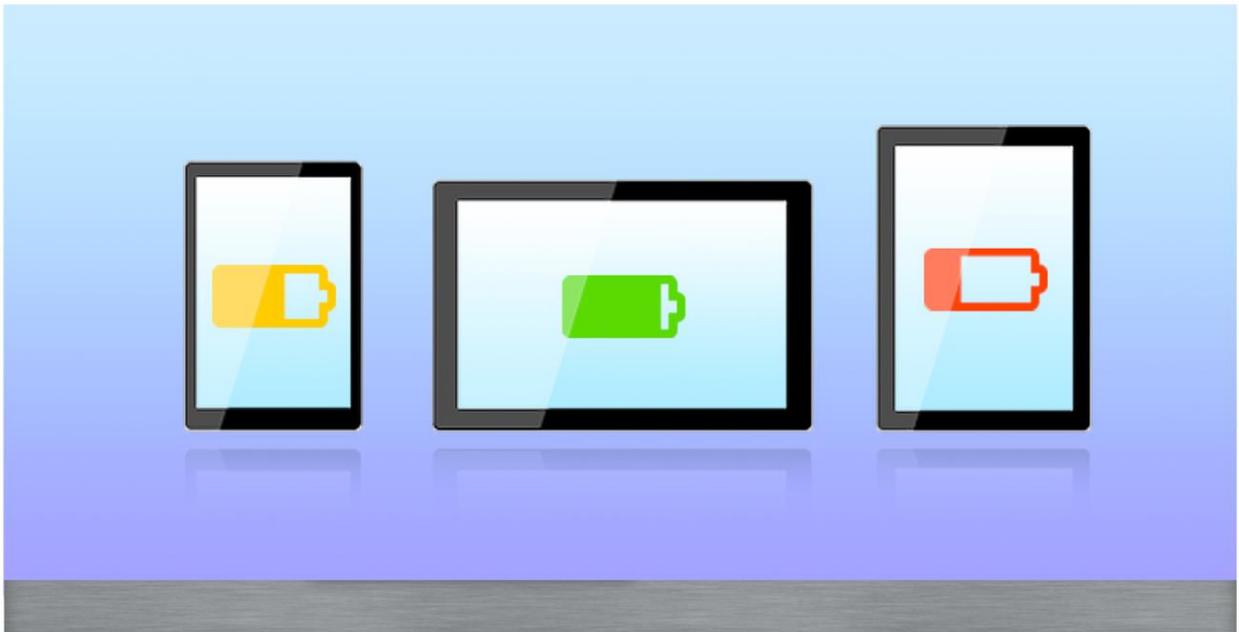


Benchmark**XPRT**

BenchmarkXPRT Development Community

Exploring the BatteryXPRT 2014 for Android Benchmark



BatteryXPRT 2014 for Android evaluates the battery life and performance of Android-based phones and tablets in under six hours.

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INTRODUCTION

This paper explains the concepts behind BatteryXPRT 2014 for Android. BatteryXPRT 2014 for Android is a tool created to evaluate the battery life of Android-based devices. It provides an intuitive user interface, a runtime allowing it to complete within one workday, Airplane and Wi-Fi/Cellular modes, and easy-to-understand results. We explain the development guidelines common to all BenchmarkXPRT benchmarks in general, as well as the specific goals and assumptions of BatteryXPRT 2014 for Android. Finally, we discuss the structure of the tests, how the benchmark calculates results, how to share results, and how to participate in the BenchmarkXPRT community.

DEVELOPMENT PROCESS

We use a unique design methodology. Instead of the closed, bottom-up approach used by many benchmarking efforts, we are using an open, top-down approach that includes the Development Community. Our approach starts by taking input from the community and examining the most common use cases. We then write a Request for Comment (RFC) proposing use cases to incorporate into the benchmark. Once we have the RFC written, we publish it to the community.

