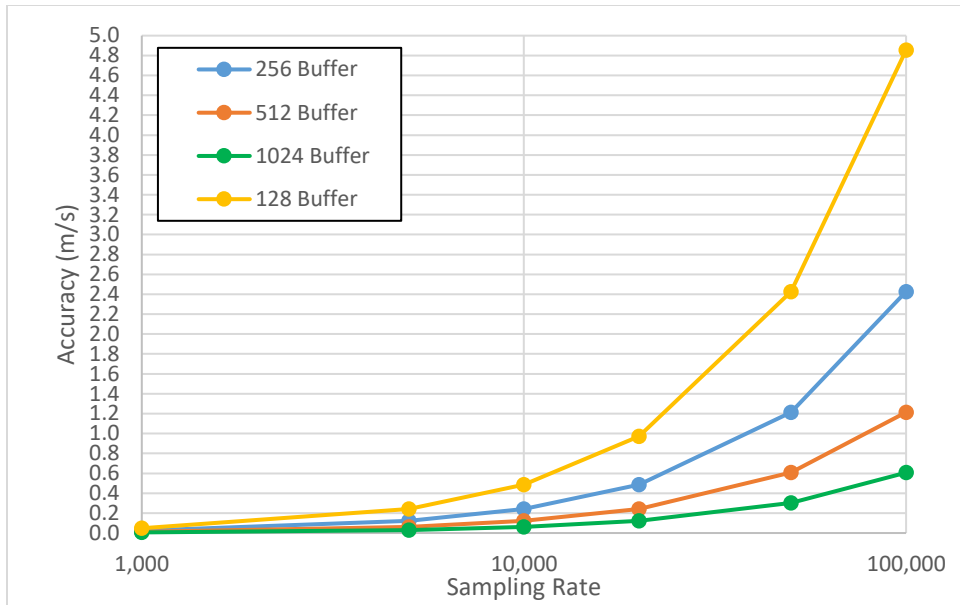


Figure 5. Doppler (-A) Buffer Size and Sampling Rate versus Resolution (no 0 padding)

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. |

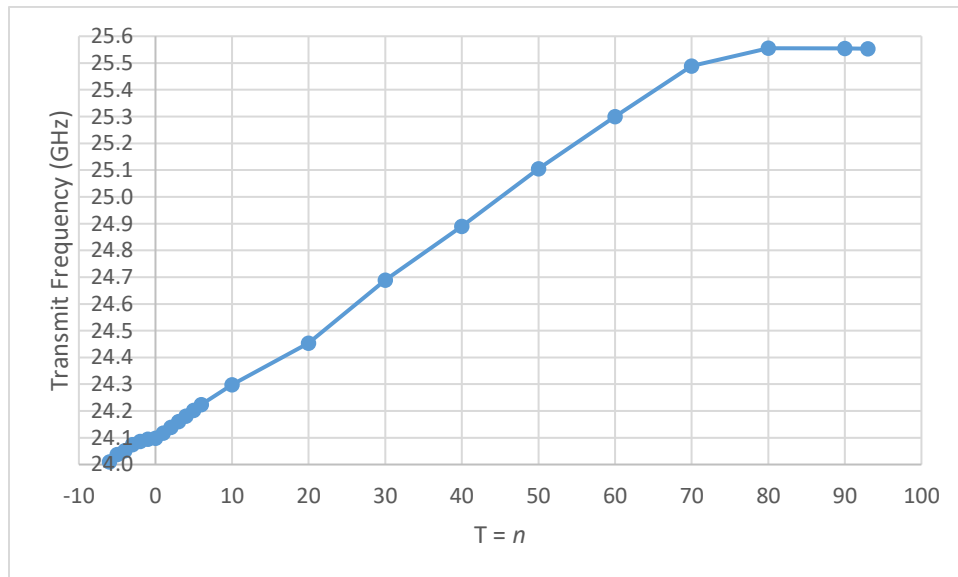


Figure 6. Frequency Setting T Values OPS241-A, OPS242-A and OPS243-A limited to 24.0-24.25

