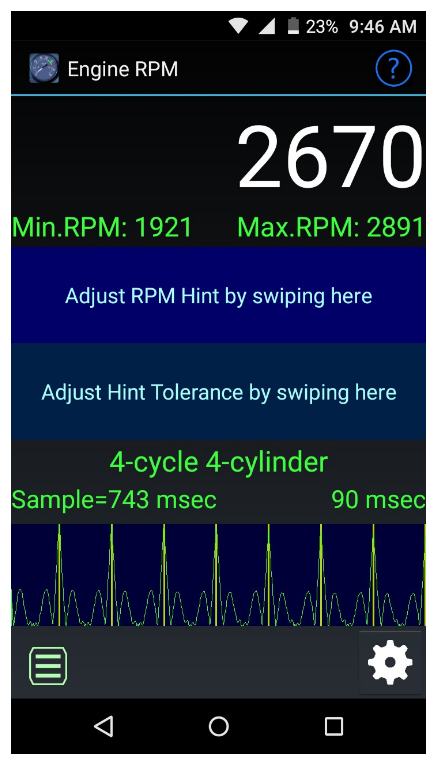
# Engine RPM

OPERATIONS MANUAL, VERSION 1.2 FOR ANDROID

## What is Engine RPM?

Engine RPM is an app that measures the RPM of an engine using the sound made by that engine. In particular, the pitch of the sound is what determines the calculated RPM.

The sound produced by an engine is complex and includes many harmonics. In addition, there is usually some extraneous noise mixed in with the engine sound, making the task of identifying the pitch more difficult. For these reasons, the Engine RPM program has a variety of settings and modes of operation designed to make the measurement process more reliable. At the very least, you must select an engine configuration (number of cylinders and 2-cycle or 4-cycle) that defines the relationship between pitch and RPM.




The main RPM display page looks like this. At the top in large numerals is the RPM. The RPM measurement is made continuously. The total measurement range is 130 RPM to 90,000 RPM. As shown here you specify a nominal RPM "hint" and a tolerance in percent. This directs the software to limit its search to the RPM range you specify. If the search range is not restricted, you may get a false reading in difficult cases. **There is also an Auto-Ranging option that eliminates the need to set a hint, as described later.**

The display of RPM is shown only if a reasonably reliable measurement can be made. The two blue bands shown here are adjustment controls that allow you to set the nominal RPM and the tolerance by swiping your finger left or right through those bands. The current result of setting of those two values is shown just above the blue bands.

Below the blue bands is shown the currently selected engine configuration. Below that is a graph that shows what is known as the **autocorrelation** function of the signal from the microphone. You don't have to understand what autocorrelation means to use the app. All you need to know is that the evenly-spaced peaks in this graph represent the periodic sound made by the engine. If the graph has clear peaks, like the one shown in this example, the sound is good enough to use. And if you see several yellow lines that coincide perfectly with the first few peaks, the RPM reading is reliable. Otherwise the RPM reading will be shown as "**-----**", or will show in red the last reliable RPM measurement. If evenly-spaced peaks are visible, but the yellow lines do not line up with them, the RPM range is probably set wrong. You should adjust the RPM range, as described later, until the yellow lines do line up with the peaks in the graph.

Above the left side of the graph is "Sample = 743 msec". This tells how long the sample period is for each RPM measurement. On the **Settings** screen you can select different sample periods from 93 msec. to 1486 msec. (1.486 seconds). In general, the longer sample periods produce a more precise reading. However the engine sound may not be stable enough to use long sample periods, and so a shorter sample period may produce more reliable readings. If the RPM is changing while you are measuring it, use a shorter sample period. Also the very longest sample period is nearly three seconds, so the RPM reading will only be updated once every three seconds. Experiment to find out what works best for a particular situation.

In the graph at the bottom of the screen showing the autocorrelation, you can adjust the upper range of the graph by sliding your finger left or right through the graph itself. The upper range in milliseconds is displayed on the right side above the graph. The actual setting of the range of this graph has **no effect on the RPM calculation**. It is only for your convenience when trying to interpret the graph. Otherwise don't worry about the range setting of the graph.

For very low RPM measurements, there is a mode that generates a sound that you can manually match to the sound of the engine. This mode is described later in more detail.

At the bottom of the screen there is the **Settings** button, which looks like a gear. Tap on this button to switch to the **Settings** page, which is also described later.