The community's input on the RFC guides the drafting of a design document. The design document drives the implementation of the community preview. After the community preview is released to the community, we take the input from the preview period and finalize the code to create a general release.

BATTERYXPRT 2014 FOR ANDROID: THE DETAILS

BatteryXPRT 2014 for Android shares the common characteristics of the BenchmarkXPRT family of benchmarks:

- It is easy to use.
- It contains relatable workloads.
- It produces easy-to-understand results.

In addition to these core characteristics, we added a requirement that users would be able to obtain a result in a single working day. Many of the implementation details derive directly from these principles. For example, consider the goal of completing the test in a day:

- To allow time for setting up the device, recording the result, and other miscellaneous activities, the test needs to complete in approximately six hours.
- Because many devices have a battery life of greater than six hours, we need to estimate the battery life.
- Estimating battery life requires repeating the workload enough times to get a valid sample. For statistical reasons, we need the test to run a minimum of seven iterations.

To fit seven iterations of a workload into 6 hours, each iteration must complete in 50 minutes or less. We created a workload that completes in 45 minutes. The battery life estimation assumes that the battery under test, for the bulk of its usable life, discharges power in an approximately linear fashion. This is a reasonable assumption for most modern li-ion batteries.¹

¹ www.technick.net/public/code/cp_dpape.php?aiocp_dp=guide_bpw2_c02_06

BatteryXPRT for Android is capable of running in one of three modes. It can represent a device in Airplane mode, a device connected to the Internet via Wi-Fi, or a device connected to the Internet through a cellular data connection. The Wi-Fi and Cellular modes are represented together on the benchmark's home page by the Wi-Fi/Cellular button. If a user wishes to estimate battery life while connected to the Internet, they simply need to select the Wi-Fi/Cellular button, and BatteryXPRT will use Wi-Fi or Cellular mode based on the current device settings. There is not an option to change the device connection settings from within the BatteryXPRT UI. There are a few additional differences between Airplane mode and the two Internet-based modes. We explain these differences in detail in the section Differences between Airplane mode and the Wi-Fi/Cellular modes.

As stated above, the test runs a 45-minute workload seven times and estimates the battery life of the device. BatteryXPRT for Android also allows you to complete a rundown test in any of the three modes. The rundown test requires more iterations of the workload to run down the battery, but is the same as the standard test in all other respects. The detailed information for the run includes the elapsed time, so you may compare the expected battery life for a rundown test to the elapsed time if desired.

Results of the complete rundown test and the seven-iteration test should be very similar. However, because it uses a large number of iterations, the rundown test may have a smaller confidence interval.

The component tests

The 45-minute workload comprises 12 individual tests along with periodic sleep periods. Faster devices will finish the work in less than 45 minutes. When the work finishes in less than 45 minutes, BatteryXPRT 2014 for Android will sleep for the remainder of the 45-minute period. Here is a short description of each component test:

- Apply Photo Effects: Apply four different Photo Effects to twenty 8MP photos and save them to JPEG/WebP format.
- Audio: Play a 3.5MB MP3 audio clip for 3 minutes.
- Browser Scroll: Browse Web pages for 2 minutes. The content will be local in Airplane mode, or served from a Web server if the test is in the Wi-Fi or Cellular modes.
- Create Photo Collages: Create five photo collages from twenty 8MP photos.
- Create Slideshow: Create a video slideshow (720p, H.264, 20 seconds) using 20 images with different transitions and effects.
- Detect Faces: Organize a photo album based on whether each photo has faces or not.
- Encrypt Personal Content: Encrypt and decrypt photos, video, and an audio clip, which takes 2 to 3 minutes.
- Gallery Scroll: Swipe through a photo gallery for 90 seconds.
- Grid Scroll: Scroll the list of apps on the device for 90 seconds.
- List Scroll: Scroll a list for 1 minute. Mimics users navigating to a video file they intend to launch.
- Video Playback: Stream a 2-minute video clip. The content is different for the for Airplane mode than for the other two modes.
- Zoom and Pinch: Zoom and pinch an image for 40 seconds.

