MOTION INSTRUMENTS

MOTIONIQ APP

USER GUIDE

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Introduction

MotionIQ is a powerful software platform from Motion Instruments that provides a comprehensive view of your bike suspension. Setting up a bike is tedious and complex, that's why you need data to help guide your decision making. A lot of terms and concepts are conflated when discussing suspension data. Topics like data acquisition, data logging, and analysis are discussed without specific definitions for what the data is and how it should be used.

MotionIQ solves this by providing a comprehensive framework to describe how your bike is interacting with the terrain. There are a number of unique features that make MotionIQ a powerful platform for analyzing a bike:

- Analysis employs specific bike geometry and shock leverage ratio
- Comprehensive bike balance analysis for stroke length and depth of travel
    - Front and rear stroke length, depth, and speed are normalized
    - Side by side watermark analysis
- A/B analysis, comprehensive side by side view of runs in a spreadsheet
- Cloud storage integration, your data is automatically migrated off of the phone
- Easy data sharing via Text, email, or AirDrop (no internet)

By leveraging MotionIQ data, you will save potentially years of testing time. You'll correlate the feeling on your bike with data. Instead of guessing what's happening, you'll see clearly what your bike is doing and what you'll have to modify to support your riding ability and speed.

Data Acquisition Sampling

What is data acquisition? Data Acquisition is simply a task that measures and records data. It could be a temperature gauge or a speedometer. Typically this task is measuring something in the analog domain and then transferring it to digital. If this device is measuring at a periodic rate, then possibly a timer goes off, a sensor takes a reading, and then something takes that reading and stores it in a file with a timestamp.

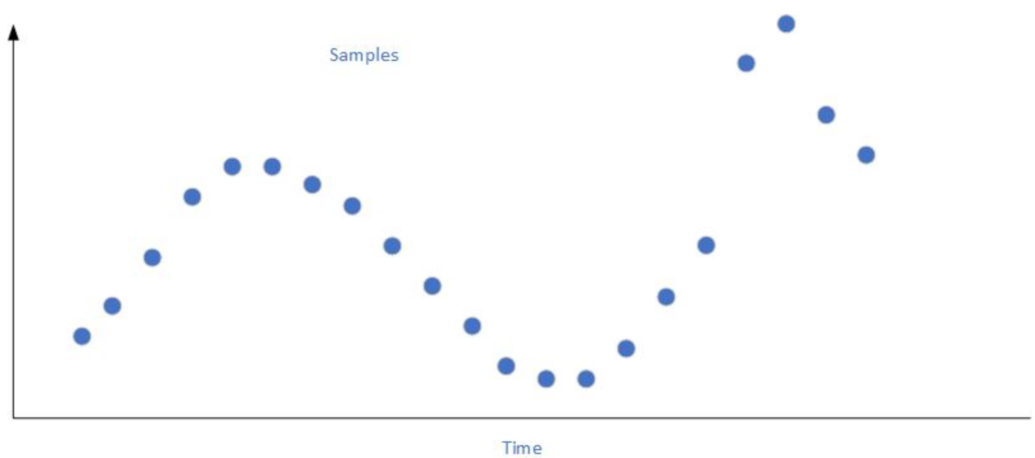
0.1 seconds , 5.0 degrees
0.2 seconds , 5.1 degrees

The sample rate is typically called out in some form of samples in specific time intervals. In all cases we've seen, this is samples per second, or Hz (pronounced hurts). For MotionIQ, we use linear potentiometers (pots) to measure a suspension. It's a really simple device, it's essentially a variable resistor. In our design, a processor feeds a voltage to the pot, then based on the position of the wiper, a fractional voltage will output from the wiper leg of the circuit.

To understand how this works, here's a simple example:

- Feed the pot 3.0 volts
- If the wiper was all the way open, the output of the pot would be 3.0 volts.
- If the wiper was all the way closed, the output of the pot would be 0.0 volts.
- If the wiper was exactly ½ the distance of the pot, then the voltage would be 1.5 volts.

As the wiper moves, the processor will sample the voltage at a predetermined data rate, in our case 200 Hz.



In the preceding diagram, samples are taken at a periodic rate. For the sake of argument, let's say it's 1 Hz. If you wanted to know the sample interval, the time between 2 samples, this is calculated 1/sampleRate. For this case 1/1Hz = 1 second. The sample rate for 200 Hz is 1/200 or 0.005 seconds.

Now that you know what sample rate is and how data is collected from a potentiometer by reading it's wiper voltage, there are a couple of other things you need to understand. All we've done to this point is collect a voltage. We have no idea what position it is in distance. This is how distance is calculated:

- The potentiometer has a wiper range, IE 100mm, 200mm, etc
- We need to convert voltage to distance
- wiper-Postion = wiper-Voltage/input-Voltage * wiper-Range

So let's expand our example above. Let's say our pot is 200mm in length, and the feed voltage is 3.0v. If you were to read a voltage of 1.5v on the wiper, what is the current position of the wiper?

1.5v / 3.0v * 200mm = 100 mm

If this is good enough for you to understand the mechanics of how data collection works. You can skip to the next chapter. But if you want to understand more, keep reading…

Resolution is a term used to define how closely you can measure between samples on the y axis. In other words, what is the smallest change in position you can detect? In the analog domain, it's nearly infinite, but the processors cannot measure beyond a certain point.

In every embedded processor, there are special pins that you can feed an analog voltage to (as long as it is not a higher voltage that the part can handle) and the processor will convert this to a digital word. This engine is called analog to digital conversion, or ADC. Every ADC has a resolution parameter, IE how many bits for a word. In our case, the ADC word is 12 bits wide. This means that a voltage read into the ADC is then converted to a twelve bit word. Here's an example:

- inputVoltage: 3.0 volts
- wiperVoltage: 1.5 volts
- 1.5v/3.0v * 2^12 = 2048
- 2048 digital in expressed in binary: 1000 0000 0000

Another aspect of resolution of the ADC is it will tell you what the minimum movement you can detect. In our 12 bit example, there are 4096 discrete positions (0 to 4095) that can be measured along a potentiometer, no matter what the size. Here are some examples of 12 bit resolution for different pot sizes:

- 200mm Pot resolution: 0.0488 mm
- 100mm Pot resolution: 0.0244 mm

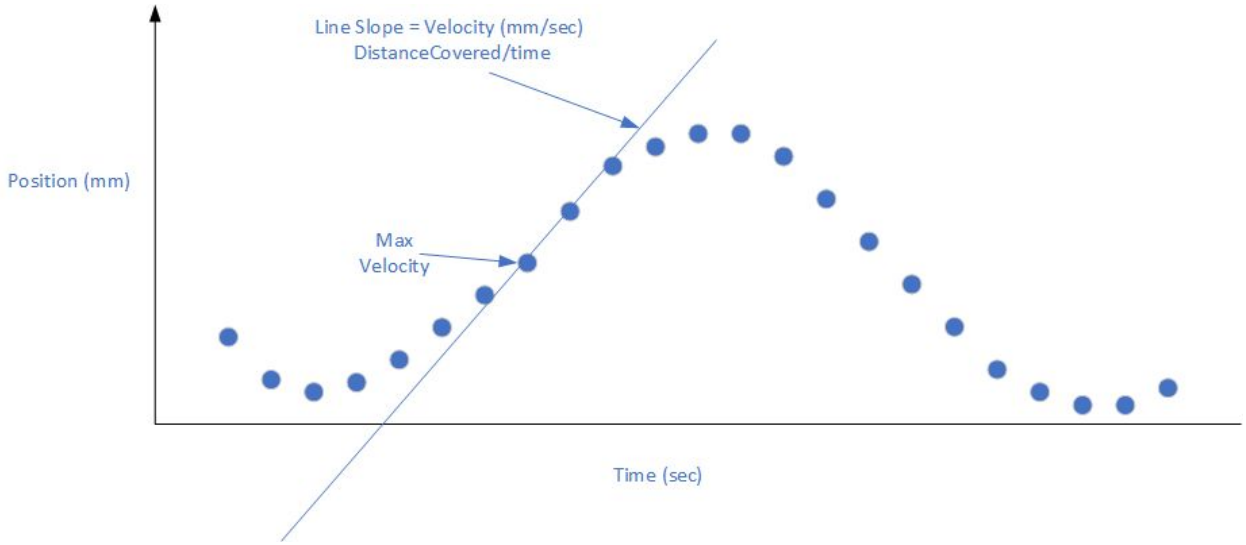
So the smaller the pot, the better the resolution. To summarize, resolution is calculated knowing the ADC bit width and the potentiometer size. Resolution = PotLength / 2^(ADC bit width)

Now that we know the potentiometer size, and the resolution. We now have the information necessary to put the sensor on your bike. All we need to know is what is the stroke range of your fork or shock, and where is the starting point? Once we know those data points, we're ready to start collecting data from the fork or shock.

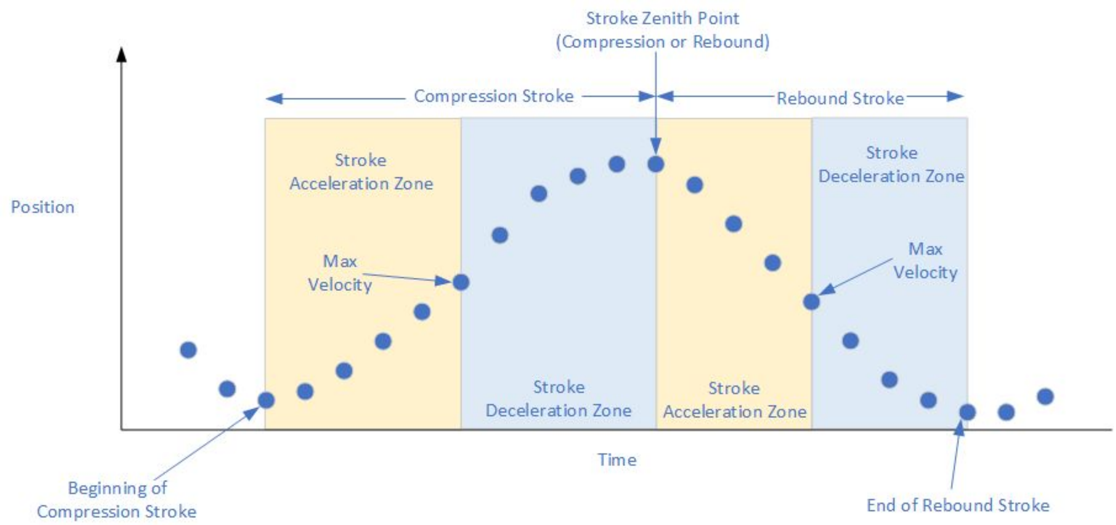
There are whole studies in electrical engineering on just transferring information from analog to digital. Doing this without adding a lot of noise to the signal is actually quite challenging and it's not as simple as just taking measurements in periodic intervals. Noise will need to be filtered out and this is done in the digital domain. This field of study is known as DSP, or Digital Signal Processing. We've done quite a bit developing our system.

Anatomy of a Stroke

A discussion is warranted on what a compression and rebound stroke is. Compression happens when you hit a bump, your suspension compresses inward. Once your stroke is maxed out, the damper will rebound. Pretty simple concept. Let's take a look at some key metrics to keep in mind for future discussions in this document.



Here we have some samples taken of a suspension compressing, then rebounding. At any sample point, we can calculate the velocity by drawing a line tangent to the waveform. In calculus, the instantaneous slope of any equation can be found by taking the first derivative of the equation, then plugging in numbers. Velocity is simply the rate of change of position. Typically called out in Inches/sec or mm/s. Knowing your stroke velocity is really important in suspension analysis because it is really difficult to measure force directly. But knowing velocity gives you an idea of how the damper is resisting external forces.



Let's dive a little deeper into some more terms we'll be pulling in later chapters. Every compression or rebound stroke starts with an acceleration phase followed by a deceleration phase. At the transition between acceleration and deceleration is a point where the stroke hits max velocity. Once this max speed is hit, the damper is starting to slow down the stroke. Once the stroke hits zero velocity, you have hit the zenith of the stroke. For a compression, this is where the stroke ends. For rebound, this is where the stroke starts.

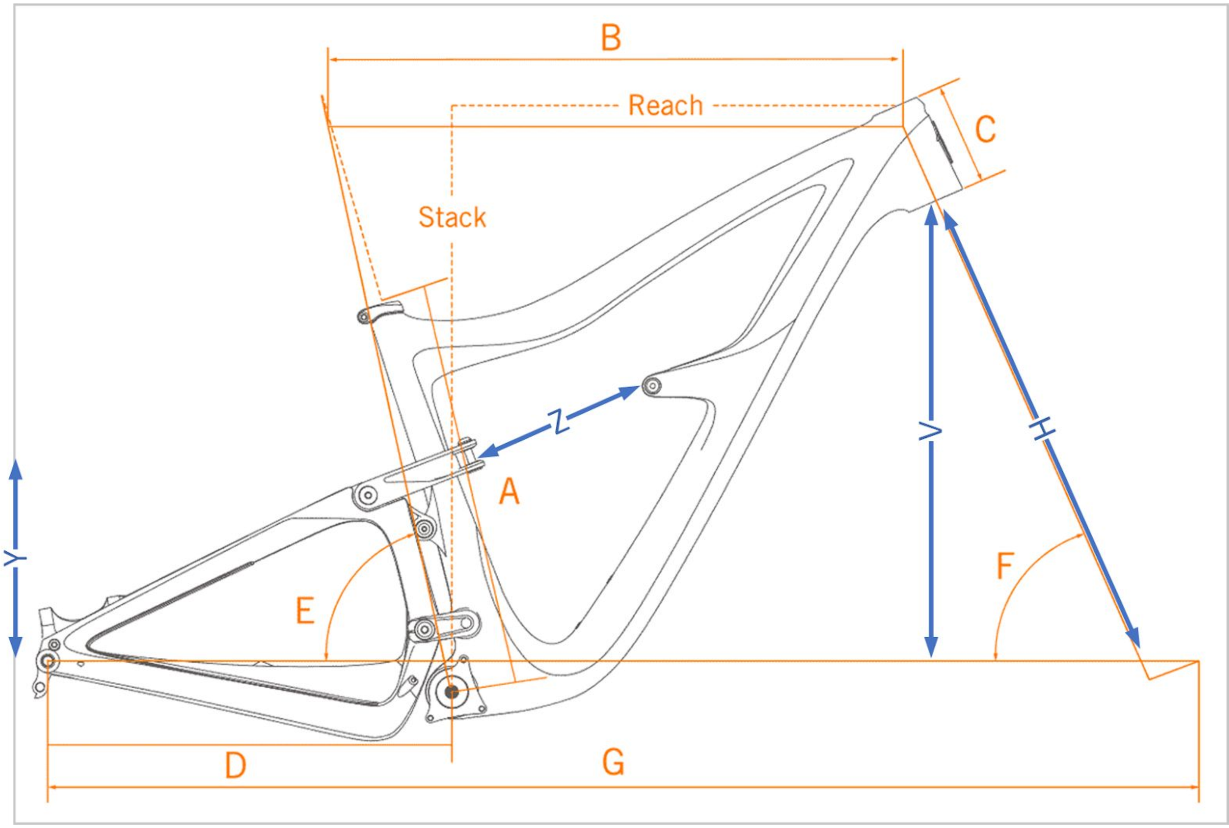
Damper engineers will want to know where the max velocity points are in the stroke. Racers probably won't need to pay attention to the position of max velocity, but will want to know the max velocity of the stroke in general. Much more on this later.