## Logging RPM measurements

When Engine RPM is measuring RPM it is constantly logging and time-stamping all RPM measurements, logging one averaged reading about every two seconds. Only the most recent 511 measurements are saved in the log. As more measurements are entered into the log, the oldest measurements are forgotten. You can view this log at any time by tapping on the logging button

found in the lower left of the screen, found in the lower left of the screen. When that log is displayed there will be a similar-looking button in the upper right of the screen that will offer the following menu of actions:

1. Reset RPM log.
2. Send RPM log by e-mail.

The first item empties the log of whatever what was stored up until that point so that you can start a new empty log. The second item lets you send an e-mail containing all the logged RPM values and time stamps.

## How the program determines RPM

The data shown in the autocorrelation graph at the bottom of the screen is what the software uses to calculate the RPM. Peaks in this graph represent periods of repeating patterns in the sound waveform. The more repeating patterns the software finds, the clearer the peaks will be. If there are no peaks, the sound does not have an identifiable pitch, and RPM cannot be calculated. Since the peaks identify the period of the repeating pattern in the sound, the software can calculate the pitch of the sound from that information.

Regardless of how the fundamental pitch of the sound is determined, calculating the RPM requires one more step. That step is the conversion of the period of the peaks to RPM based on engine configuration (the number of cylinders and whether a 2-cycle or 4-cycle). For example, suppose you select the 4-cycle 4-cylinder engine configuration, and that engine is running at 2400 RPM. We assume that the peak sound from the engine comes once for every power/exhaust strokes. Since each revolution of the engine crankshaft produces two exhaust strokes, the total number of exhaust strokes over any period of time is going to be twice the number of crankshaft revolutions. If the crankshaft speed is 2400 RPM, the sound will contain 4800 exhaust strokes per minute, which is 80 pulses of sound per second. Therefore the Engine RPM software will measure a primary pitch of 80 Hz. To convert 80 Hz to RPM the software multiplies by 60 (to convert from cycles per second to cycles per minute) then divides by the number of engine events per crankshaft cycle, which is 2 in this case. Therefore the Engine RPM app calculates:

$$80 \times 60 \div 2 = 2400\,RPM$$

and so it displays 2400. This is all automatic and you do not have to understand the calculations to use the app.

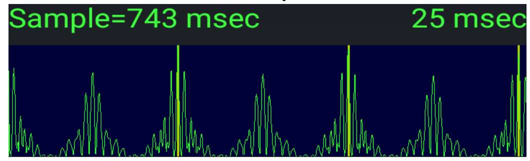
## Fixed hint band operation

This is the default and the most reliable mode of operation, but it also comes with some inconvenience. To use this mode, you must give the software a "hint" of what RPM range to expect. Then the software will only search within that range. In certain cases, the distinction between one RPM and double that RPM is ambiguous from the sound alone. Without the hint, the software might pick the wrong one and display, for instance, 1214 RPM when it really should be displaying 2428 RPM. By setting a hint band of 2200 ± 25% we allow the program to search between 1650 and 2750. Therefore it will report the correct RPM of 2428 and not the half-RPM of 1214. If the setting of a hint is inconvenient, you may be able to use Auto-Ranging mode instead.

## Auto-Ranging operation

Auto-Ranging is an option that can be selected by a switch on the Settings page. This option eliminates the need to specify a Hint Band and a Hint Tolerance on the main page. This can be a convenience if the range of the true RPM is not known ahead of time, or if the RPM is expected to change over a wide range. However this convenience comes with limitations. If the engine sound is unclear, Auto-Ranging is not as reliable as the normal Hint Band mode where you specify a restricted range for finding the RPM, as described in the previous paragraph. There are several ways to tell if Auto-Ranging is a viable option for you to use. One is the reasonableness of the displayed RPM. If the displayed RPM is consistently close to what you know the RPM should be, you can confidently rely on the result. Another way to tell if Auto-Ranging is suitable for a particular measurement is to examine the graph at the bottom of the screen. If every peak in that graph looks similar, and is marked by a yellow line, the reading is reliable. The picture on the previous page shows such a pattern. If it looks like that, you can depend on Auto-Ranging to give the correct result.

However, if the peaks look something like the ones in this graph, we see that every other peak is lower than the others, and that only the higher peaks have been marked with yellow lines. This will cause the displayed RPM to be half of what it should be, assuming every peak corresponds to a cylinder firing. In this case it would be better to use the hint band and force the software to choose the correct spacing for the yellow lines.




Other than this type of error, Auto-Ranging is just as accurate as Hint Band mode. If you use it with that understanding you can recognize when the RPM is unreasonable and interpret the reading accordingly. But if you want to force the software to recognize only the correct RPM and you know the range of the correct RPM, it is best to leave Auto-Ranged turned off and use the Hint Band adjustments.