Differences between Airplane mode and the Wi-Fi/Cellular modes

Airplane mode and the Wi-Fi/Cellular modes differ in several ways:

- The Wi-Fi/Cellular modes require the device to connect to the Internet using either Wi-Fi or a cellular data connection.
- In the Browser scroll test, the Wi-Fi/Cellular modes browse live Web pages, whereas Airplane mode browses cached pages.
- In the Video Playback test, the Wi-Fi/Cellular modes stream a 2-minute, 720p, H.264 video clip from Internet. In contrast, Airplane mode plays a 2-minute, 1,080p, H.264 video clip from local storage.
- The Wi-Fi/Cellular modes download a small amount of text and image data (80 KB) at 1-minute intervals to mimic the device synchronizing email and apps.

Our testing has shown that Wi-Fi mode yields approximately 10 percent lower expected battery life than Airplane mode, while Cellular mode yields approximately 20 percent lower expected battery life than Airplane mode. Similarly, Cellular mode yields approximately 10 percent lower expected battery life than Wi-Fi mode. However, Individual devices may exhibit greater or lesser differences between the modes. Figure 1 compares the workload differences between the modes. For readability, Figure 1 does not present the simulated email and application synchronization.

	Wi-Fi/Cellular modes component test	Airplane mode component test
List Scroll	Scroll a list for 1 minute. Mimics the user navigating to a video file they intend to launch.	
Video Playback	Stream a 2-minute, 720p, H.264 video clip from the Internet.	Play a 2-minute, 1,080p, H.264 video clip from local storage.
Stand by	Device goes to standby for 1 minute.	
Zoom and Pinch	Zoom and pinch an image for 40 seconds.	
Apply Photo Effects	Apply four different Photo Effects to twenty 8MP photos and save them to JPEG/WebP format.	
Stand by	Device goes to standby for 1 minute.	
Gallery Scroll	Swipe through a photo gallery for 90 seconds.	
Stand by	Device goes to standby for 1 minute.	
Detect Faces	Organize a photo album based on whether it has faces or not.	
Audio	Play a 3.5MB MP3 audio clip for 3 minutes.	
Browser Scroll	Browse Web pages from a remote location for 2 minutes.	Browse local (cached) Web pages for 2 minutes.
Video Playback	Stream a 2-minute 720p H.264 video clip from the Internet.	Play a 2-minute 1,080p H.264 video clip from local storage.
Create Photo Collages	Create five photo collages from twenty 8MP photos.	
Stand by	Device goes to standby for 1 minute.	
Encrypt Personal Content	Encrypt and decrypt photos, video, and an audio clip, which takes 2 to 3 minutes.	
Audio	Play a 3.5MB MP3 audio clip for 3 minutes.	
Create Slideshow	Create a video slideshow (720p; H.264; 20 seconds) using 20 images with different transitions and effects.	
Stand by	Device goes to standby for 1 minute.	
Grid Scroll	Scroll the list of apps on the device for 90 seconds.	
Stand by	Device goes to standby for the rest of the 45-minute cycle.	

Figure 1: Comparison of Wi-Fi/Cellular modes and Airplane mode tests.

SCORING

BatteryXPRT produces two main scores: an estimated battery life and a performance score. The test reports the expected battery life in hours and qualifies that result with a performance score. The detailed test results include a confidence interval for the result.

The performance qualifier is a simple number based on the speed with which the device completes its work. (The time spent sleeping is not included in the calculation of the performance score.) However, we do not guarantee that the performance qualifier result is comparable to any other benchmark score.

Statistical concepts we use

This section assumes a basic familiarity with statistics. The BatteryXPRT calculations are straightforward. There are only a few concepts we use that are beyond basic arithmetic. We briefly define those concepts below. A full explanation of these terms is outside the scope of this paper, but the footnotes give links to pages with more information. This section will also explain why BatteryXPRT uses a minimum of seven iterations.