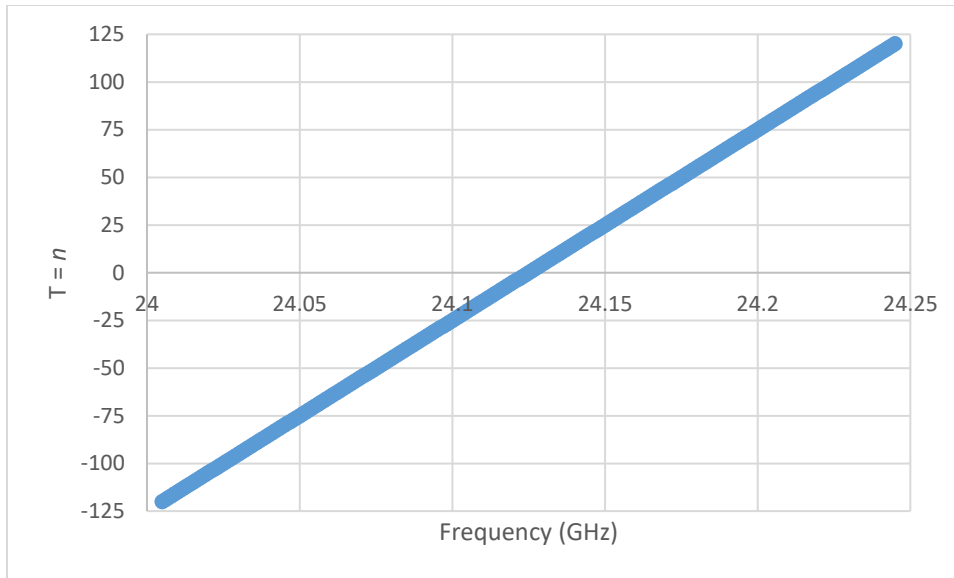


Figure 7. T Value versus Frequency Setting for OPS243-C

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

The OPS241-B 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. <i>n</i> 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. <i>n</i> 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 |

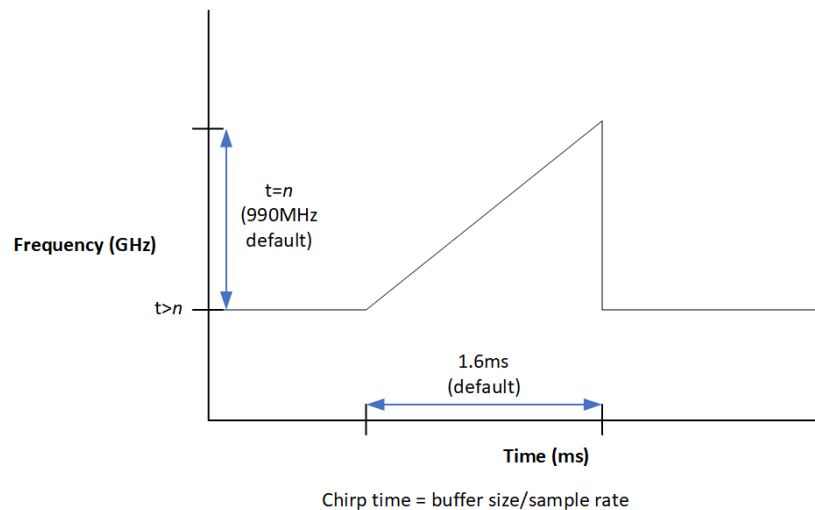


Figure 8. Chirp Time and Bandwidth for OPS241-B

Data Output – set to control the data output. In general, use capital Ox for Doppler control and little ox 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= <i>n</i> 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 (OI). 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 | Radar Sign Mode | Write | Sensor looks at a stream of data to confirm an object is present and then reports the max speed of the object from all the speed reports. If a higher speed is seen it will be reported. This simplifies the data output to a single speed report for a detected object instead of the typical 5-20 reports. Use On to turn the mode off. |
| On O= <i>n</i> | Number of Reports | Write | Define how many reports to provide. <i>n</i> is a number between 1 and 9 when using On. To set up to 16 outputs, use O= <i>n</i> . The number <i>n</i> 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). |
| 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. |