One other important note is the length of the stroke. This is defined as the difference between the zenith and stroke start or end. Stroke distance and speed are important metrics we'll want to pay close attention to for balance. We'll also want to pay close attention to the zenith point of the stroke and max velocity of the stroke. We will dive deep into these concepts during bike balance.

For now, just keep these terms in the back of your mind. These are key concepts to memorize.

- Stroke Start or End point
- Stroke Max Velocity point
- Stroke Max Velocity position (mm of displacement)
- Stroke Zenith
- Stroke acceleration zone
- Stroke deceleration zone
- Stroke depth (distance the stroke traveled in mm)

Bike Geometry Key Concepts



Here we have a generic bike geometry diagram. We're not going into everything on this chart except for the key concepts we need to understand about analyzing a bike suspension. The rear suspension moves up and down. This is typically called out as the VERTICAL distance traveled of the rear axle. Key point here, vertical up and down distance, not the arc length or total axle movement in the x and y direction. Keep in mind, bike axles move in 2 directions. Axles can move backward and forward in a full stroke. There is a whole area of frame geometry study on anti-squat you can reference on the x axis motion (back and forth). What we're concerned with is the up and down motion for our analysis.

Next, fork shaft length is called out on the datasheet. Bikes do not call out the vertical displacement of a fork. For the purpose of analyzing bike balance, we want to calculate the vertical travel of the front axle. We will compare front and rear axle motion in the vertical direction. To get to the vertical motion distance, we simply multiply the stroke distance of the fork by the sin(F) where F = the head tube angle. If you need a refresher on trig, sin is simply the ratio of vertical/hypotenuse for the imaginary right triangle on the head tube angle (V/H).

Now we need to know what the rear axle is doing. We cannot measure axle position directly so we have to derive it from another source of data. We typically do this by measuring the shock position. If we have the bike's leverage curve, then by knowing the shock position, we can do a simple calculation to derive the axle position. It is possible to measure anything that moves on a linkage system, but you'd have to manually measure the movement and come up with a table that describes the motion.

In MotionIQ, we use a bike definition file (.mibd) to describe the bike. The file is comprised of the leverage curve and other metrics. When you select a bike, this file is used to derive axle position based on shaft position of the fork and shock. In short, we are analyzing a combination of shaft speed data along with axle speed and position data to quantify what your bike is doing during your ride.

Finally, leverage is a very simple concept. It's a force multiplier. You can come up with the force multiplier ratio by knowing the instantaneous lever ratio. A typical bike leverage curve will start out high, then ramp to low numbers near the end of the rear axle max position. So the leverage changes as shock position changes. A simple linear leverage approximation is just the ratio of rear axle range of motion to shock range of motion. If your shock moves 50mm and your rear axle moves 150mm, the linear leverage approximation is 3 (150mm/50mm). In reality, rear triangle kinematics are designed to minimize pedal bob and maximize suspension performance. So leverage ratios are never constant, even for a motorcycle with no linkage.

Before we leave this section, here are the key concepts:

- Rear axle motion is called out in vertical direction
- Fork motion is called out as shaft motion, we have to derive the vertical motion
- A bike has a leverage ratio to describe forces applied to the shock through the entire range of motion
- One way to analyze bike balance is to compare front and rear vertical axle motion
- The head tube angle forms an imaginary right triangle. To get front axle vertical motion, multiply the fork position by sin(F), where F is the head tube angle.

Data Analysis

By now you have a basic understanding of sampling, position and velocity, and bike geometry. Now it's time to start looking at analyzing the signal you collected when you ride your bike. Every metric we'll talk about should be easy to understand and started with a question. We'll try to give you context into what information we were looking for when we wrote the software to extract the answer. An analogy we like to use to describe our system is as follows: Record your voice, if you look at the recording on an oscilloscope, it will just look like a squiggly lines. Your suspension will also look just like a squiggly line. The analogy here is that data acquisition or telemetry is just a recording, or a squiggly line in the time domain. Once you have this data, could you tell what was said by looking at the voice waveform? Probably not. This is called voice recognition. Voice recognition is our analogy for Data Analysis. Just because you can collect data, does not mean you have any insight into what happened. You need to thoroughly analyze the signal to extract useful information. Do not get overwhelmed by the gobbly gook on the charts and graphs, just try to understand the underlying concepts. If you understand the concepts, the charts will convey meaning to you and you will not be intimidated.

For each set of data, we will also describe what you can do to change the data. The key thing to keep in your mind while reading this document is that no suspension change is made in isolation. They are all inter-related. Every clicker, token, air pressure change, etc will have an effect on the entire system. Changes made to the front of the bike will have an effect on the back of the bike and vice versa. With the potentially billions of combinations of settings at your disposal, you won't have time to try them all. But understanding the data you collect and analyze, you will be able to get to your ideal setting in very little time. In the process, you will become a suspension expert and will have the confidence to make changes to your suspension with no second guessing. This will have a profound impact on your ride quality and ability. With confidence, you should make strides in your riding ability too. Data is not just for the EWS and DH world cup racer, it's for you. Read on and get ready to become an expert.

Suspension Watermarks

Your fork and shock come with o-rings attached for a reason. O-rings make setting sag a lot easier. Also, how would you know what your max travel was without the o-ring? Jason Marsh, Greg Minnaar's mechanic, would spread some orange grease on the shock shaft to see how far the damper compressed. On a coil shock, it would be tough to get a visual measurement because it's impossible to get a set of vernier calipers on the shock shaft without taking off the spring. But at least there is a method, cumbersome as it may be.

Other metrics you may want to track about the fork or shock shaft may be the following:

- How many times did I hit bottom?
- How many times did my fork or shock go fully open?
- What was the max compression or rebound speed of my ride?
- How many compression or rebound strokes?
- What was the total up/down distance traveled on my fork or shock?

Basic shock or fork metrics are just the starting point of understanding what your bike is doing. But you need to start here. You can't jump to bike balance without getting your bike basically dialed in with these metrics. Once you've got the bike working within the range you want, then you can jump over to bike balance and start turning knobs.

Axle Position: Static Sag (Pre-ride)

Static sag is a basic o-ring measurement. With the help of someone else, you get on your bike, jump up and down, get into an aggressive riding position. Then your buddy drops your o-rings down to the current position of the fork and shock. You get off the bike and measure the o-ring position with a tape measure or vernier caliper. From this measurement, you can calculate the percentage of travel.

Why is static sag important? Well the manufacturers have done a lot of testing and have determined what sag percentage you should start out with for your fork and shock. We recommend starting with their recommendations. This should give you enough headroom to hit large bumps and jumps, but also be compliant enough to absorb small bumps when pedaling on flat ground.

You can move your static sag measurement by adding or removing air pressure. For a coil, you will twist the spring clockwise to add preload, or counterclockwise to remove preload.

Axle Position: Minimum Position

Once you are comfortable with your static sag. It's time to ride your bike with the recommended clicker settings given to you by your manufacturer. It's your best starting point. Leverage the hundreds of hours they've already put in.

This datapoint is only interesting to see if your shock or fork are fully rebounding to an open position. Your bike should have left the ground and if so, your fork should go to fully open. If this is not happening, chances are your seals on the fork or shock are sticky, or possibly not lubricated. I've seen fork manufacturers recommend setting the bike upside down to lubricate the seal every now and then.

Another thing we've seen in testing is blockage between positive and negative air chambers can prevent a fork or shock from getting fully open. Minimum position is not really a setting metric, but more of a "Is my fork or shock working correctly" metric.

Axle Position: Maximum Position

Maximum axle position will tell you if you have the correct preload or progressivity in your ramp up during compression. If your max position is only 50% of the travel range, then your preload is too high. If you are bottoming out, especially multiple times, then your preload is too low. Adjusting air pressure and/or adding/removing air tokens can modify the max position. Lastly, if you sent it and had 1 bottom out, that's not necessarily a bad thing. But if you heard metal on metal and felt a big slam, you may want to address this by making the proper adjustments.

Axle Position: Average Position

There is context you need to be aware of with this metric. Typically this is referred to as dynamic sag, or the average position during your ride. I want to focus on the "ride". If you are riding on flat ground, this metric is not going to mean much. You really want to know your average position on a long aggressive downhill section with obstacles you'll encounter often. Jumps, bumps, rocks, gaps, etc.

First off, how is the metric calculated?

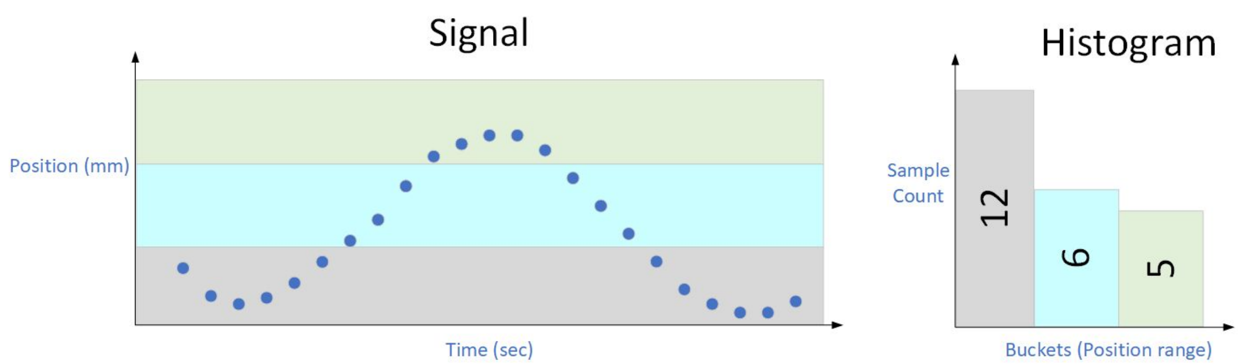
- Sum(every position sample) / number-of-samples.

You simply take every sample position and add it up, then divide by the number of samples. That's it. Average position should be taken in context with the position histogram which we'll discuss later. For now, just remember how this was calculated and that it does matter where you rode when looking at this metric.

Dynamic Data Collected over Time

Once you know the basics about your bike with watermark measurements, then you are now ready to look at other data about your bike. You can only derive so much information with watermark data, you need to look at velocity and position histograms to see the entire ride data in comprehensive single graphs.

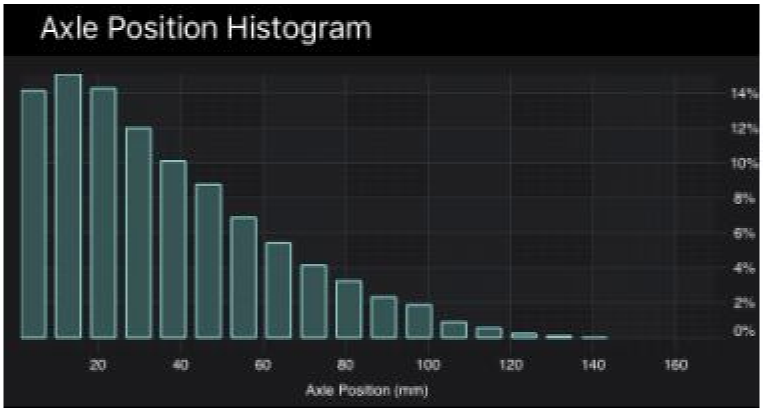
First thing, what is a histogram? It is a simple chart that shows you recurring events indifferent measurement ranges. This is a really powerful way to get a macro view of a large dataset.



In the preceding diagram, you will see a signal in the time domain. Samples are taken in a periodic time interval. On the y axis, 3 discrete position ranges were defined. For now, let's call them bottom, middle, and top. On the right graph, we've taken those buckets and placed them into a histogram. On the y axis, this is simply the number of samples taken per bucket. On the x axis, each bucket has a starting and ending point in mm. So a histogram is simply a chart organized with a series of buckets. Each bucket contains a number of samples that were recorded within that bucket range. Going forward, we'll refer to a histogram as buckets and samples. The samples could be position, stroke velocity, or other metrics we track.

For analyzing suspension and bike dynamics, the shape of these histograms will yield a lot of information. It's one of the best macro charts to convey information of large datasets. Now that you know what a histogram is, let's look at some data.

Axle Position Histogram



The axle position histogram works exactly like the simple histogram example above. Instead of 3 buckets, we separate into 20 discrete buckets. On the y axis, bucket height is called out in % of total samples. The width of each bucket is just the range of motion of the fork or shock divided by 20. So if you had a 200mm fork, you'd have 20 buckets of 10mm. Bucket #1 goes from 0 - 10mm, Bucket #2 goes from 10-20mm, and so on.

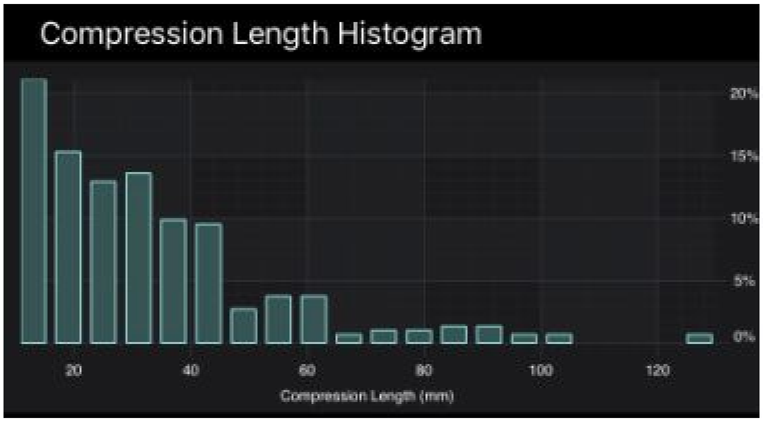
The axle position histogram should only be looked at if you have a valid dataset with your most aggressive riding. Flat ground riding will skew the data to the left, IE: more samples in buckets to the left.

