

Engine RPM

OPERATIONS MANUAL

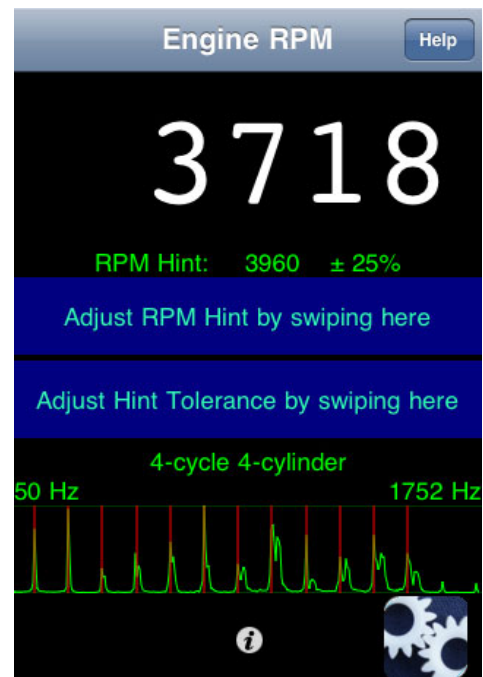
1. What is Engine RPM?

Engine RPM is an iPhone app that measures the RPM of an engine using the sound produced by that engine. In particular, the pitch of the sound is what we need to measure in order to calculate the RPM.

The sound produced by an engine is complex, including many harmonics. In addition, there is usually some extraneous noise mixed in with the pure 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 itself. The RPM measurement is made continuously, and updated about once every 3/4 of a second. The total measurement range is 500 RPM to 90,000 RPM. The page shown here is of the program in **fixed hint band** mode, which is described in more detail later. In this mode you specify a nominal RPM “hint” and a tolerance in percent. Without restricting the search in some manner like this, it would be impossible to determine the RPM over a wide range of possibilities. 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 setting of those two values is shown just above the blue bands.

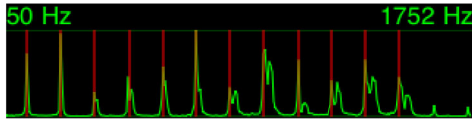
Below the blue bands is shown the currently selected engine configuration. Below that is the frequency spectrum display. That is the graph shown in green that shows how the sound is distributed across the frequency spectrum. The left side of the graph always starts at 50 Hz, as shown by the label on the left side of the graph. The right side of the graph goes up to some limit that you can adjust by swiping your finger left or right through the graph itself. The adjustment of the upper end of the spectrum graph is just for your convenience in viewing the graph. It has no effect on the actual RPM calculation. This graph is very useful in helping you adjust the various settings in the program, as will be described later.



Finally, there is the Settings button, which looks like two gears. Tap on this button to switch to the Settings page, which is also described later.

2. How the program determines RPM

The data shown in the spectrum graph is the same data that the program uses to determine RPM. The spectrum graph shows various peaks that correspond to specific frequencies in the sound. When the sound is being produced by a continuous periodic signal (like a running engine), then the peaks in the frequency spectrum correspond to harmonics of a fundamental frequency. Harmonics are multiples of the fundamental frequency. Therefore we would



expect the peaks in the spectrum to be evenly spaced throughout the spectrum. For example, suppose a 4-cycle 4-cylinder engine is running at 2400 RPM. Since each revolution of the engine produces two “bangs” (due to the exhaust strokes), that is 4800 “bangs” per minute, or 80 “bangs” per second. Therefore the fundamental frequency in the sound spectrum should be 80 Hz. But this 80 Hz sound also produces lots of harmonics. So we would expect to see some sound energy at the multiples of 80 Hz. That would be 80 Hz, 160 Hz, 240 Hz, 320 Hz, 400 Hz, etc. Therefore we should see peaks in the frequency spectrum at these frequencies. So if the spectrum display is set up to show everything from 50 Hz to 450 Hz, then we might see five distinct peaks in the graph.

Every time the program needs to produce an RPM reading, it tries all the frequencies in the current search range and evaluates each one to see how well that frequency and its harmonics match up with peaks in the frequency spectrum. As we said before, the displayed portion of the frequency spectrum is merely for your convenience. It does not affect the calculation. Even though you are displaying only a portion of the frequency spectrum, the program has the entire frequency spectrum available for its calculations. So if you want to see all the data that is being used in the calculation, make sure the upper end of the frequency spectrum graph is high enough to cover all the harmonics that are being used.