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 JS 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. |

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. |

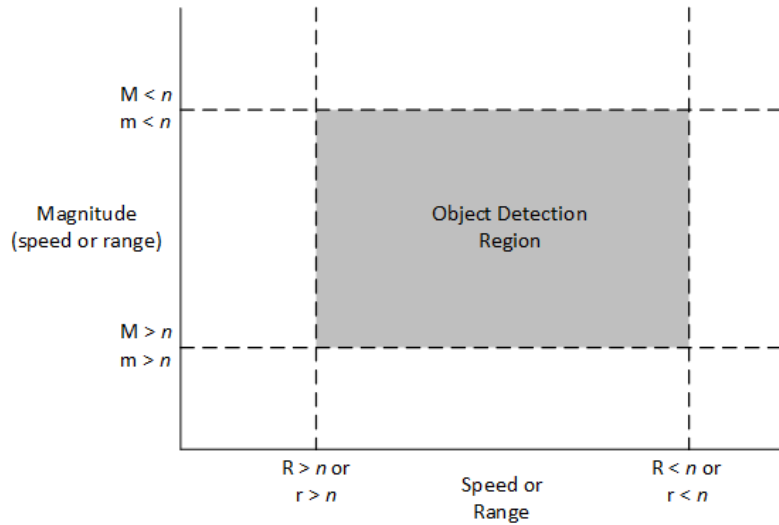


Figure 9. Speed, Range and Magnitude Filtering

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.

| 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. |

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 pulse and buffer of data. Use when the sensor is set to PI mode. |
| P7 or PN | Transmit Power Control or 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 | Transmit Power Control or 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 | Transmit Power Control or Max Power | Write | Transmit power is set at its maximum value with maximum range. PX has additional “overdrive” of 0.2 dB when utilized. |
| PO | Transmit Off | Write | Turn transmit off and put in sensor in receive only mode. Use P! to turn transmit back 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 | |
| W1 | 1ms delay | Write | |
| WV | 5ms delay | Write | |
| WX | 10ms delay | Write | |
| W2 | 20ms delay | Write | |
| WL | 50ms delay | Write | |
| WC | 100ms delay | Write | |
| WD | 500ms delay | Write | |
| WM | 1000ms delay | Write | |
| Wn | n*100ms delay | Write | $0 \leq n \leq 9$ |

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. |
| Z1 | 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. |

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 10 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= <i>n</i> | Hibernate Time | Write | Set value of <i>n</i> to the time in seconds for the sensor to hibernate between pulses. Ex., Z=1 will hibernate for 1 second. The values for <i>n</i> should be whole numbers. Default value is 1 second. |
| Z> <i>n</i> | Hibernate Delay | Write | Set value of <i>n</i> to the time in seconds to delay going into hibernate mode after active pulsing. The default time is 0.5 second. The value of <i>n</i> 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}) |