The shape of this histogram can be changed in a couple of ways:

- To move the entire graph to the left, add air
- To move the entire graph to the right, remove air
- To increase the ramp, you can add a spacer to modify the progressivity of the air spring.
- To widen the ramp, you can take out a spacer.

Within MotionIQ, there are features you can use to isolate your analysis on sections of trail that matter. Use the handlebar button to drop pins on your ride, you can analyze your suspension between any 2 pins. Also, Strava segments allow you to quickly choose a strava segment. Pick segments with steep difficult terrain. The key thing to note is how different your data will look when comparing steep and deep vs. flat or climbing. Flat and Climbing data should not be included in your analysis.

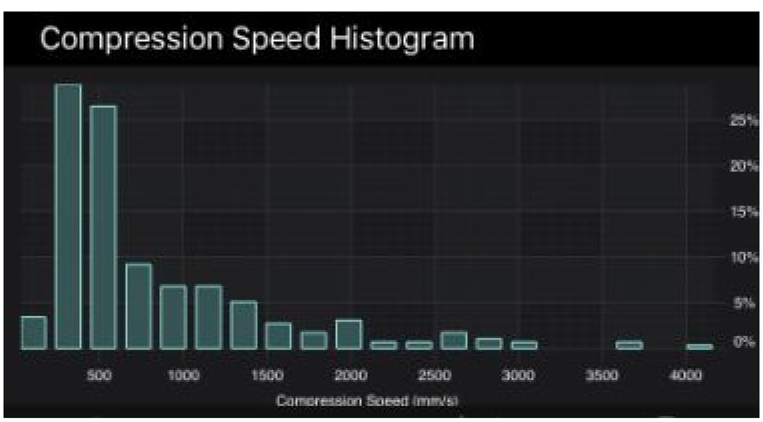
Compression Length Histogram



The compression length histogram simply looks at the length of every compression stroke. It doesn't discern compressions that start deep or early in the travel. They are all treated equally. This histogram is more informational and is highly dependent on the trail. If you are on a jump trail, you should see more strokes that are deep in the travel. A more xc or rocky downhill will see stroke lengths of things you hit. It's pretty rare to have full length strokes (IE fully open to fully closed) but when they happen, it's due to big jumps. If you do get a lot of these, you may need to increase your air spring. But you'd see this from looking at the max position data in your watermarks.

Do not make changes in isolation based on this chart alone. This chart just gives you a visual of the stroke lengths encountered during a recording or filter (segment within a recording such as a strava segment or MotionIQ Trace between 2 pins).

Compression Speed Histogram



The compression speed histogram is a single chart that shows you every compression stroke with maximum speed of the compression. Every stroke is put into a bucket. The range of the bucket sizes depends on the maximum speed stroke.

Bucket size = maxSpeedCompression/20

Then every stroke is counted in each bucket. From this you will see a relative stroke speed comparison by count. The slow speed compressions will be much higher in numbers than the really fast strokes. The shape of this graph can be modified with high and low speed clickers as well as preload and volume spacers. Volume and preload will have an effect on max speeds and the position of the max speed of the stroke due to resistive forces against compression. High and low speed clicker settings will restrict the oil flow within each pathway dedicated for high and low speed compression. Deciding on preload & air tokens vs. damper settings will be a trial and error approach. You will need to look at the compression speed histogram and position histogram when iterating on different settings.

Rebound Length and Speed Histograms

These histograms are just the same as the compression histograms mentioned above, except for the reverse direction.

Vibration Analysis

In the Motion Instruments system, there is an accelerometer built into the Fork Tracer. This measures vibration in g-forces in the direction of the fork to the rider's hands. The circuitry is referenced to the bike frame and now the up/down motion of the fork. This accelerometer, therefore, measures vibration that was not suppressed by the fork or shock. Essentially it's the vibration the rider is experiencing while riding their bike.
Accelerometer data, just like position data, is sampled at a periodic rate. The way to think of an accelerometer is a mass suspended between two springs. A force will cause the mass to accelerate and will oscillate. The maximum position of the oscillation will determine the max g-force. There are infinite ways to condition accelerometer data and our purpose is not to deep dive on that field of study. Suffice to say, if you're interested in this, there is a lot of information out there. The field of study is deep and be prepared to open your physics and differential equations textbooks from college.

Motion Instruments is using accelerometer data as a macro statistics, not a micro measurement for discrete movements. What matters in this analysis is the relative vibration that a rider experiences with the same hardware, same trails, same bike, but varying the suspension settings. As you make changes to your settings, the suspension will move more or less for the same trail (different damping forces restrict motion differently). Also, your acceleration data will be higher, the same, or lower. Even if the vibration is the same value, but your suspension moves more, it may be a better or worse feel.

The point being, take vibration data with a grain of salt. Your numbers are only relevant to you on your bike, riding your trails. You will use these numbers over time to track your performance as to what you like or dislike. These numbers are not transferable to another bike and rider. Some riders smash rocks with no regard, others drop their heels and get their weight back to loft the front wheel through a rock garden. Some manual through everything. Also, different bikes have different head tube angles, fork lengths, etc. Bottom line, don't compare notes on vibration data. It's a personal thing. Average g force is a metric that can be discussed as comparison, but without context of riding style, etc., it's usually not a conversation that will yield any actionable results. Vibration data is to be taken in context of all the other metrics you've collected with MotionIQ. These numbers are not to be used in isolation.

Vibration Measurements

During a ride, it is useful to look at what is the source of vibration in your ride and how much is coming from compression, rebound, or flat riding (<10mm of travel in compression or rebound). Within MotionIQ, every vibration sample is continuously added together into these three buckets. After the ride, the calculation is made where we sum the vibration samples by the # of samples collected for the entire ride. In most cases, the compression and rebound vibration will be roughly the same. Typically a compression stroke will happen faster than a rebound stroke so there will be more samples collected on rebound than compression.

Fork Movement-to-Vibration Ratio

This is an interesting statistic that is relative to a rider, how their bike is setup, and how aggressive the trails are. Use these statistics when analyzing side by side runs on the same course. In general, as each number goes up and to the right, your bike is getting dialed in. Let's explain the metric.
We often refer to this metric as the magic carpet number. It's a simple ratio of total up/down fork movement to the total number of g-force samples added together. The magic carpet number is infinity:

$$\frac{TotalWheelMovment}{TotalVibration}$$

Magic carpet = High Wheel Movement divided by near zero vibration. Point being, if your wheel travels a lot and then you feel no vibration, your bike is a magic carpet. Pretty simple concept. This ratio is more conceptual. As your bike suspension works more and suppresses vibration, this number indeed goes up.

The number can go up for a few different reasons:

- Vibration stays the same, but the wheel moves up/down more
- Wheel up/down motions stays the same, but vibration goes down
- Wheel up/down motion increases AND vibration goes down

Likewise, the number can go down for opposite reasons. An important point to consider is that the rider may be going a lot faster, but vibration naturally goes up. The bike may feel better. You want to note how the bike feels in rocks, corners, and jumps along with the data MotionIQ provides.

Every tune has context and you cannot look at any 1 set of data without looking at all of it together. This is a metric that cannot be taken alone. It is part of a dataset and needs context. Riding flat ground will yield a terrible number because the wheel doesn't move up/down but you accumulate vibration. There are other cases like this so do not make big tuning changes based on this metric alone.

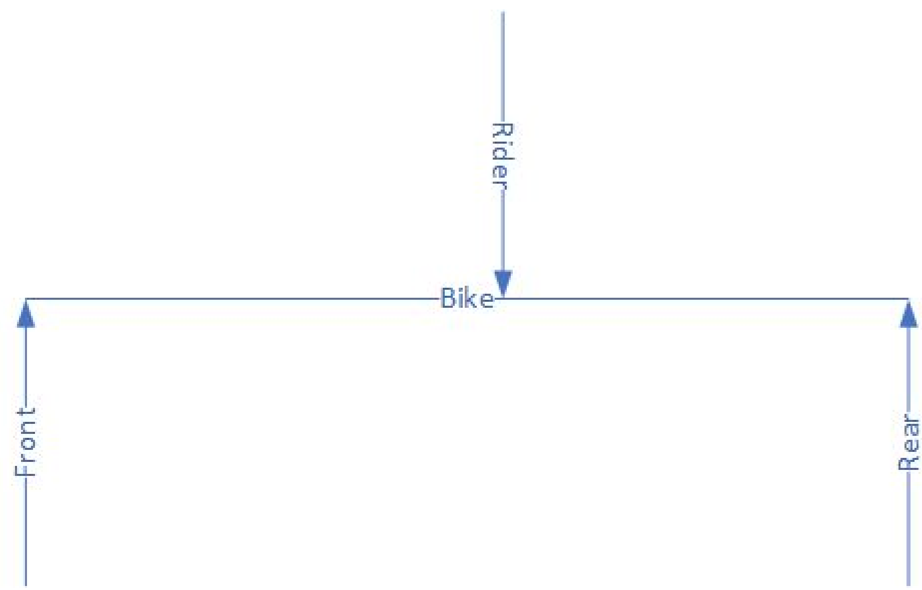
Vibration Averages

These metrics are pretty simple to understand. For compression, rebound, and other, all vibration samples are summed and averaged. That's it. Average g-force is a good metric to understand how much total vibration you are taking in. Again, the overall ride needs to be taken into context.

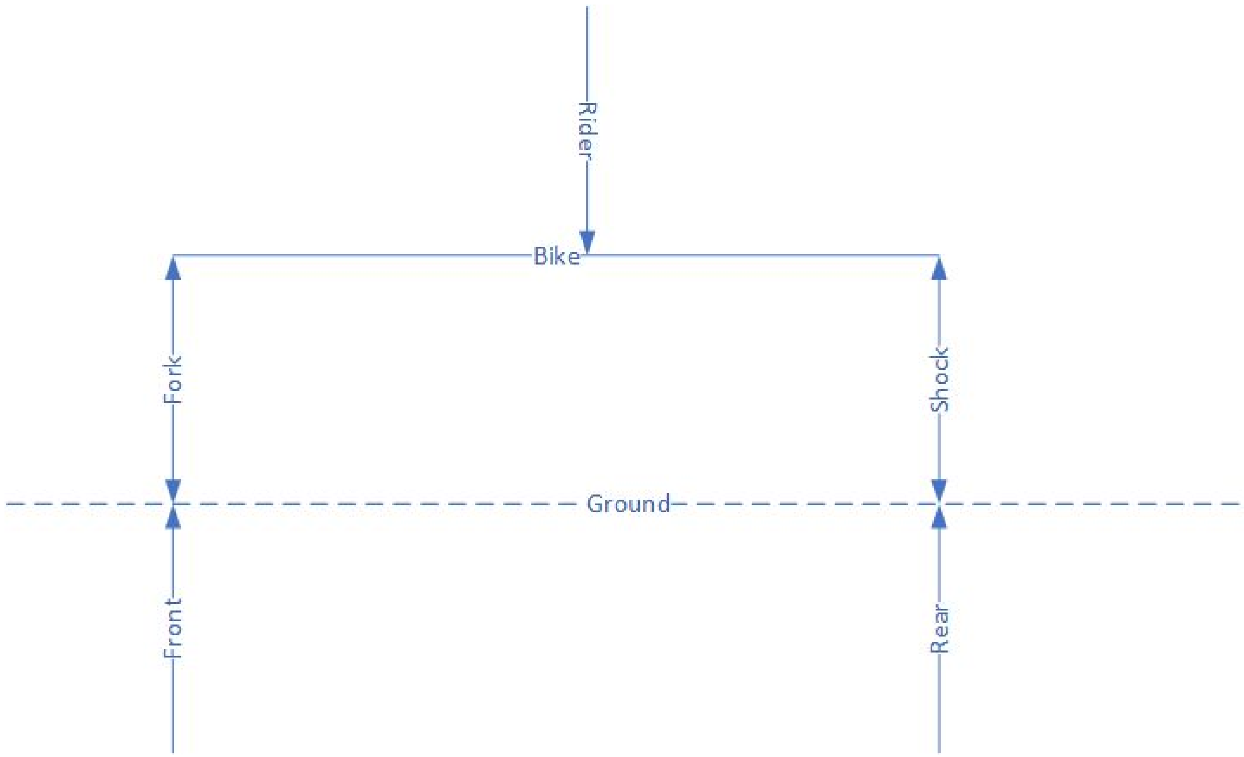
Bike Balance

What is bike balance? How do you quantify it? This is something we've heard everyone talk about but we've seen no data on how to measure the performance of bike balance. Even if you could quantify balance, on what trails should you measure it? Motion Instruments spent a lot of time working with many riders on the quest to quantify this mysterious metric.

The first thing to think about is that your bike is interacting with the ground and there is a balance of forces that are happening in real time. A simple view of your balance of forces can be summarized in a simple free body diagram:



The rider (when standing up) has a down force centered on the bottom bracket, there are matching forces that the ground responds with against the wheels. Between the forces that the ground exerts on the rider and your bike frame, there is a front and rear damper that is dispersing energy from these forces in the form of heat. When a damper compresses or rebounds, energy is distributed in time to reduce the sudden impact of incoming forces.



We need to quantify the front and rear damping characteristics to see if they balance out. There are several things we want to know when comparing the front and rear motion:

- Average position, or dynamic sag
- High and low compression speeds of the front and rear axle
- High and low rebound speeds of the front and rear axle
- Total up/down distance traveled of front and rear.

Conceptually, if your rear shock preload was so high that the shock barely moved, you can visualize that all of the force that the earth puts on the rear wheel is going to get transferred to the front of the bike, and vice versa if the fork was locked out. This example can be carried on with damping settings, IE: if your front compression is super damped, but the rear is not, a lot of forces are going to get transferred to the rear of the bike. On rebound, the damper is expanding and putting exerting a force back to the rider, and earth. So if one of your dampers was opened all the way, but the other was not, then the open damper is going to transfer energy to the other end of the bike. The rider will feel all of these forces on their feet, hands, and possibly saddle too. The bike will feel rocky, unstable, and will be difficult to ride in certain situations.

First and foremost, your bike was designed to handle terrain on downhill. Your bike's head tube angle, shock leverage curve, etc. was optimized to keep the rider center of gravity in a way to ensure the bike is stable. You don't want the rider feeling like they are going to go over the bars on a steep downhill for example. This is all part of the bike geometry. What is much more difficult to understand is how to set the bike up for the terrain you typically ride. This is where data is crucial.