When a frequency is found that best matches the peaks in the spectrum graph, then that frequency and its harmonics are indicated by vertical red lines in the spectrum graph. Therefore when things are working properly, you should see the red lines coincide with peaks in the graph. This is the best way to evaluate the reliability of any particular RPM measurement.

Each search for a best-fit frequency is carried out over a limited range of frequencies. As we said before, this is how we improve the reliability of the measurements. However if the actual RPM (and its corresponding set of harmonics) is outside the current search range, then the program will try to find a frequency that is within the search range that best matches the peaks in the spectrum graph. But in this scenario, there is no proper match. Therefore the program will pick some frequency, seemingly at random, and calculate the RPM from that. This will result in random-looking RPM measurements that do not seem to relate to the actual engine RPM. You can fix the situation by adjusting the search range so that it does include the actual RPM.

3. Fixed hint band mode

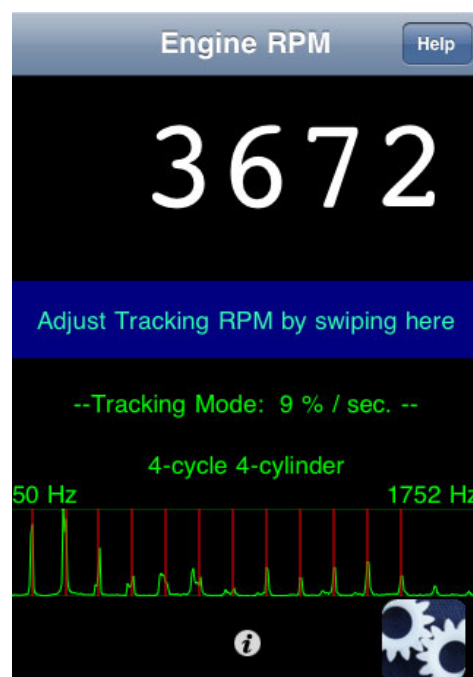
This is the mode where you specify a nominal RPM and a tolerance in percent. For example, suppose you set the nominal hint RPM to 2100 and the tolerance to $\pm 10\%$. That would establish a search range from 1890 RPM to 2310 RPM. As long as the actual RPM is in that range, the program has a chance of finding and displaying it. The tolerance can be set as high as 60%, however such a wide tolerance range should only be used for very clear engine sounds with very distinct peaks in the frequency spectrum. But if the situation is less than ideal, then a wide tolerance range makes it more likely that harmonics will be mis-identified, and the calculated RPM will be in error. Using the example cited earlier with the 2400 RPM engine and engine harmonics at multiples of 80 Hz, consider what might happen if the search range included both 40 Hz and 80 Hz. Since multiples of 80 Hz are also multiples of 40 Hz, it is possible that 40 Hz might be declared the best-fit fundamental frequency. This will result in a display of 1200 RPM instead of the correct value of 2400 RPM. Using a tolerance range of less than 33 % will ensure that this particular confusion will not occur.

The fixed hint band mode is enabled by a switch on the Settings page. When that switch is turned off, the program operates in **tracking** mode.

4. Tracking mode

Tracking mode, as shown here, is enabled by turning off fixed hint band mode. In this mode, the program establishes a search range around the previous RPM reading. After the current reading is displayed, the search range is again centered around the current reading, so the next reading will be restricted to be inside that range. The effect of constantly recalculating the search range based on the previous reading is to establish tracking behavior. The program can track gradual changes in the actual RPM, even if the actual RPM ultimately varies over the entire 500-90,000 RPM range.

In order to be effective, this mode must have a way of manually forcing the RPM close to the actual RPM. This is necessary when first getting started in this mode, or when the actual RPM manages to move outside the tracking range. In tracking mode, the displayed RPM can be forced to any value by swiping through the blue band below the RPM display. When you do this, the displayed RPM turns yellow to indicate that it is not a calculated reading, but is just a forced value that you are controlling. Then when you stop adjusting it, the displayed RPM turns white and once again represents the calculated RPM based on the search through the frequency spectrum.