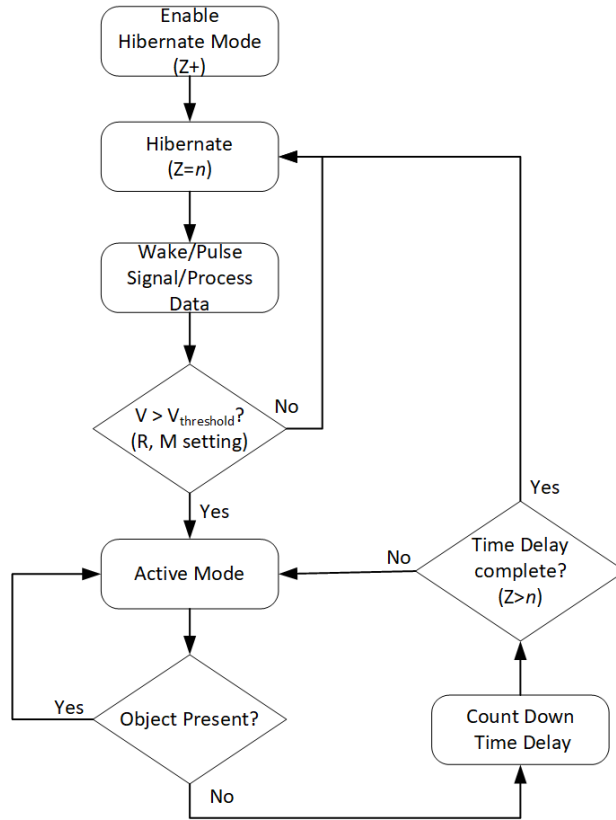


Figure 10. Hibernate Mode Operation

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 | V1.0.5 | V1.0.6 | V1.0.7 | V1.0.8 | V1.1.0 | Notes |
|--------------------------------------------|--------|--------|--------|--------|--------|---------------------------------------|
| Persistent Memory | • | • | • | • | • | |
| System Reset | • | • | • | • | • | |
| Simple Counter | • | • | • | • | • | |
| Hibernate Mode | • | • | • | • | • | V1.0.6 includes further power savings |
| 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 | | | | | • | |
| Binary Output | | | | | • | |

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

| Feature | V1.0.0 | V1.1.0 | V1.1.1 | V1.1.6 | V1.1.7 | Notes |
|----------------------------------------------------|--------|--------|--------|--------|--------|----------------------------------|
| Common Features with OPS243-A plus Range reporting | • | • | • | • | • | |
| Hibernate Mode | | • | • | • | • | |
| Serial Number | | • | • | • | • | |
| Build Date | | • | • | • | • | |
| 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 |

Table 10. Persistent Memory Command Support

| Command | Code |
|----------------------------|--------------------------------------------|
| Buffer Size | S), S[, S<, S> |
| Baud Rate | In |
| 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 | Fn |
| Output Units | UC, UF, UK, UM, US, uM, uC, uF, ul, 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 |
| 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. |
| U | July 2, 2020 | <p>Added API Command Conventions section Added A! and AX timeout recommendation Corrected Xn and added Table 4 Added changes incorporated in V1.0.8 (OPS243-A)</p> <ul style="list-style-type: none"> • Improved RTC clock timing • Added OH command for Unix Epoch timestamp output? • Added A? persistent memory report • Added ON Radar Sign mode • Added O? output settings <p>Added changes incorporated in V1.1.1 (OPS243-C)</p> <ul style="list-style-type: none"> • Improved RTC clock timing • Added OH command for Unix Epoch timestamp output • Added A? persistent memory report • Added range resolution control (Xn command) • Added OP command to output phase data • Added ON Radar Sign mode • Added O?/o? output settings |
| V | January 5, 2021 | <p>Added changes incorporated in V1.0.6 (OPS241-B)</p> <ul style="list-style-type: none"> • Chirp bandwidth control (t=n, t>n, t?) • Chirp sample rate/timing control (s=n) • Added Serial Number, Build Date, and Label option (L command) <p>Added changes incorporated in V1.0.9 and V1.1.0 (OPS243-A)</p> <ul style="list-style-type: none"> • Added OB Binary output mode • Improved robustness of RS-232 interface • Increased max FFT size to 2048 <p>Added changes incorporated in V1.1.5 and V1.1.6 (OPS243-C)</p> <ul style="list-style-type: none"> • Added OB Binary output mode • Improved robustness of RS-232 interface • Increased max FFT size to 2048 • Increased max outputs to 16 |
| W | March 17, 2021 | <p>Added changes incorporated in V1.1.7 (OPS243-C rev D boards)</p> <ul style="list-style-type: none"> • New IS/lS command to select RS-232 or UART output |