Regarding bike geometry and stability, going back to the unbalanced preload example, if your fork was over inflated (air) and your shock was under inflated, then your bike geometry is going to change significantly, IE: the head tube angle is going to decrease because the front of your bike is riding high or "Raked Out". In the reverse case, your head tube angle will increase making your bike feel really unstable going downhill.

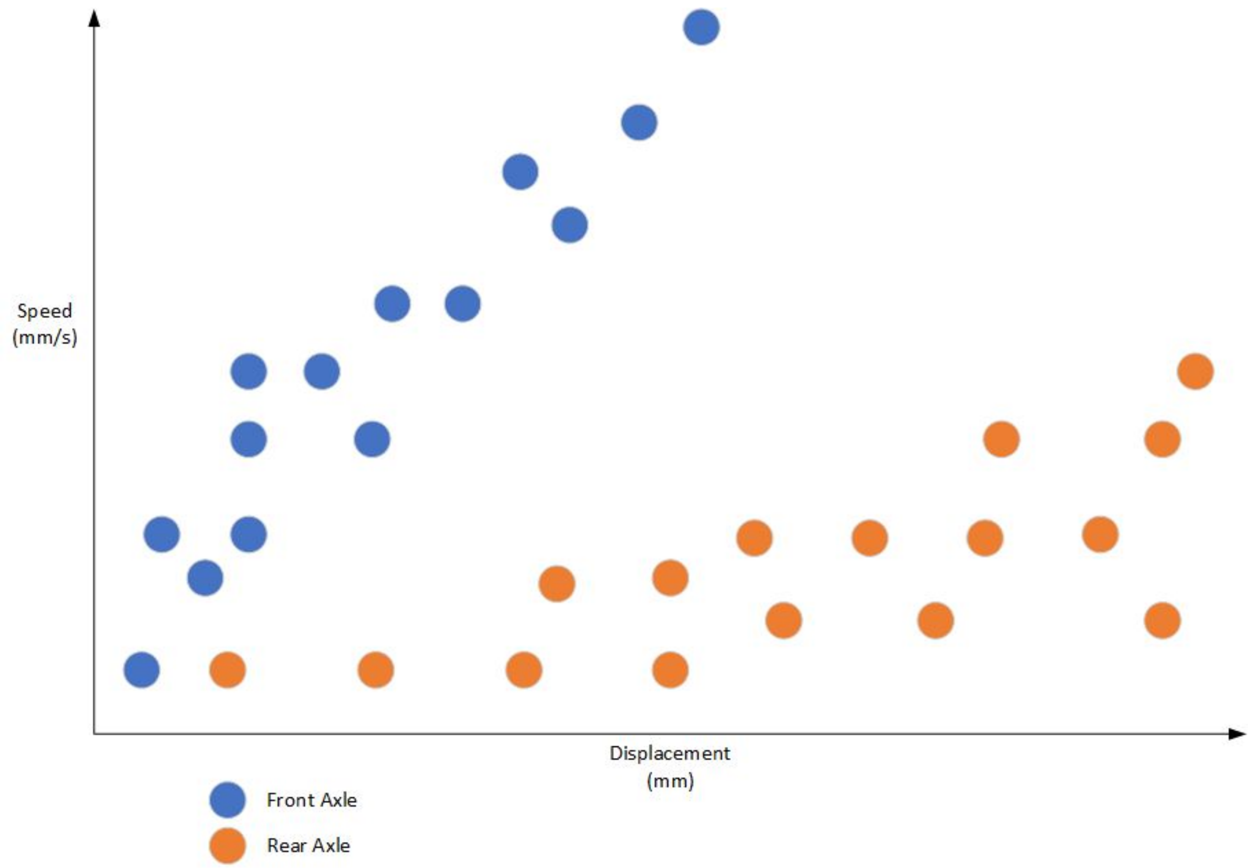
Dynamic Sag (Average Position)

An important metric to keep in consideration is your dynamic sag, or average position. In MotionIQ, we accumulate every sample and then divide by the number of samples to give you an average position number. You want to look at this number on aggressive trails, not flat riding. We make this easy for you in the app several different ways. When you analyze your downhill runs, you want to note your average position of the front and rear. If they are different, then you are intentionally changing the geometry of the bike. If you tend to ride off the rear of the bike, this will be reflected in the dynamic sag and you may need to compensate to get the bike balanced, IE: matched dynamic sag numbers (% of travel).

Front and Rear Dynamic Balance

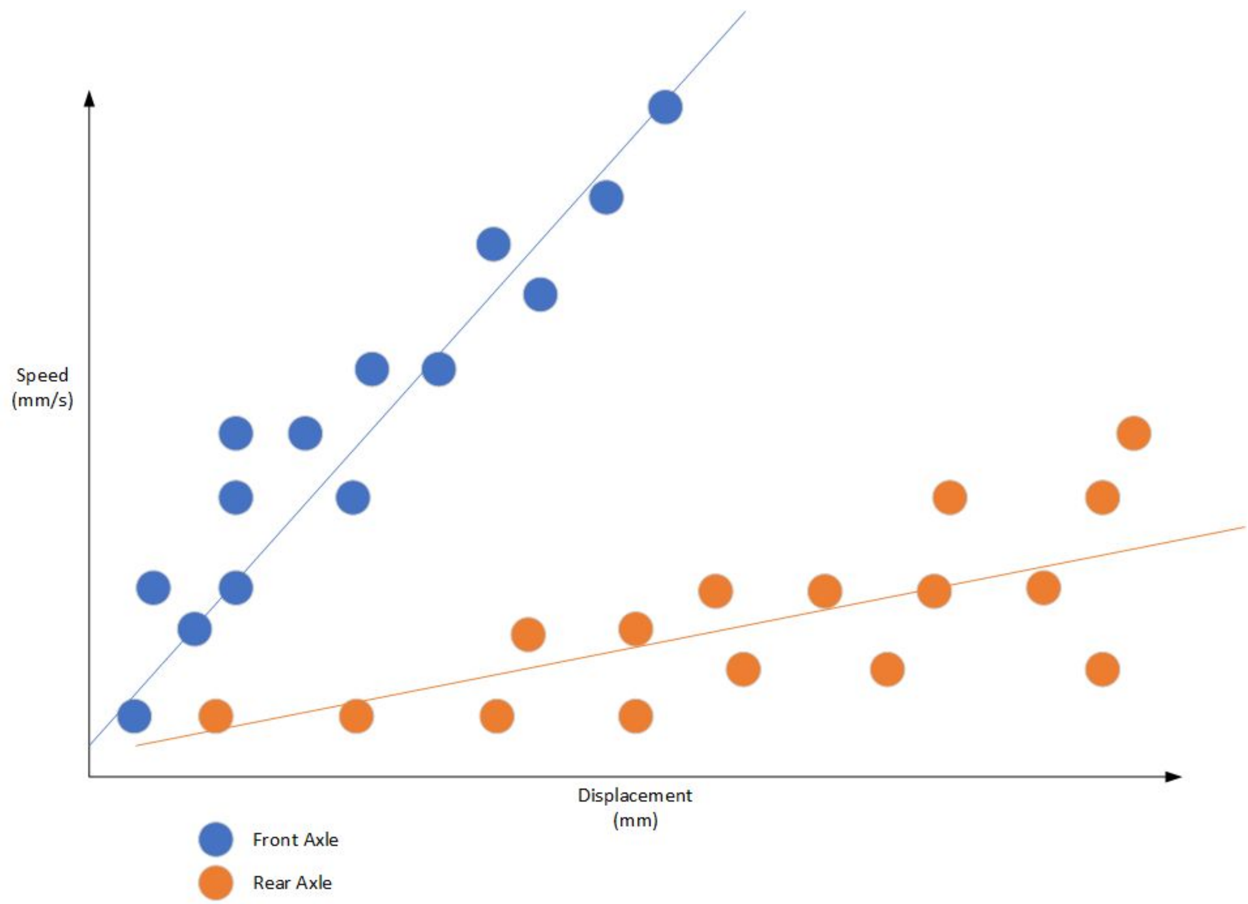
Force = mass x acceleration. By measuring the position of the fork or shock, we can simply calculate acceleration from the collected position data. The instantaneous slope at any point along the position curve is velocity. Acceleration is just the instantaneous slope at any point along the velocity curve. The difficulty is knowing instantaneous mass. If the rider stays in a fixed position on the bike, then it's easier to know the instantaneous mass, but we know riders are all over the bike. So it's actually difficult to measure the front and rear *forces* directly. Our goal, however, is to balance the damper forces from both sides of the bike. By doing this, the rider will get a consistent, stable feel.

Since we can't measure force directly, we need another method. A visualization of how the front and rear wheel is interacting with the earth will give us a really good indication of balance. Since the front and rear wheel are mostly hitting the same objects and terrain, they should be moving with the same speed for the same wheel displacement. Again, taking prior examples of unbalanced pre-load, the same theory applies for dynamic wheel movement. If your front wheel moves out of the way quickly when hitting a rock, but the back end does not, then your rear will apply a reactive force back to the front, and vice versa. Velocity and displacement are two important metrics when looking at balance.

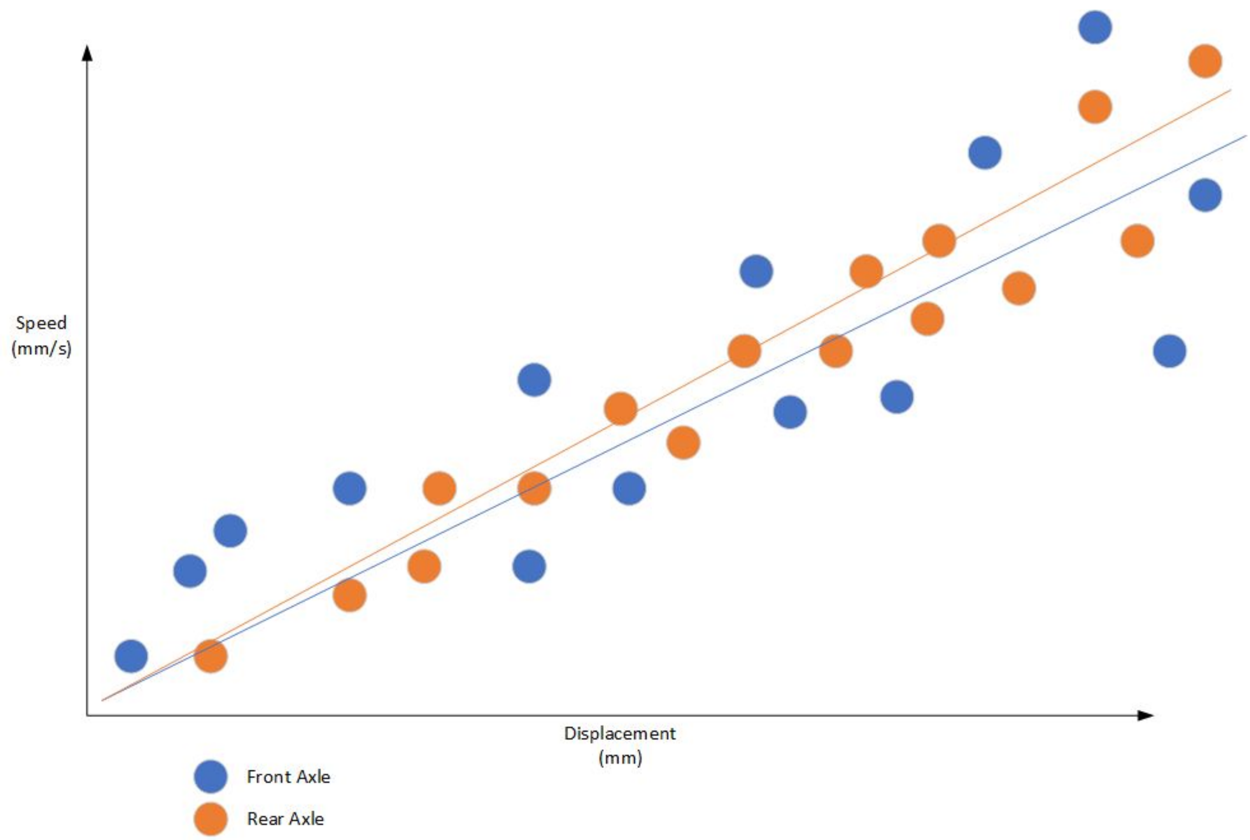


In the diagram above, we have plotted every compression stroke for a short ride. Each dot represents a compression event. The dot is placed on a 2 dimensional graph based on the maximum velocity of the stroke (mm/s) and the displacement distance in mm. Notice the fork compressions are moving much faster than the rear. Also notice that the rear is getting much more travel. This does not look like a balanced bike. The front is faster than the rear and not getting much travel.

This conceptual scatter plot is the underlying thesis of our bike balance. We've taken an additional step and have performed a linear regression analysis for each set of dots, front and rear. This regression analysis basically creates a best fit line through the data.



Notice after calculating the regression lines, how much different they are. If you were to try and balance this out, what would you attempt to change in your setup? If you were to remove some preload on the front fork, you may get more travel. This would have the effect of spreading out the dots across the graph. On the rear, you may be happy with the use of travel, but maybe you'd want to speed things up by opening up the compression a bit.



After making the changes and re-running the test, we've been able to get the bike balance. The fork is using more travel, the shock is compressing faster. The regression lines are now pretty balanced.

With any algorithm, you need to have context into the analysis. Bike balance is just a description of balancing forces on both ends of a bike. We employ some simple concepts to describe balance. Just because your bike is balanced, doesn't mean it is set up correctly. You may have balanced the bike, but at ½ the necessary speed. So the bike is going to feel very over damped.

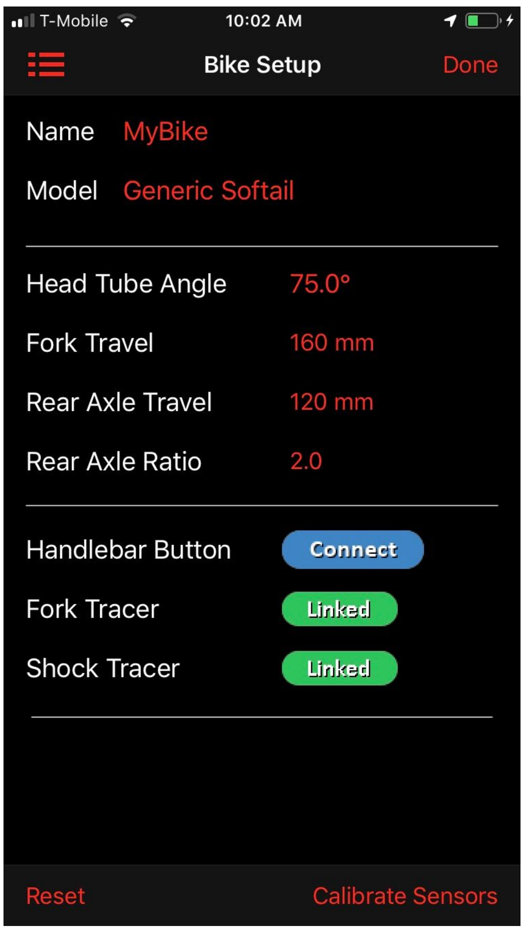
Also, there may be situations where you need to imbalance the bike for a certain race. IE, a super steep sustained downhill may require a slacker front end to make the bike feel stable.