- Confidence interval (CI): The confidence interval is a range of values that corresponds to a given probability of including a sample value. In practice, it is common to state confidence intervals at the 95% confidence level, as we do in BatteryXPRT.²
- Degrees of freedom: The number of values in the final calculation of a statistic that are free to vary.³
- Interquartile range (IQR): The range of values that are in neither the top quartile nor the bottom quartile. Sometimes called the “middle 50.” Note: There are several methods of calculating the IQR. We will show the method BatteryXPRT uses in the calculations below. This method is not the same as the one Excel uses.⁴
- Arithmetic mean: What people typically mean by “average.” It is the sum of the values divided by the number of values. In this document, the average is always an arithmetic mean.⁵
- Geometric mean: Another way of calculating an average. It is defined as the n^{th} root of the product of the values. For reasons that are outside the scope of this paper, the geometric mean is better than the arithmetic mean for some of the calculations involved in determining the BatteryXPRT results.⁶
- Outliers: A value that is distant from other values. BatteryXPRT considers any value further than 1.5 times the interquartile range (IQR) from the mean to be an outlier.⁷
- Square root: The number which, when multiplied by itself, gives the value in question.⁸
- Standard deviation: A measure of how dispersed, or spread out, the set of data values is. The lower the standard deviation, the more tightly clustered the data values are.⁹

² en.wikipedia.org/wiki/Confidence_interval Also, the Principled Technologies white paper [WebXPRT 2013 results calculation and confidence interval](#) covers the confidence interval in detail.

³ [en.wikipedia.org/wiki/Degrees_of_freedom_\(statistics\)](https://en.wikipedia.org/wiki/Degrees_of_freedom_(statistics))

⁴ en.wikipedia.org/wiki/Interquartile_range

⁵ en.wikipedia.org/wiki/Mean#Arithmetic_mean .28AM.29

⁶ en.wikipedia.org/wiki/Geometric_mean

⁷ en.wikipedia.org/wiki/Outlier

⁸ en.wikipedia.org/wiki/Square_root

⁹ en.wikipedia.org/wiki/Standard_deviation

- t value: A t statistic can be used for testing a hypothesis. If the t statistic you calculate is greater than your proposed cut-off, the hypothesis is false. Conversely, you can use a particular t value to determine the bounds within which the hypothesis is true. That is what BatteryXPRT does when calculating its confidence interval. In this document, the t value is always the two-tailed Student's t value.¹⁰

With this background, we can now explain why BatteryXPRT uses seven iterations. For the Student's t value, the degrees of freedom is one less than the number of iterations we use to calculate the expected battery life. For the statistics to be valid, we need at least five iterations. To understand why, look at the first 10 values of the two-tailed Student's t value at the 95% confidence level:¹¹