One example of when a half-RPM reading is likely is in a two-cylinder engine where one cylinder is producing less power than the other (or less sound, which is more to the point). This could be from a problem with one cylinder or from a difference in how the sound from one cylinder gets out into the air compared to the other cylinder. In such a case, a two cylinder engine may be detected as if only one cylinder is firing, which would then cause the software to report half of the true RPM. These are fundamental limitations of any system that measures RPM from the sound of the engine.

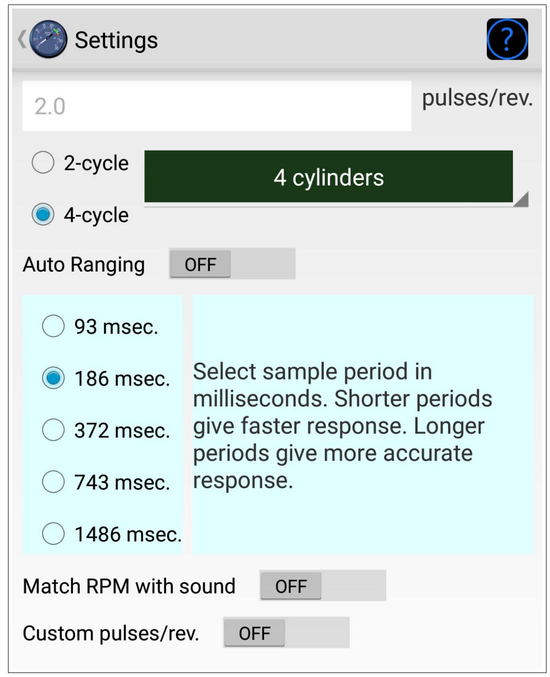
## Manual Matching of RPM with Generated Sound

Detecting the pitch of the sound of an engine is the most difficult when the RPM is extremely low. Sometimes our ears can hear a repeating pattern in the sound when software cannot find this pattern by analyzing the waveform. This is the case in the antique "hit-and-miss" engines. In this case you can use **Manual RPM Match mode**. In this mode the software generates a "ticking" sound at a known rate. You can adjust this rate by swiping through the blue adjustment bar. When the ticking sound matches the sound from engine, the resulting RPM can be read from the screen.

When this option is selected, the engine configuration works differently from the listening modes. With this option, the generated ticks are assumed to be one tick every other rev (for 4-stroke engines) or one tick every rev (for 2-stroke engines). The number of cylinders is ignored. If the engine configuration is an explicit "Events per rev", then that number will be taken as the number of generated ticks per revolution. (For example, 0.50 events per revolution would mean a 4-stroke engine.)

This mode works all the way down to 55 RPM. To use this method, listen to the engine for a while to get a sense of the rhythm of the sound. Then listen to the ticking sound generated by the software. Adjust the ticking rate until it sounds like the same rhythm as the engine. Finally, listen to both the engine and the software ticking sound together. Determine if the software ticks are falling behind or getting ahead of the engine sound. Make small adjustments accordingly in the software ticking until the engine and the generated sounds track together for as long as possible. When you have adjusted things as closely as possible, just read the RPM off the screen.

## The Settings page




Tap on the Settings button that looks like a gear to see the Settings screen shown here. On the settings screen you can select the engine type, the sample period, and other options.

This shows what the Settings screen looks like with all the options showing. In various modes, some of these options are irrelevant and so are hidden.

The question mark button at the top shows a help file specific to the Settings page.

**Engine Configuration** must be selected to conform to the proper engine type (number of cylinders and two-stroke or four-stroke). Tap on the number of cylinders to change the setting. The only purpose of these selections is to define the number of sound pulses per revolution. In most cases the sound pulses are produced by the firing events in the engine. In unusual cases you may want to define the number of pulses per revolution explicitly. For those times you can switch on the "Custom pulses/rev." switch and enter a value in the field at the top. This value will override any value calculated from the engine configuration.

The **Auto-Ranging** switch eliminates the need to adjust the Hint Band, but has limitations, as described above.

The **Sample Period** selection lets you select between six different sampling periods, ranging from 93 msec. to 1486 msec. As described earlier, the longer sample periods may be useful for low RPM and the shorter sample periods may be more useful for RPMs that are changing (not very stable). Also long sample periods result in less frequent RPM updates.

The **Match RPM with sound** switch enables the mode where the software generates a ticking sound, as described above. When this switch is turned on, all the other options except for engine configuration are hidden. This mode is for RPMs that are slow enough to count individual rotations.