It's important to correlate this data along with the feeling of the bike to get the correct setup. This will take trial and error, but once you have this experience under your belt, you will be very confident in your setup which will yield dividends at the race.

MotionIQ App Overview

The remainder of this document will focus on the MotionIQ app and will highlight the 3 major areas of the app: 1) Bike Setup, 2) Recording, and 3) Analysis.

Bike Setup

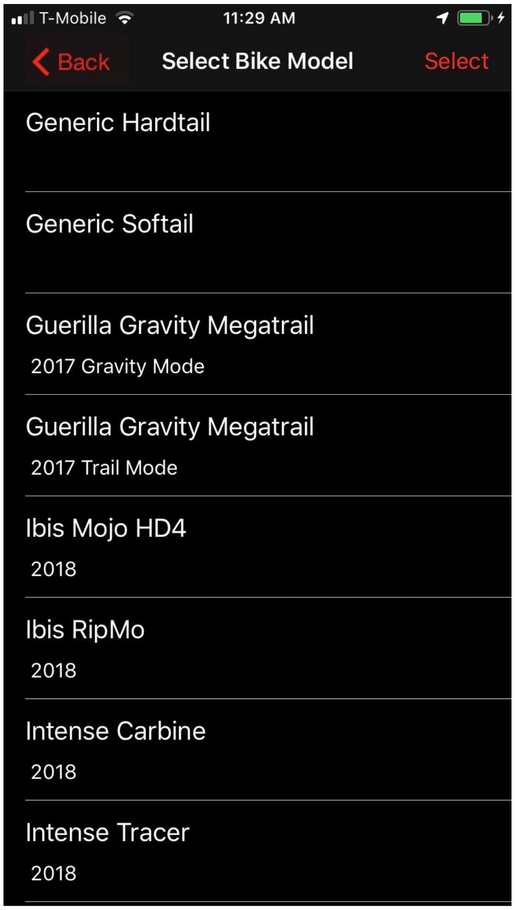


Setting up your bike is quick and easy. The bike setup screen allows you to configure the settings for your particular bike model and connect to your sensors. MotionIQ works with any bike model including hardtails, full suspension, air or coil.

Once you have named your bike, your bike will be saved in the bike profile list. By tapping the upper left icon, you will see a list of previously created bikes. Just tap on a bike, and all of the sensor pairing information is already configured.

Bike Frame Geometry

Motion IQ analyzes your bike, not just your suspension. MotionIQ uses your unique bike frame geometry to provide the most accurate analysis of your suspension performance for your specific bike. Your frame geometry and shock leverage ratio is used to accurately calculate the vertical travel and velocity of your front and rear axle. This data is critical for properly balancing your front and rear suspension. If your bike is not listed in our supported bikes, send an email to info@motioninstruments.com and let us know your make/model/year of the bike you'd like us to support. If we can't get it from the manufacturer, we can precisely measure the frame directly.

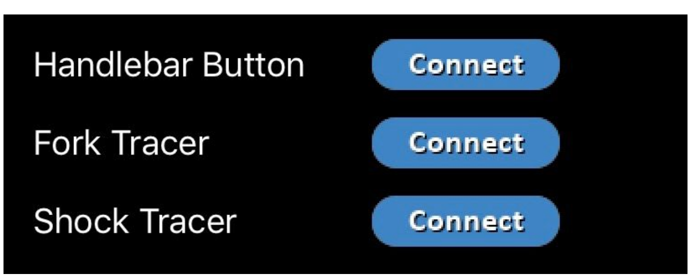


Bike Setup Files

Motion Instruments provides bike setup files for many popular bike models. Selecting one of these files will automatically load all of your bike settings including a detailed progression curve for your rear axle. PRO users can share bike setup files with other PRO users via email, iMessage, or AirDrop.

If your particular bike model is not yet supported you can select a “generic” bike model and manually configure your bike geometry. For generic softail MotionIQ will do a simple linear calculation for your rear axle position based on the sensor position and the axle ratio you provide.

Connecting Devices



Connecting to your Tracer devices is easy. Just tap the connect button and hold your phone next to the Tracer device for a moment. You will hear a “click” when the connection is made. If your phone is set to vibrate, then your phone will vibrate once connected to the device.

MotionIQ eliminates connection errors by only connecting to compatible devices. For example, if you are connecting to your Fork Tracer the app will ignore all Shock Tracer devices that might be nearby.

Tracer devices will automatically drop into sleep mode when not in use. To wake them up just shake your bike for 1-2 seconds.

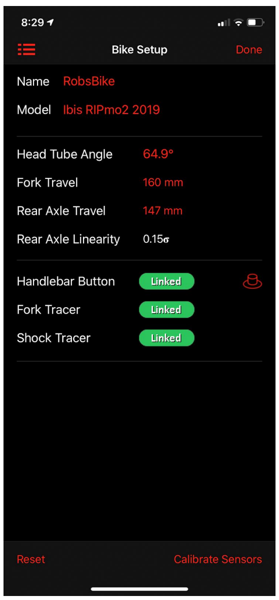
All connected devices will be saved automatically to your bike profile. MotionIQ will automatically reconnect to the same devices the next time you run the app and select the same bike profile.

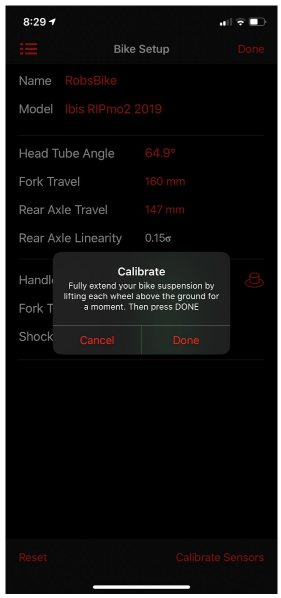
If more than 1 device has access to the hardware, it's a first come, first serve connection. To avoid confusion, only allow 1 device to be active when connecting.

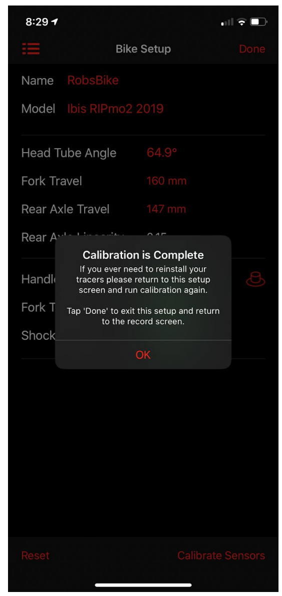
To connect the handlebar button, MotionIQ must have internet access when connecting. If another MotionIQ app wants to take control of the button, then the user must push the button for >10 seconds when connecting. This will sever the prior connection to the button and allow the new user to take control.

One Time Calibration

When you have all devices connected you will calibrate your sensors. This will set the zero point of your suspension. Tap the calibrate button on the bike setup page and put your phone down. Lift your bike so both wheels are off the ground and then set it back down. This will fully extend your suspension for a moment. Go back to the phone and tap done. There is no need to calibrate again unless you move your Tracer devices. Once you complete calibration you can exit the bike setup screen and return to the record screen.





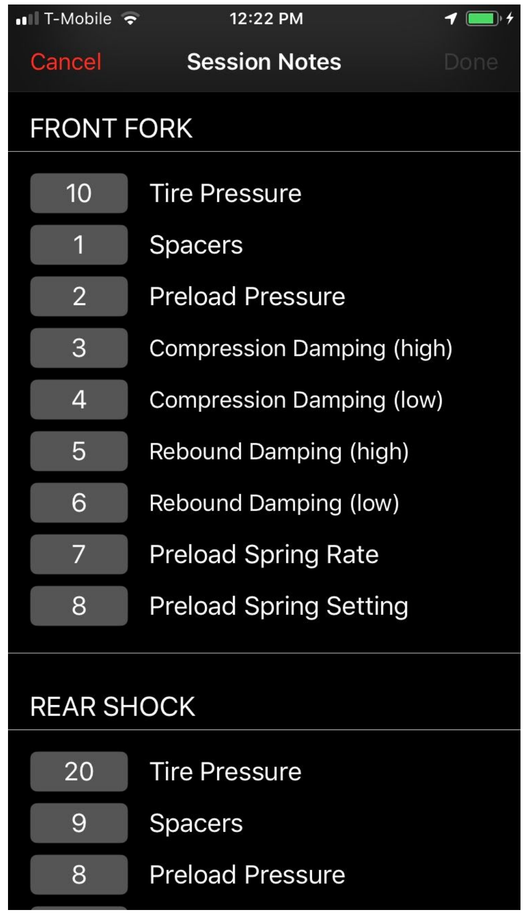


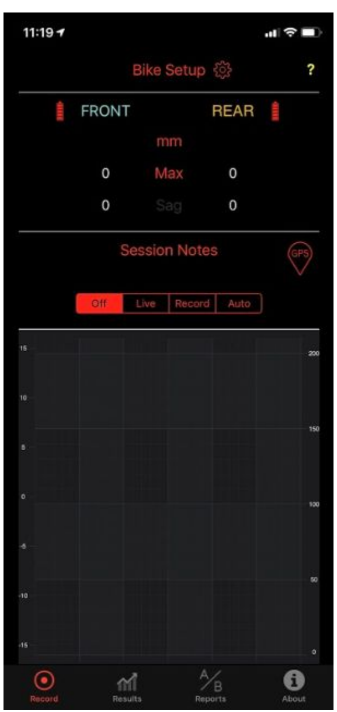
Bike Profiles

All of your bike settings and Tracer devices are saved in a named profile which you can access from the bike setup screen. You can create as many bike profiles as you want and switch between them easily.

Setting Notes

The session notes page lets you keep track of everything about your recording. This includes suspension settings, tire pressure, notes about the ride, ride score (0-10), Key words such as packing, chatter, etc, location/trail, and trail conditions. If you are diligent with your notes, you will have detailed historical data of your bike on your trails along with your perception of bike setup. Session notes can be edited after your ride if you forgot to add something. In the notes section, you can either type your notes with a keyboard or hit the microphone and MotionIQ will automatically dictate your voice to text.





Record Screen

Auto Sensor Connect

MotionIQ will automatically connect to your Tracer devices when you select the record screen. The battery status for each Tracer is displayed when the connection is made.

Current Position

If MotionIQ is connected to your bike and in Live, Record, or Auto Mode, you can view the current position of each sensor. You can view this in either millimeters or percentage of full travel.

Max Position

MotionIQ will track and record the max position during a Recording or Live mode. This can be viewed in mm or %.

Set and view Sag

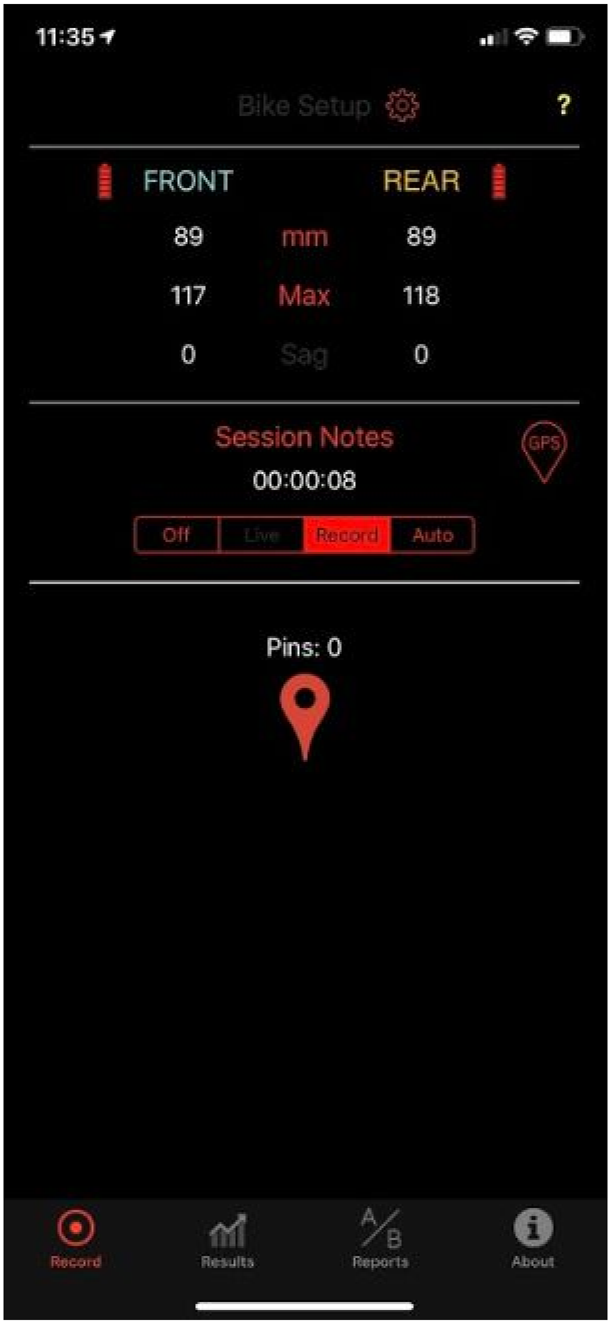
In Live Mode, you can set your sag. Hit the Sag button, then get on your bike in your normal aggressive riding position, jump up and down, and let the bike settle into position. Then record your sag position by tapping the “set sag” button in the app or push your handlebar button. Your handlebar button must be configured in the bike setup screen.

Live Mode

Once MotionIQ is connected to your sensors as indicated by the battery icons, you can do a quick check to see if your sensors are functioning properly. Hit the “Live” button and jump on your bike. You will see the position graphs move on the screen. You will also see the vibration curve (yellow) move up and down. Tapping the handlebar button will display a dot on the graph.

GPS Hunting

When you first navigate to the record screen, the GPS receiver will be hunting for a GPS signal. You will see a red flashing lighting bolt while this is happening. As soon as you have acquired a GPS signal, you will see the GPS pin. By tapping on the pin, you will see the current horizontal and vertical accuracy of your location.