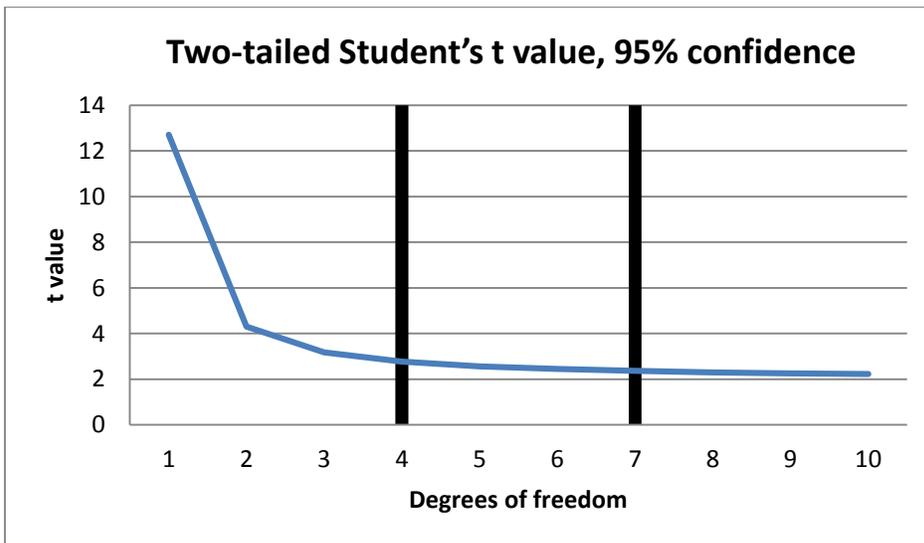


Figure 2: Student's t value for 1 to 10 degrees of freedom.

In the chart above, the higher the value of the blue line, the less reliable the estimate will be. As you can see, the reliability is very flat above seven degrees of freedom, which is why seven iterations is the default for BatteryXPRT. There is a small but acceptable loss of reliability between four and seven degrees of freedom. However, below four degrees of freedom, the confidence goes down rapidly. As you will see in the detailed calculation below, as the t value goes up, the confidence interval gets wider. At three degrees of freedom or lower, the CI becomes so wide that the confidence in the estimated battery life would be very low.

Excluding the outliers, BatteryXPRT checks to make sure there are at least five iterations in range, ensuring that there are at least four degrees of freedom. If there are not five usable iterations, BatteryXPRT will return an error. Therefore, in a standard seven-iteration run, the number of iterations could be five, six, or seven. That means the degrees of freedom would be, respectively, four, five, or six.

As shown above, the t values go up slowly above four degrees of freedom. Increasing the number of iterations has a minimal effect on the estimated battery life. Therefore, BatteryXPRT does not limit the maximum number of iterations.

¹⁰ en.wikipedia.org/wiki/Student%27s_t-distribution

¹¹ www.sjsu.edu/faculty/gerstman/StatPrimer/t-table.pdf

Sample detailed calculation of the expected battery life

This example uses results from a standard seven-iteration run. A rundown test will typically have more iterations of the workload, but the procedure is the same. Below is an outline and detailed description of the calculation that follows.

1. Discard outliers if any exist.
2. Average the percentage battery drop for the remaining values.
3. Divide the average battery drop into 100 percent to get an expected number of iterations.
4. Multiply the expected number of iterations by the length of an iteration to convert to hours. An iteration lasts 45 minutes, or 0.75 hours.
5. Compute a confidence interval for the run and convert it to hours.

The test measures the remaining battery capacity at the beginning and end of each iteration. This lets the benchmark determine how much battery capacity each workload iteration uses. The Android API for determining the battery level is limited to two decimal points of precision, so we can always represent the battery drop percentage as a whole number.

Figure 3 shows the battery use during the seven iterations of BatteryXPRT for Android.

Iteration	Starting battery level (%)	Ending battery level (%)	Battery drop (%)
1	100	95	5
2	95	89	6
3	89	84	5
4	84	78	6
5	78	72	6
6	72	66	6
7	66	60	6

Figure 3: Battery use during seven iterations of BatteryXPRT 2014 for Android.

The calculation of the expected battery life proceeds as follows:

1. Determine the outliers. An outlier is anything further than 1.5 times the interquartile range (IQR) from the mean. Any outliers would not be used in the calculations from step 2 onward.
 - a. Sorting the drops in battery capacity from the table above, we get 5, 5, 6, 6, 6, 6, and 6.
 - b. There are several methods of determining the quartile. BatteryXPRT for Android uses the median of the lower half for the first quartile, and the median of the upper half for the third quartile. The lower half comprises {5, 5, 6}, so the median is 5. The upper half comprises {6, 6, 6}, so the median is 6. Note that this is not the method Excel uses, and may give different results than the Excel quartile functions.
 - c. Subtract the lower quartile from the upper quartile, $6 - 5 = 1$. Multiplying the difference of 1 by 1.5, we get 1.5.
 - d. The lower bound is $5 - 1.5 = 3.5$. The upper bound is $6 + 1.5 = 7.5$.
 - e. Because all values in the set are between 3.5 and 7.5, there are no outliers in this test.
2. Find the average drop in capacity. That is $(5 + 6 + 5 + 6 + 6 + 6 + 6) / 7 \sim 5.71\%$.