The **Custom pulses/rev** switch disables the engine configuration selections and replaces them with a number you enter in the top field. This may be useful when it is desired that the displayed RPM represent something other than the rotation of the crankshaft. For instance, if it is desired to display the RPM of the propeller of an airplane where the propeller is gear-driven from the engine, you can use this option to take into account that gear ratio.

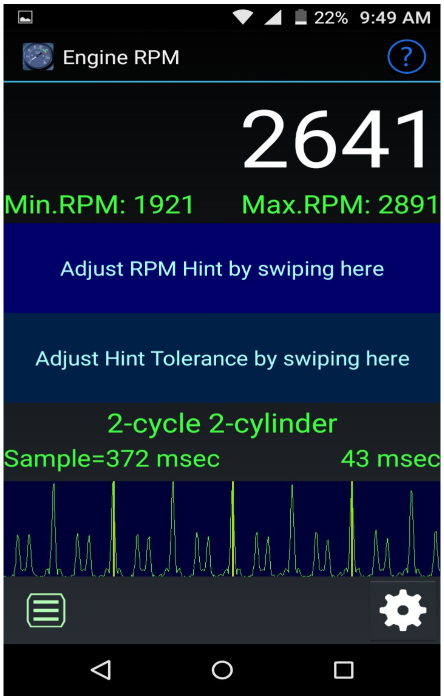
## Problems with RPM Measurement

There are some situations where the RPM is measured with great difficulty or not at all with the Engine RPM app. Here are some things to look out for.

- If sound is being produced by something besides the engine itself, this sound can interfere with the pitch detection and RPM calculation. These interfering sounds could be coming from the alternator, water pump, air conditioner, or any other attachment to the engine. For example, consider a riding lawnmower with belt drive to the blades. It is possible that the cutting blades can be making more noise than the engine. And since the blades are driven by belts, their RPM is not the same as the RPM of the engine. So the sounds made by the blades are at completely different frequencies from the engine sounds. Under these conditions the Engine RPM app will not be able to produce a reliable measurement, and the displayed measurement probably will be some random number. If possible, disengage the blades from the engine so only the engine is making a sound, or else position the microphone so that it picks up mostly engine exhaust and not the blades.

- If engine sound is muffled then the sound may have no discernible pitch. For normal passenger cars with a muffler, you may not be able to get an RPM reading at all, except perhaps at higher RPMs, and then only if the muffler is leaking.

- If the actual RPM is outside the RPM search range of the software, the calculated RPM will not be correct. But you can use the autocorrelation graph to diagnose the problem and determine a more appropriate range, or switch on **Auto-Ranging**. For instance, consider the autocorrelation graph shown here. The yellow lines that mark the detected peaks actually are marking every other peak. This means the software is finding a pitch that is half the true pitch, and so the displayed RPM is probably half of what it should be. Most likely the RPM search range has been set too low and the true RPM is double the RPM shown. In the example shown here, the real RPM is 5282, but that number is not within the search range of 1921 to 2891. So the software was able to find a match for only half of the correct RPM (2641). The remedy is to make a quick swipe through the adjustment band in order to raise the RPM search range to include the true RPM. Of course, this assumes you have set the engine configuration correctly.




- If the RPM changes rapidly, the pitch of the sound also will be changing. If that pitch is not constant over the sample period, the software will be unable to detect the pitch. This would be the case for a chainsaw or motorcycle, where rapid changes in RPM are common. When possible, keep the RPM of the engine constant while making a measurement, or select a shorter Sample Length in the Settings.

- If the autocorrelation graph does not look something like the ones shown in this manual with distinct peaks in the graph, the software will not be able to find the RPM. In general this means the sound is not very periodic or is combined with too much noise. The software draws yellow lines to mark the peaks that it finds. If a peak is too low compared to other peaks, it is not counted. So the number of yellow lines is a measure of how good the peaks are. If you do not see lots of peaks with yellow lines on them, try improving the sound perhaps by moving the microphone to a better location until the display improves.
- If all else fails, for low enough speeds, try **Match RPM with sound**. It always works if you can match the generated sound to the engine sound by ear.
- It is possible to measure the RPM of an engine that is far away from where you are. For example, you can measure the RPM of a distant airplane engine since it usually is so loud. However, if the engine is moving toward you or away from you, remember that the Doppler Effect will distort the pitch of the sound. If you are trying to measure the RPM of an airplane engine that is flying overhead, the RPM reading will be inaccurate, unless the airplane is moving perpendicular to you (neither toward you nor away from you).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