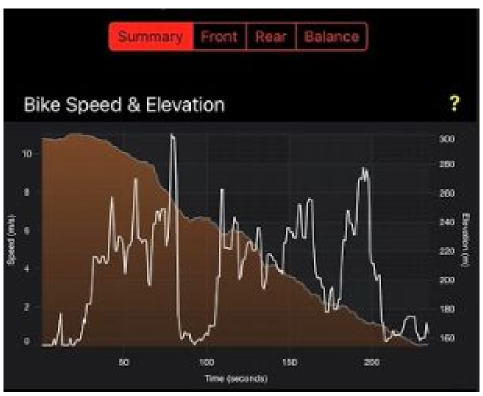
Record Mode

In “record mode”, MotionIQ will record everything. You can hit the pin button to drop a pin from the app. Or you can hit the handlebar button while riding. This will place markers in your data to help you find areas you want to investigate later.

Auto Record Mode

If there is an adequate GPS signal in your location as indicated by the GPS pin, then you can record in Auto mode. This will intelligently start and stop recording based on your movement. If you come to rest, MotionIQ will stop saving data in your record file. When you start moving, MotionIQ will wait until you are moving > 1m/s, then start appending data in your record file. This feature will attempt to reduce the size of your files.

Analysis



After your recording is complete and you've saved the recording, you can navigate to the Results view (second icon in the bottom navigation bar). Here you can select form four sub-views: Summary, Front, Rear, and Balance.

Bike Speed and Elevation

You can see the elevation and bike speed for the entire ride on the uppermost chart on the Summary Results Page. Tap anywhere in the graph to show the specific elevation and speed for that moment in time. Pinch to zoom in and out. Double-tap to zoom back to the original view.

Waveform Viewer

Use the waveform viewer to see exactly what your suspension is doing at any point in the recording. If you created any pins during the recording they will be displayed here in the waveform graph. There are four sub-views available:

- Pos: Shows the position of the fork and rear axle together with vertical G force
- Speed: Shows the speed of the fork and rear axle
- G-force
- Fork: Shows the fork position and speed
- Shock: Shows the rear axle position and speed
- Detailed Front and Rear waveforms along with Speed are viewable. The blue line are always the front axle position, the orange waveform is the rear axle.

Waveform Controls: Use the checkbox in the upper left corner to selectively enable or disable any waveform. Use the two-finger pinch and zoom to control the view. Use a single finger to pan left-to-right. Double tap to zoom back to the original view.

GPS Map

The GPS map viewer will place your tracks onto a map. You will see a start (S) and finish (F) pin along with any pins you dropped along the way. You can view your tracks on a Standard, Satellite, or Hybrid map view. Tap the pin to view the elapsed time for that pin.

Export: In the GPS map view, there is an export button on the upper right corner. This will allow you to share your GPS tracks to Strava, Google Earth (KML), and GPX. Tapping GPX will create a file that you can share with anyone via text, Mail, AirDrop, etc. GPX files can be used on GPS devices such as Garmin.

Export Recording File

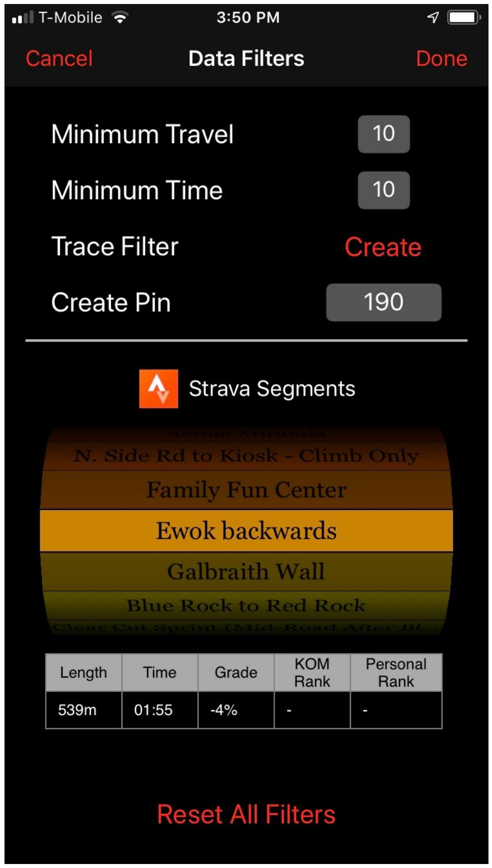
Tap the share button to send your recording to another MotionIQ user via text message, AirDrop, Email, or save to your favorite Cloud Storage Provider (Google Drive, DropBox, Box, etc).

Edit Notes

This icon will let you go back to your recording notes to edit. If you forgot to update a setting, or something, you can do this after your ride.

Delete File

Hit this key when you no longer want to keep this recording. This will delete the file from your phone and iCloud drive.



Filter

The Filter section is a powerful set of tools to enable you to focus the MotionIQ analysis engine on specific areas of your recording.

Minimum Travel: A configurable field to define a valid stroke range for the purpose of analysis. This filter will define which strokes will be placed into histogram buckets. The default is 10 mm. This means the MotionIQ analysis engine will ignore stroke lengths below 10 mm. The minimum is 1 mm.

Minimum Time: A configurable field to determine the minimum time range of a stroke event. This value is in units of data samples. Each data sample is equal to 1/200 of a second. The default value for this setting is 10 which works out to 1/20 of a second. This means MotionIQ will ignore any compression stroke shorter than 1/20 of a second.

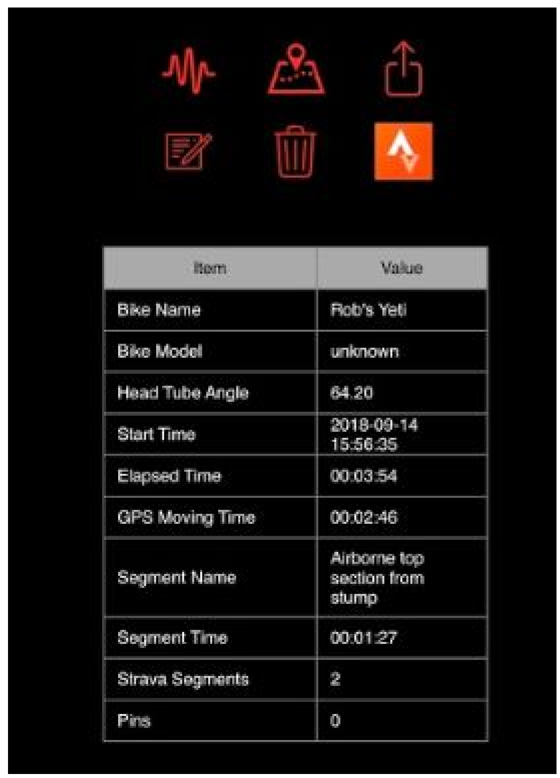
Trace Filter: This filter allows you to focus the analysis between any 2 pins. By default, all analysis is between the start and finish pins. If these are the only pins in the recording, you cannot create a trace since it's already been created by default. If you do have additional pins, then you can go into this field and create a trace by selecting a start and stop pin for the trace.

Create Pin: If you want to create a pin at a specific point in the recording, just enter the elapsed time for that point here to create a new pin.

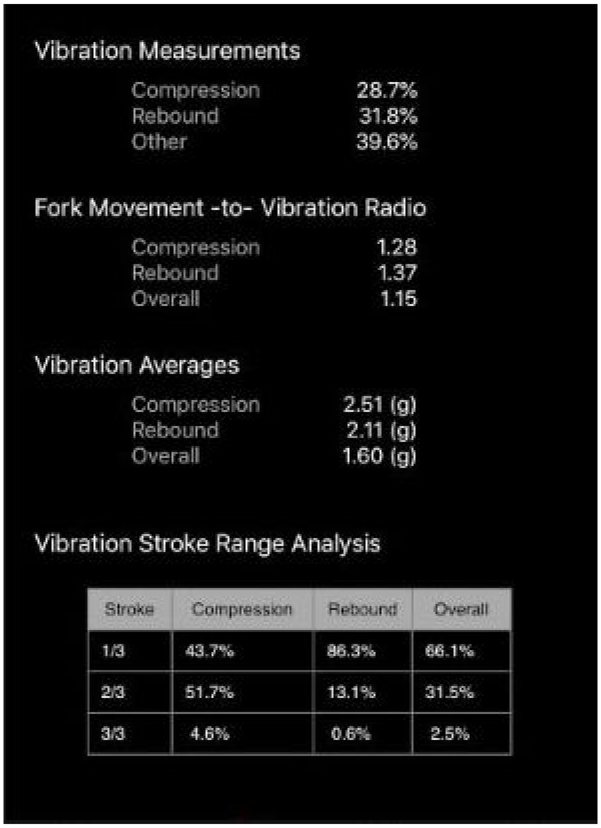
If you need an easy way to find the elapsed time for an event you can go to the elevation graph and hold your finger on the graph at the point of interest. Move your finger left or right to find the point of interest. You will see a popup message showing the X and Y values for the point where you are touching. The X value is the elapsed time in seconds. In this example, you'll see 36.836 seconds, you would type in 36.836 into the Create Pin text box to create a new pin at 36.836.

Strava Segment: If you uploaded your GPS tracks to Strava in the GPS map view, then you will see a list of Strava Segments from your ride here on the filter screen. You can scroll through these and choose one. As you scroll through, you will see some of the statistics Strava provides for the segment such as Length, Time, Gradient, KOM Rank (if you pulled a KOM…) and Personal Rank (Only if this was your fastest run). This is a great feature to analyze your bike's suspension on a particular segment.

Lastly, once you have chosen a Strava Segment in the filter screen, when you hit done to exit back to the Summary page, you will notice that the filer icon changed to a Strava icon to remind you that you are viewing a segment in the analysis. You will also see red lines on the elevation graph indicating the start and stop point for the segment. If you navigate back to the GPS screen, you will see a red line on the map detailing the tracks of the Strava segment. Lastly, on the main Summary table, you will see the name of the Strava Segment in the "Segment Name" row.



To remove the Strava filter, just hit the Strava icon, and "Reset All Filters" in the Data Filters view. This will reset all filters back to default. Hit done, and the app will recalculate all of the statistics for the entire ride.



Vibration Measurements

Compression	28.7%
Rebound	31.8%
Other	39.6%

Fork Movement -to- Vibration Radio

Compression	1.28
Rebound	1.37
Overall	1.15

Vibration Averages

Compression	2.51 (g)
Rebound	2.11 (g)
Overall	1.60 (g)

Vibration Stroke Range Analysis

Stroke	Compression	Rebound	Overall
1/3	43.7%	86.3%	66.1%
2/3	51.7%	13.1%	31.5%
3/3	4.6%	0.6%	2.5%

Vibration Measurements

Embedded in the Fork Tracer is a 9 axis accelerometer/gyro/magnetometer. We capture the vibration on the axis of the fork to measure vibration that has escaped the fork and is passed onto the rider. We quantify this vibration into a few focus areas.

- Compression: For the total vibration recorded for the ride, defines % vibration during events defined as compression.
- Rebound:For the total vibration recorded for the ride, defines % vibration during events defined as rebound.
- Other: For the total vibration recorded for the ride, defines % vibration during events not defined as compression or rebound.

Fork Movement-to-vibration Ratio

This data tries to correlate vibration and total fork movement for a recording. As your bike is dialed in, this number should go up and to the right. The equation for this data is as follows:

- Numerator: Total up/down movement of your fork in mm
- Denominator: Summation of every y axis (up/down) g force reading for the entire ride, segment, or trace. Acceleration data moves in an oscillation above and below zero g, so the absolute value of every sample is used. This equation is interested in the shake amplitude values.

How to interpret the ratio values:

- These values only represent your bike on your trails riding at your speeds. So do not compare these values to other riders. Fork movement is different based on length, settings, and riding style. These values are meant to compare your runs in a side-by side manner.
- If your bike was set up perfectly, the fork up and down movement would be high, and the vibration reading would be zero. So theoretically, this number could go to infinity. But no bike is perfect and it's impossible for any damper to reduce the rider vibration to zero. But, if things are getting better, the vibration number should go down, meaning the ratio number would go up.

- If your fork is over damped and barely moves, then the vibration reading would be extremely high, resulting in a low ratio number. This would represent the other extreme.
- As you make changes to the fork, this number will move in either direction. Just note if you like the change, or not. You cannot tune your bike with this number, but it should give you an impression of the ride quality.

Vibration Averages

These numbers are calculated as follows:

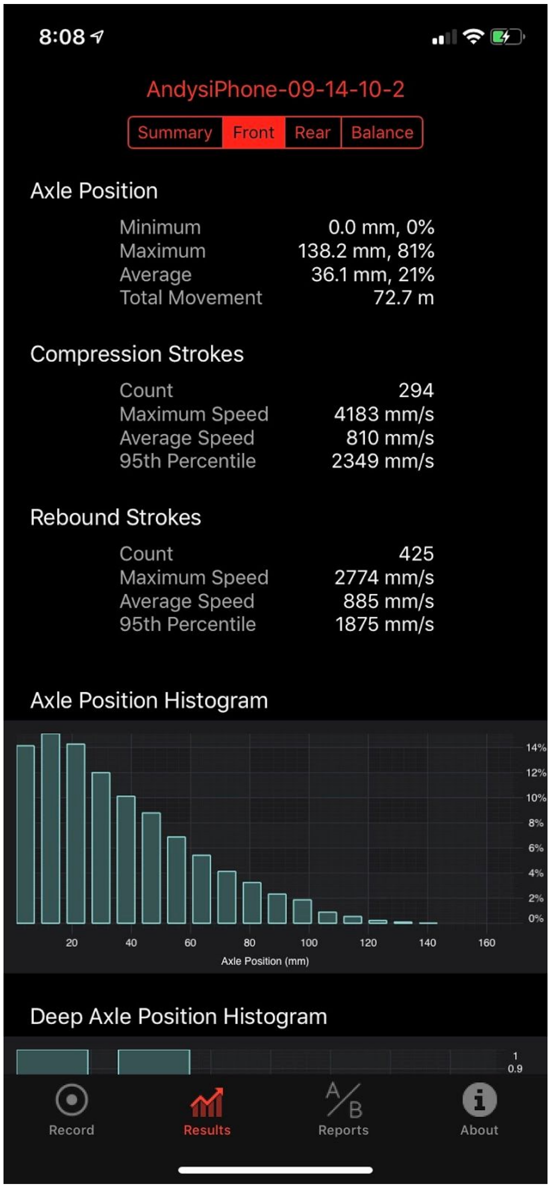
- Total summation of every g-force sample. Since accelerometer data is oscillatory in nature, the absolute value is used for every sample to make sure the number is positive. Then the total summation value is divided by the number of samples (dependent on sample rate, either 200 or 1000 Hz).
- Overall: Uses all data in the file
- Compression: Uses data from defined compression (See movement filter) events.
- Rebound:Uses data from defined rebound (See movement filter) events.