3. Dividing 100% by the average drop (~5.71%), we get the estimate that the device should be able to complete approximately 17.50 iterations of the workload.
4. As explained above, each iteration lasts 45 minutes, or 0.75 hours. Multiplying 17.50 iterations by 0.75 hours, we get approximately 13.13 hours, or about 13 hours and 8 minutes.

The calculation of the confidence interval for the expected battery life proceeds as follows:

1. Calculate the standard deviation of the data. In this case, the standard deviation is 0.452.
2. The t value for 95% confidence for a two-tailed data set with seven values, or six degrees of freedom, is 2.447.
3. The formula for the confidence interval is $t * Stdev / \sqrt{\text{sample set size}}$. Using the values for our data, we get $2.447 * .452 / (\sqrt{7}) = 0.42$.
4. The confidence interval of 0.42 is for the percent loss in battery capacity per iteration. To convert this to variation in hours, we use this formula: $\text{Variation in Hrs.} = 100 * \text{Iteration duration in Hrs.} * CI / \text{SQR (Average drop per iteration)}$. Using the values from our sample gives $100 * 0.75 * 0.42 / (5.7 * 5.7) = 0.96$ hours, which rounds to 58 minutes. The results page presents the confidence interval as a percentage, so 58 minutes variation equals 7.4 percent of the estimated runtime of 13 hours and 8 minutes.

Therefore, the result is 13 hours and 8 minutes with a confidence interval of +/- 7.4 percent.

Example calculation of the performance score

As explained in *Statistical concepts we use*, BatteryXPRT will always have at least five valid iterations if it returns a result. BatteryXPRT will calculate a performance score for each iteration. The final performance score will be the median of the per-iteration performance scores.

BatteryXPRT derives the per-iteration performance scores from the timings of the individual workloads. You will find those timings in the `batteryxpert_results.xml` file for each iteration. It is important to note that the timings in the `batteryxpert_results.xml` file will be less than the timings you would get by subtracting the end time from the start time in the detailed results. That is because the use cases contain some idle time and fixed-rate work, in order to better mimic real-world behavior. The time spent resting or working at a fixed rate is not included in the performance calculations.

Like the other BenchmarkXPRT benchmarks, BatteryXPRT uses a calibration system. The calibration system for BatteryXPRT is the Motorola Droid Razr M¹², and you will find timings for the calibration system in the `calibration.xml` file.

The performance score is the geometric mean of the ratios of the timings from the calibration system divided by the timings of the test system. We then multiply the geometric mean by 500.

Figure 4 shows the timings for an iteration from a BatteryXPRT test.

Component test	Timings (from <code>batteryxpert_results.xml</code>)	Calibration values (from <code>calibration.xml</code>)	Ratios
Apply Photo Effects	37.96	66.00	1.74
Create Photo Collages	13.04	36.64	2.81
Create Slideshow	28.00	50.00	1.79

¹² The specs are available at www.gsmarena.com/motorola_droid_razr_m-4973.php.

Detect Faces to Organize Photos	7.98	14.22	1.78
Encrypt Personal Content	62.87	168	2.67

Figure 4: The timings for an iteration from a BatteryXPRT test.

The geometric mean of 1.74, 2.81, 1.79, 1.78, and 2.67 is slightly less than 2.11. The geometric mean multiplied by 500 is approximately 1,053, which is the performance score for this iteration.

AFTER RUNNING THE BENCHMARK

Comparing results to the database

You can view results for BatteryXPRT 2014 for Android [here](#). To find detailed information on any set of scores, click the link under the Source column.