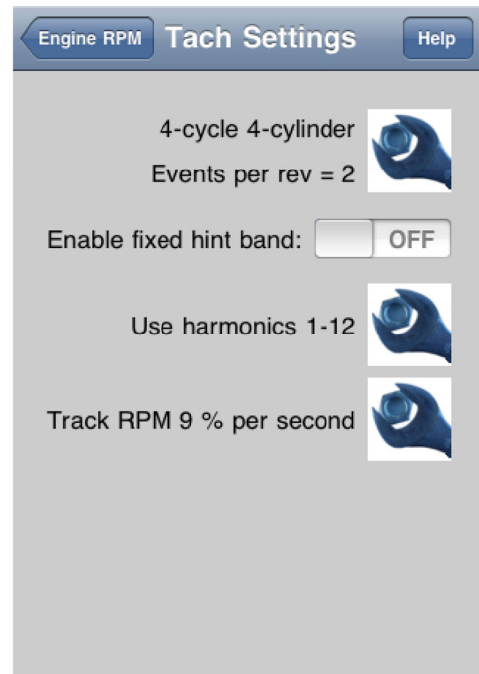
When using tracking mode, you must force the displayed RPM to be within the tracking range of the actual RPM, based on your knowledge of the engine and what the approximate RPM should be. If you are not sure what the approximate RPM should be, then you can use the spectrum display to help to

decide how the displayed RPM should be adjusted. If you see that the peaks in the graph are spaced more closely than the red lines, then you know that the actual RPM is lower than the displayed RPM. Therefore you should swipe left through the blue control band to made the displayed RPM come down. Similarly, if the peaks in the spectrum graph are spaced further apart than the red lines, then the actual RPM is higher than the displayed RPM, and you should swipe right to make the displayed RPM go up. You can tell when the program manages to lock onto the correct RPM when you see the red lines match up with the peaks in the graph.

In tracking mode, the width of the tracking range is determined by a Setting that you adjust on the Settings page. That setting is indicated by “**Track RPM X % per second**” You can set **X** to any value from 1% to 20%. For example, suppose you set it to 5% per second. Since the RPM readings are recalculated every 3/4 of a second, a change of 5% per second means a change of about 3.75% for each reading. So if the current reading is 2100 RPM, then the tracking range for the next reading will be from 2021 RPM to 2178 RPM. This range only applies to the very next reading. The one after that will have a tracking range that is centered around the next reading. A narrow tracking range can be used, provided you are ready to force the displayed RPM into the correct range if it should ever wander out of lock.

5. The Settings page

Here is the Settings page that appears when you tap on the Settings button (the one that looks like gears). This page shows your current engine configuration, the hint mode switch, the enabled harmonics, and the tracking rate (for use in tracking mode). Each of these items can be adjusted by tapping on the adjustment button next to the item you want to adjust (the button that looks like a wrench adjusting a nut). And the hint mode switch can be turned on and off by sliding the switch control, or by just tapping on the switch.



6. Selecting harmonics

One of the options on the Settings page is the selection of which harmonics will be used in searching for the best-fit fundamental frequency. The available harmonics are 1 to 16, where 1 corresponds to the fundamental itself. You specify a range of harmonics by specifying the lowest and highest harmonic to be used. For an ideal situation with a clear engine sound with well-defined peaks, it will not matter much which harmonics you enable. Any set of harmonics will give you the same RPM. However if the situation is marginal, with a muffled engine, or extraneous noise, you may be able to improve the reliability and accuracy of the readings.

If the engine is very muffled, then it is likely that only the fundamental and maybe a few lower harmonics are getting through. In that case you would do well to enable only those few lower harmonics where there may be peaks in the frequency spectrum. Perhaps enabling only the

fundamental itself (harmonics 1-1) would be best. If you enable higher harmonics in the search where there are no harmonics there just makes the search more sensitive to extraneous noise that might be in the higher regions of the frequency spectrum.

On the other hand, a very harsh engine sound (such as a string trimmer or a chainsaw) has lots of higher harmonics. It would be well to enable the higher harmonics in that case, perhaps even the full range of 1-16. And if you want to omit the fundamental and maybe the 2nd harmonic, you can start with harmonic 3 and avoid being sensitive to low-frequency extraneous noise. You could even set up the program to use just one mid-range harmonic, such as 5-5, if it turns out that the 5th harmonic is especially clear in the frequency spectrum and the other harmonics are not.

7. Technical details

Here are some interesting facts related to the implementation of Engine RPM. You don't need to know these facts to use the program, but if you are curious, here they are.

The sound is sampled from the microphone at a rate of 11,025 samples per second. This allows us to calculate the frequency spectrum up to 5512 Hz, which is high enough to cover any reasonable engine sound.

The sound samples are processed in blocks of 8192 sample. This corresponds to roughly 0.74 seconds, and that is why the RPM calculation is updated every 0.74 seconds.