Vibration Stroke Range

In this table, the data is to be read per column. The data is divided into three fork segments in ⅓ increments. In the compression, rebound, and overall columns, the numbers in each column will add up to 100%.

- Compression: As a fork compresses, vibration will escape to the rider. MotionIQ will keep track of the cumulative vibration for each stroke segment. This is an average number.
- Rebound: As a fork rebounds, vibration will escape to the rider. MotionIQ will keep track of the cumulative vibration for each stroke segment. This is an average number.
- Overall: For the entire ride, vibration will escape to the rider. MotionIQ will keep track of the cumulative vibration for each stroke segment. This is an average number.

Front/Rear Summary Statistics



Ride statistics

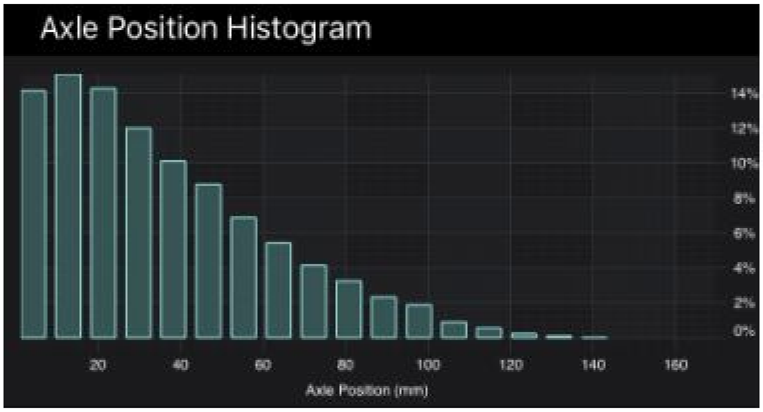
The text data at the top of the Front and Rear Summary page is a summary of key statistics of the total ride, Strava Segment, or Trace.

Axle Position

- Minimum: The lowest position of your axle during the recording segment.
- Maximum: The high water mark during your ride.
- Average: Derived by adding every position sample together, then dividing by the number of samples in the recording.
- Total Movement: The summation of every up and down segment in the recording.

Compression & Rebound Strokes

- Count: Total number of strokes from the ride. A stroke is defined in the filter section (x ms in duration, y mm in length). If the stroke is less than the length filter, it will not be counted.
- Maximum Speed: MotionIQ records position data at a periodic interval (sample rate). The first derivative of speed is velocity. The near instantaneous velocity is calculated at every sample (instantaneous slope of the position curve). For every stroke (compression or rebound), MotionIQ will determine the maximum speed of that stroke. After the ride, the fastest stroke speed recorded will be displayed.
- Average Speed: The summation of every stroke max speed is summed, then divided by the number of strokes. This is the average speed for every stroke.
- 95th percentile. Every stroke is organized from slowest to fastest in a list. If you had 100 strokes from slowest to fastest, the 95th out of 100 would be listed here. If you had 1000, the 950th of 1000 would be listed, and so on.

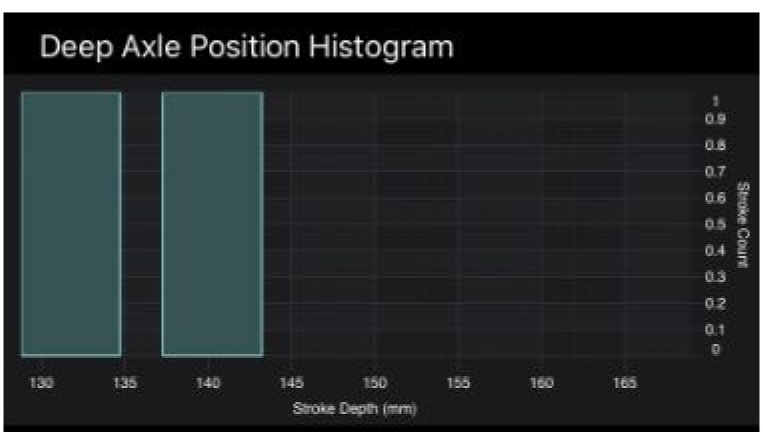


Axle Position Histogram

For a given range of suspension travel, total range is divided into 20 bins. MotionIQ will drop every sample into one of these bins for the entire recording. This graph will give you an idea of where your fork is spending all of it's time. You can press your finger on the graph and two vertical lines (horizontal and vertical) will appear making it easy to see the exact value of each bar (mm, and %).

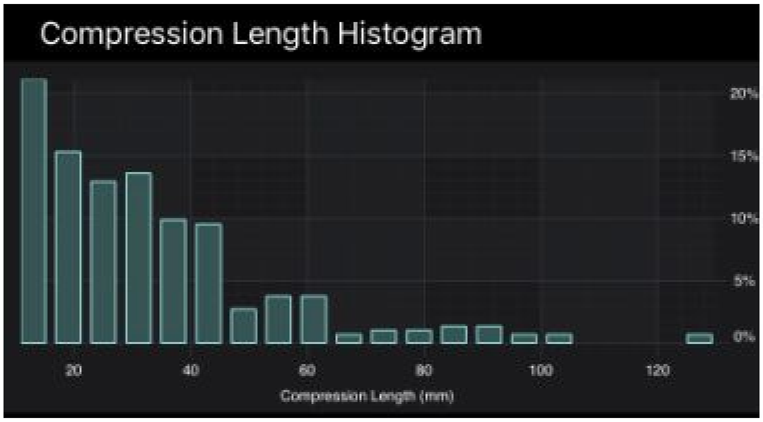
Tuning variables that affect the shape of the Axle Position Histogram:

- Preload: The entire graph can be moved left or right based on air pressure or spring rate.
- Air Tokens (where applicable): The ramp of this graph can be changed by making the air spring more or less progressive. A progressive air spring will make the ramp dive faster. A less progressive, more linear, air spring will broaden the shape.
- Knobs can also change the shape of this graph.
    - Overly damped rebound will cause the damper to stay deep in the travel longer. This is one, not the only, cause of packing. Packing is the phenoma you feel when the bike gets stuck deep in the travel and you are getting jarred by successive bumps.
    - Overly damped compression can cause the bike to sit up higher in the travel. It can also make the bike feel like it's packing, but the cause is from the compression resisting the damper from compressing. It's hard to tell what the cause of packing is without data.



Deep Axle Position Histogram

This graph is a close up view of the top 25% of the axle position histogram. The bins do not represent position samples. Instead they count the number of compression strokes that entered into this region of the front or rear axle. By holding your finger on the graph, you can get a detailed information of each column. If your axle is not getting into this range, then this graph will be blank.



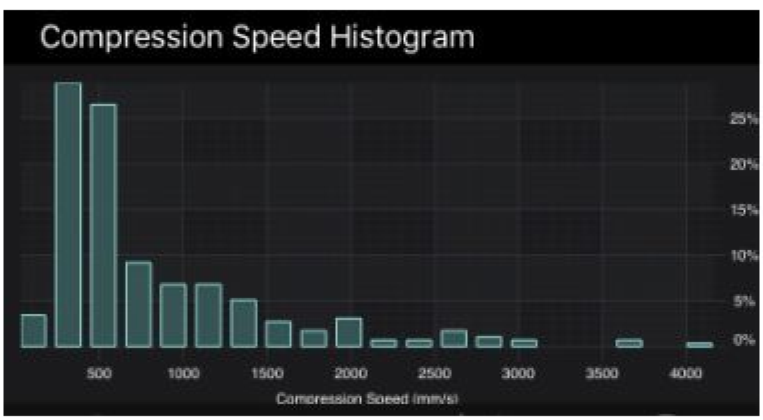
Compression Length Histogram

MotionIQ calculates the stroke length of every compression event, then places the stroke into one of 20 buckets depending on the length of the stroke.For example, a stroke in the largest bucket represents a stroke that started out in the open position and compressed all the way to the final stroke range (IE, hit from a big jump).

Tuning variables that affect the shape of the Axle Length Histogram:

- Preload: Heavy preload will resist deep compression events.
- Air Tokens: More air tokens will make the air spring progressive, which will resist the damper from moving deep into the travel.
- Heavy Compression damping will resist compression movement.
- Heavy Rebound damping will cause the damper to stay open longer. If your damper is not back into optimum position to absorb the next bump, you will feel a packing phenomena.

Compression Speed Histogram

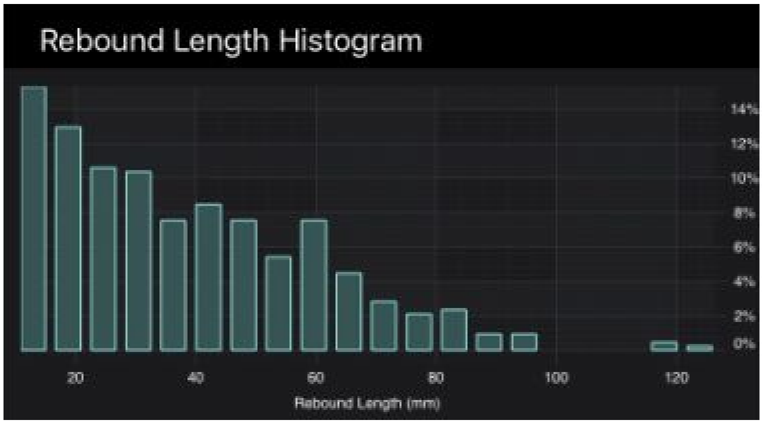


This chart uses the max stroke speed for every compression and places it into 1 of 20 buckets. The largest bucket range is dictated by the fastest stroke. Every stroke is placed into a bucket. This will give you an idea of the outlier strokes vs. the typical stroke speeds for your ride.

Tuning variables that affect the shape of the Axle Compression Speed Histogram:

- Preload and Tokens: These will slow down compression events across all ranges
- Compression damping: Will alter high or low speed events based on settings.
- Rebound damping: Will alter compression events based on damping of rebound. If a damper is held open longer via rebound damping, then the compression events will start at a higher position, IE a position with more compression resistance.

Rebound Length Histogram

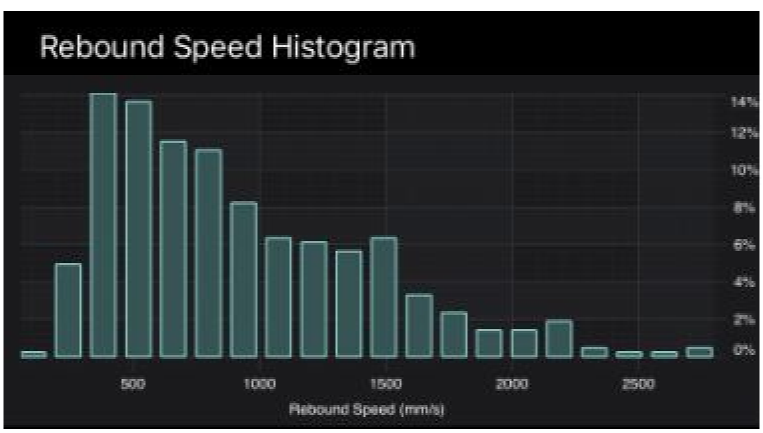


MotionIQ calculates the stroke length of every rebound event, then places the stroke into one of 20 buckets depending on the length of the stroke.For example, a stroke in the largest bucket represents a stroke that started out in the closed position and rebounded all the way to the initial top stroke range (IE, a rebound event after a big landing).

Tuning variables that affect the shape of the Rebound Length Histogram:

- Preload and Tokens: By altering the shape of the position histogram with tokens, the movement of the damper is affected by preload.
- Over damped compression: by resisting compression strokes, the damper does not get deep into the travel, therefore the rebound strokes will be shortened as a result.
- Over damped rebound: by resisting the rate at which the damper closes, the lengths will be reduced because the time to open the damper is lengthened.

Rebound Speed Histogram



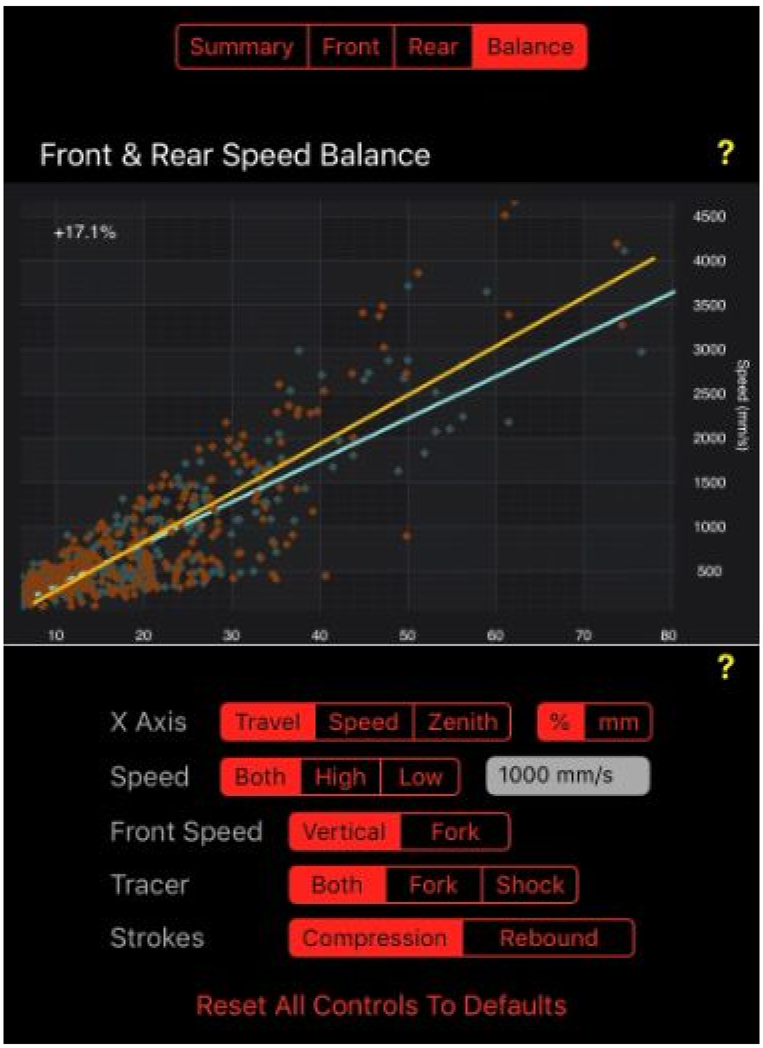
This chart uses the max stroke speed for every rebound and places it into 1 of 20 buckets. The largest bucket range is dictated by the fastest stroke. Every stroke is placed into a bucket. This will give you an idea of the outlier strokes vs. the typical stroke speeds for your ride.