Important note: Never compare results from one mode to results from a different mode. As explained in the section Differences between Airplane mode and the Wi-Fi/Cellular modes, the three modes may return different results because your device will use different amounts of power depending on whether it is accessing the Internet, and whether the Wi-Fi is enabled.

Submitting results

BatteryXPRT 2014 for Android allows you to submit results to Principled Technologies. Simply click the Submit Result button on the result screen. Fill in a contact name and e-mail address. The address and comment fields are optional. Then, all you have to do is click submit.

BatteryXPRT 2014 | Submit Results

Name

Email

Address

Comments

ABOUT THE BENCHMARKXPRT BENCHMARKS

The BenchmarkXPRT tools are a set of apps that help you test how well devices do the kinds of things you do every day. In addition to BatteryXPRT 2014 for Android, the BenchmarkXPRT suite currently comprises the following tools:

- MobileXPRT, an app to test the responsiveness of Android devices
- TouchXPRT, an app to test the responsiveness of Windows 8 and Windows RT devices

- WebXPRT, an online tool to test the Web browsing capabilities of any device with Internet access
- HDXPRT, a program that uses commercial applications to test the capabilities and responsiveness of PCs

We designed the apps to test a wide range of devices on a level playing field. When you look at results from XPRTs, you get unbiased, fair product comparison information.

The community model

We built BenchmarkXPRT around a unique community model. Community membership is open to anyone, and there are many different ways to participate.

Members of the BenchmarkXPRT Development Community are involved in every step of the process. They give input on the design of upcoming benchmarks, contribute source code, and help test the benchmarks. Community members have access to the source code and access to early releases of the benchmarks in the form of community previews.

The community helps us avoid the ivory tower syndrome. Diversity of input during the design process makes the tests more representative of real world activity. Giving community members access to the source code both improves the implementation of the benchmark and increases confidence in the code.

The community model differs from the open source model primarily by controlling derivative works. It is important that the BenchmarkXPRT benchmarks return consistent results. If the testing community calls different derivative works by the same name, the result would be that the test results would not be comparable. That would limit, if not destroy, the tools' effectiveness.

Where can I get more information?

Visit us at BatteryXPRT.com or follow us on [Twitter](#) and [Facebook](#). We announce breaking news on the [BenchmarkXPRT blog](#) (available to everyone) and the [BenchmarkXPRT forums](#) (available to members only). If you cannot find the answer to your question, or if you need help with BatteryXPRT, send an email to our team at BenchmarkXPRTsupport@principledtechnologies.com.

WHAT IS THE BENCHMARKXPRT DEVELOPMENT COMMUNITY?

The BenchmarkXPRT Development Community is a forum where registered members can contribute to the process of creating and improving benchmarks, including BatteryXPRT. If you are not currently a community member, we encourage you to join! (Yes, that means you – our community is open to everyone, from software developers to interested consumers.) Not only will you get early releases of future versions of BatteryXPRT, but you will also be able to download the source code (available to members only) and influence the future of the app. [Register](#) now, or for more information, see the [BenchmarkXPRT FAQ](#).

CONCLUSION

We hope this paper has answered any questions you may have about BatteryXPRT for Android. If you have any other questions, or if you have suggestions on ways to improve the benchmark, please post them on the community forum or e-mail us at BenchmarkXPRTsupport@principledtechnologies.com. For more information, visit us at BenchmarkXPRT.com and BatteryXPRT.com.

ABOUT PRINCIPLED TECHNOLOGIES



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Our founders, Mark L. Van Name and Bill Catchings, have worked together in technology assessment for over 20 years. As journalists, they published over a thousand articles on a wide array of technology subjects. They created and led the Ziff-Davis Benchmark Operation, which developed such industry-standard benchmarks as Ziff Davis Media's Winstone and WebBench. They founded and led eTesting Labs, and after the acquisition of that company by Lionbridge Technologies were the head and CTO of VeriTest.

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