Tuning variables that affect the shape of the Rebound Speed Histogram:

- Preload and AirSpring tokens: By creating a faster rampe with either Preload or tokens, the spring force will be amplified for a given position during rebound. A higher spring rate will have more force to move the damper back into position at a faster rate.

- Rebound damping: Damping will alter the speed at which a damper can get back into position. So increasing damping will slow down every stroke. Decreasing damping will speed up a stroke. High and low speed settings will affect strokes in their speed ranges.
- Compression damping: By altering the speed of a compression stroke, the depth of the stroke will be affected. Therefore, given the spring rate of the damper, the rebound speed will be altered based on the starting position of the rebound.

Balance View Graph



The balance view is a comprehensive display engine to help you visualize how balanced your front and rear suspension is. There is a control section which changes the graph. In all, there are 108 different views that can be generated. However, there are a limited number of control combinations that are important. We will talk about the graph, what it represents, and how to change the views. Finally, an in depth discussion will follow discussing each control knob and what data is being teased out.

The balance view graph looks at front (blue) and rear (orange) events. Using the “Strokes” control, you can toggle between Compression and Rebound. Each dot on the graph is an individual stroke which represents the top speed of the stroke in mm/s along with a stroke position in % or mm. By using the % control (default), front and rear range is normalized by %. On some bikes, the front and rear stroke range is different, so using mm makes the view confusing and will skew results. If you need to know position in exact mm, use the mm knob. For all other cases, just use %.

The graph displays every compression or rebound stroke during the ride. For each end of the bike, a linear regression is calculated for this specific dataset. This line represents a best fit line for this dataset. Mathematically, a perfectly balanced bike will be displayed with both regression lines having the same slope. This may or may not be ideal for the rider, that's why we don't make a recommendation. MotionIQ just gives you data so you'll have a way to visualize what your bike is doing.

What constitutes a balanced bike mathematically? If a bike is perfectly balanced, the front and rear regression lines will line up. This needs to be taken in context because you can have a perfectly balanced bike as displayed by the data in this graph, but the bike may feel terrible. An example:

- The bike is perfectly balanced, however
- All the dots are on the left hand side of the graph. This means you are not using all of the travel of the bike
- All the dots are super slow, like less than 500 mm/s. This means the bike is so overdamped that it's terrible to ride.
- You may be a downhill racer and have purposely slackened the bike by making the fork stiff, and the shock soft. This will show up in the average position numbers being uneven.

Those are just a couple of cases to give you an idea that, yes a bike can be balanced but it could be a terrible bike to ride.

A balanced bike is a very personal thing based on what feels good. Can you go fast, and maintain control. Does the bike behave predictably even when the terrain surprises you? This comes with time on the bike and understanding what you like. We suggest you use all of the data at your disposal to guide you, but don't rely on the data 100%. You have to like the bike. Once you get what you feel is a perfect bike, you can use the data to help you understand what your view of a balanced bike is. You can use these settings when setting up a new bike.

In general, this is how Motion Instruments has developed bikes with riders of all abilities. The process is iterative. In some cases, we've been able to make huge strides in just 3-4 runs. In others, we've had to send suspension in to get a lighter tune. You won't know what you need until you go through the process.

Motion Instruments has good experience with riders loving their tune when the following conditions are met:

- When the front and rear are using a similar range of travel.
- Your suspension has margin for big hits, you shouldn't see dots hit the 100% mark unless this is a "once a year" event.
- For any given event, the front and rear are hitting the same speeds for compression and rebound.
- The rebound should be fast enough to minimize packing events, but not so fast that the bike feels unstable. Our target rebound speed is 1800 - 2500 mm/s. The faster you ride, and the rougher the trail, the higher the rebound speed. So don't try to go for world cup rebound speeds when you are just a weekend rider. If you have questions, send us your file and we'll be happy to make some suggestions and help out where we can. We've seen all kinds of data.

- Compression rebound speeds will be much higher and dependent on the type of terrain you are riding. Rock gardens at really high speeds will yield speeds into the 5000 mm/s range. When analyzing compression balance, it's important to isolate data on downhill only, not flat riding to the steep and deep. So view this data with an eye toward terrain and quality downhills.

Another important thing to remember is you want to use data that is representative of the terrain you want to optimize your bike for. So don't do easy cross country runs for your data collection when you want to set your bike up for enduro. We have put in a lot of thought into making it easy for you isolate trail sections that are meaningful. You can use the Trace filter option which is just a section between 2 pins, or you can use strava segments. With strava segments, you can just pick segments of your ride that are worthy of analysis. This is why data is so problematic in our view, junk in = junk out. You need to eliminate junk data from your analysis. Keep this in mind while testing, you have the tools you need with the handlebar button, GPS, Strava, etc.

Balance View Controls

Even though there are 108 different combinations of settings, you can eliminate tons of them when you understand what the controls perform.

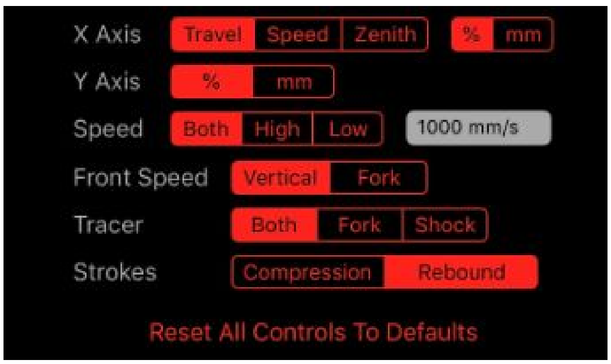
X-Axis

The X Axis control looks at 3 different views of the scatter data: Travel (default), Speed (only useful for suspension tuners, so ignore this data), and Zenith. We discussed the % and mm control already. In general, use % for all views in general. The mm is important for suspension tuners when viewing Speed data.

- Travel: Every dot on the graph represents the travel distance of the stroke and the maximum speed of the stroke in mm/s. This view is useful when tuning damper controls on your suspension. In general, you will see if the front and rear have similar stroke count at different lengths, and if the speeds are similar. If it all lines up, then the bike is speed balanced. Note: If your dynamic sag is way off, then this data will be tough to balance and line up. You may have a specific reason for the dynamic sag mismatch, like you are racing down a super steep run and you want to "rake out" the fork for control.
- Speed: There is no balance regression analysis in this view. We simply plot the position where the max speed happened in the stroke. So if you need to change damping characteristics for a certain segment of the travel, this is an important tool. You can press your finger on the graph, a vertical and horizontal line will appear. If you want to get the values of any dot on the graph,

move your finger to that dot and a pop up will appear giving you x and y coordinates of the dot. Toggle to the mm control if you want to see the data in mm vs. % of travel.

- Zenith: Every dot on the graph represents the maximum position of the stroke, for compression this is the top of the waveform or ending point, for rebound, this is also the top of the waveform, or starting point. The zenith view will give you a sense of your front and rear suspension is using an equal range of travel.
    - You can adjust the position of the dots for front or rear damper with preload, spacers, and compression & rebound settings.
    - You can get more context of the balance by comparing dynamic sag (average position) for the front and rear.
    - You can also view the position histogram to get a sense of travel usage for front and rear.



Y-Axis

The Y Axis row lets you look at your bike's actual stroke/velocity data in actual velocity (mm) or relative velocity (%). If your bike has an unbalanced stroke range (IE: 160 front, 140 rear), you can click on the % and all data will be adjusted as if your bike had 100 mm of travel front and rear equal. For a 160mm front fork, velocity data will be multiplied by 100mm/160mm. For the 140 Rear, all velocity data will be multiplied by 100mm/140mm. This will normalize the velocities as if they were equal stroke lengths.

Recording Picker

All of your recordings are stored on your phone until you delete them. A backup copy is also stored on your iCloud drive (if enabled) which makes it easy to access your recordings from any device such as iPad, Mac, or PC.

Access the recording picker by tapping on the Results icon in the lower navigation bar, or if you are already in the results viewer just tap on the name of the current recording at the top of the screen.

The elapsed time for each recording is shown in the picker view if the recording was found on the local device, otherwise it will say "iCloud". Either way, just tap the row to load the session. MotionIQ will automatically download the file from your iCloud drive if needed.

You can also load recordings from any other cloud provider by tapping "Cloud Providers" in the lower toolbar.

Swipe left on any row to delete that row, or tap "Edit" to select multiple rows for deletion.

Storing Your Data

Your storage needs may be different depending on who you are. If you are just an individual user, having your data stored on your phone and/or within your iCloud storage account may be adequate. If you are a large OEM with multiple design projects, riders, test teams, race teams, etc. Your needs will be quite different. You'll want to have a cloud storage system with advanced file sharing controls such as access controls, etc. You will have many use cases where you'll want to keep certain data private, isolate teams from seeing each other's data, etc. MotionIQ has taken the approach of using best of breed systems to accomplish this. MotionIQ supports Dropbox, Box, iCloud, and Google G-Drive. To use these systems, you'll need their app on your phone in conjunction with MotionIQ.

Cloud Storage Providers

MotionIQ works with all cloud storage providers supported by iOS. To get started all you need to do is choose a storage provider and install their app on your device. Once you have that done you can use MotionIQ to read and write files in your cloud storage. Here are links to the most popular storage providers:

- Google One (a.k.a. Google Drive)
- Microsoft OneDrive
- Amazon Drive
- DropBox
- Box.com

Setting up your bike

Even with the best data, bike setup is still a personal exercise. A bike that's been setup for one rider will not necessarily be transferable to another rider. Many factors go into bike setup and it's highly dependent on rider weight, riding style, speed, and terrain. A bike may feel planted and stable at one speed, but when you make a jump up (Sport to Expert for example), your bike may feel harsh and unstable. Your suspension is designed to support a wide range of riders, that's why they are infinitely adjustable.

Step 1: Dynamic Sag Setup

Start with the manufacturers recommendations for preload and settings. Measure your static sag and make sure the bike is within the recommended sag points for your weight. Go ride the bike and collect some data.

- Ride at your limit on trails that matter
- Use the tools in the app to isolate difficult sections via pins or Strava Segments
- Compare your front and rear dynamic sag (average position)
- View the position histogram, what is your max position, what does the ramp look like?
- Adjust pre-load to get the bike's average position

Step 2: Front

You will probably notice big improvements in your ride by focusing first on the fork. Let's face it, stuff you ride over will be noticed by your hands. You put a lot of weight on the bars during braking, descending, etc. So you will notice a lot on the front of the bike.

- High Speed Rebound: Target the highest rebound speeds you can handle
- Most pros are in the 2500 mm/s range. They need the wheel back on the ground FAST because they are moving so fast.
- Even if your fork is opened all the way, you may not get these speeds because you are just not as fast as a pro.

Next focus on high speed compression. If you are riding really tough downhills, your max speed range will be in the 3000 mm/s range. Enduro pros are in the 4000 - 5500 mm/s range. Downhill can achieve speeds > 7000 mm/s. You want your wheel up and out of the way, if your fork is over damped on compression, something has to give, and it ends up being the whole bike. Your handlebars will move up into your hands. So if your max speeds are in the 2000 mm/s range on compression, then assume your bike is overdamped on compression.

- Open your high speed compression as much as you can without losing support.
- Note your max position, are you able to get to 85%, or are you stuck at 60%

Adjusting high and low speed rebound will significantly affect how much the wheel moves up and down. Also, your average position will move up or down based on damping. Note this as your adjust your settings. You want your wheel to move. On compression, you want your wheel to get out of the way, but still provide support deep in the travel. On rebound, you want the wheel back on the ground. Your suspension won't be in an optimum position for the next bump if it's stuck in the air because it can't get back to earth fast enough. Also, you can't decelerate (under braking) if your wheel is off the ground.

Step 3: Rear

If your front is feeling fast, planted, and stable, start working on bike balance. This is where the data becomes crucial. No adjustment is made in isolation and you'll see the balance being affected as you make modifications. Changing rear dynamics will change the loading effect on the front of the bike, and vice versa. Go out and ride some difficult terrain and note the following:

- Average position, does it match the front? Or is it much deeper? Note the average position when isolating your data analysis on steep and deep. It will be much different than when you are on flat ground for obvious reasons.
- Rebound? Does the max speed match the fork? If it's super slow, speed up HS rebound.
- Compression, typically rear compression speeds will be faster, but if the shock is over damped on compression, it will be slower than the fork. Open up compression until you are getting similar speeds.

Step 4: Balance

Assuming your front and rear average positions are in similar percentages for front and rear, start to look at balancing the bike.

- Start with slow speed rebound. Try to get within 20% slope. If your shock is really opened up on slow speed rebound, you may get <10%. Note how the bike feels. Just because the lines are balanced, doesn't mean you'll like it. Most of the riders we've tested with do like their bikes when they are balanced.
- Focus on overall compression, High and low speed. Adjust front and rear to change the slopes of the regression lines. Aim for slope differences <10%. We've had riders dial their compression to less than 1% difference with great success.

There are many factors that will affect balance. Improper preload will have drastic effects on regression line slopes. A fork with too much preload will have a really steep slope because there is no data deep in the travel. Likewise, a shock with inadequate preload will have too much data deep in the travel so the slope will be flatter than the shock. See the explanation of balance earlier in this guide to understand this.

- Low speed balance will have big effects on cornering and jumping.
- High speed balance will have big effects on straight line rock gardens.

Once you understand the basics of bike setup, and feel what a properly tuned bike is like to ride, you won't go back to the old ways of tuning. It's important to isolate what you may be feeling in the data. If you changed something, and you like it, or dislike it, find out what changed. If you can feel it, it can be measured. But you may have to study the differences between different files (runs). Use the A/B reports to further isolate changes. Also, look at the metrics, balance, and histograms. Correlating rider feeling with data is the feedback loop that will make you an expert in setting up your bike.

Conclusion

MotionIQ is a powerful platform with a holistic view of data lifecycle management. MotionIQ makes it trivial to analyze any bike on any trail. With the rich suspension metrics and taxonomy provided, anyone can converse and troubleshoot suspension performance issues based on data vs. opinions.