On Differences in Linear Switches

-ThereminGoat, 3/3/2024

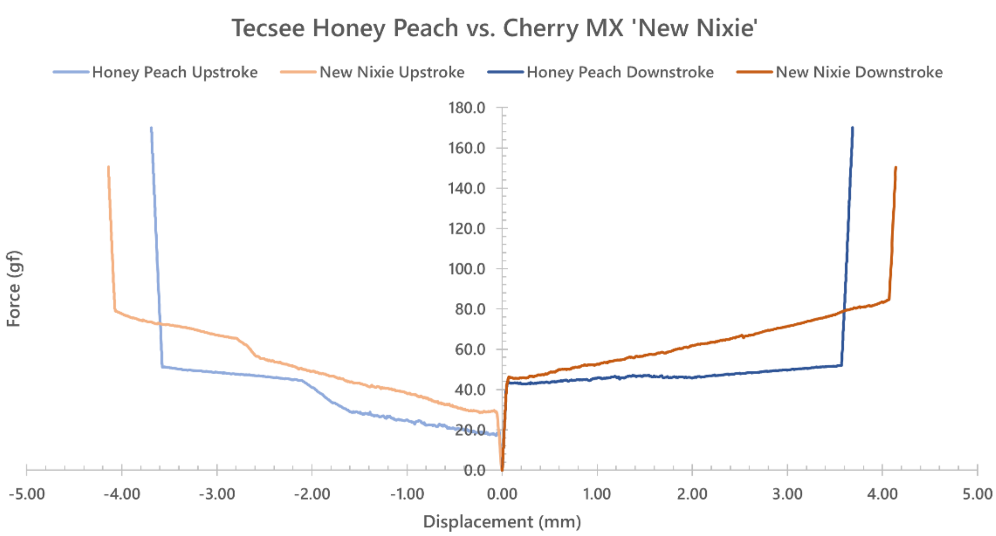
While I would really like to just open this article with a cold opener, I know that that would probably just fly over some people's heads as they scroll past it. So, ignore the previous sentence and behold the *actual* start of this article:

<u>Cherry MX 'New Nixie'</u>

- For how different these two switches are in terms of their construction and marketing points, they have fairly similar overall sound profiles and feelings as each other. Whereas the Tecsee Honey Peaches have a bit more inconsistency and some more pointy metallic bottom outs and the Cherry MX 'New Nixies' have a bit more scratch to their stroke and depth to their housing collisions, these feel a lot closer to each other than one might expect upon initial guess.

- The Cherry MX 'New Nixie' switches have quite a bit less stem wobble than the Honey Peach switches in both the N/S and E/W directions. (Note that this is pretty unusual for a comparison between a switch made by Cherry and one made by another manufacturer.)

- In terms of their overall sound profiles, the 'New Nixies' are quite a bit more subdued, bass heavy, and have a larger amount of their sound profile eaten up by scratch than the comparatively higher pitched, sharper, and thinner sounding Honey Peaches.



As you look closely at this excerpt from last week's review, I want to ask if you see the issue with this comparison between Tecsee Honey Peaches and Cherry MX 'New Nixies'. While you may not know what I'm going on about unless I somehow missed another egregious typo and/or committed more grammatical atrocities that are still there, I know that I definitely see the problem. The problem is that I'm feeding into *the meme*. That's right, this ostensibly innocuous comparison section perpetuates the talking point brought up by every armchair mechanical keyboard expert that I've been fighting against for nearly four years now in that 'all linear switches are basically the same.' Look, I basically admit to that in the very first comparison between these two incredibly different switches. Obviously, I can't just let this happen and now you're getting to read this entirely unasked for article of mine where I prove once and for all that not all linears are the same. To start my Olympic-paced backpedaling on the claim in that comparison section above, let’s go ahead and zoom in on just the downstroke force curves for these two switches.

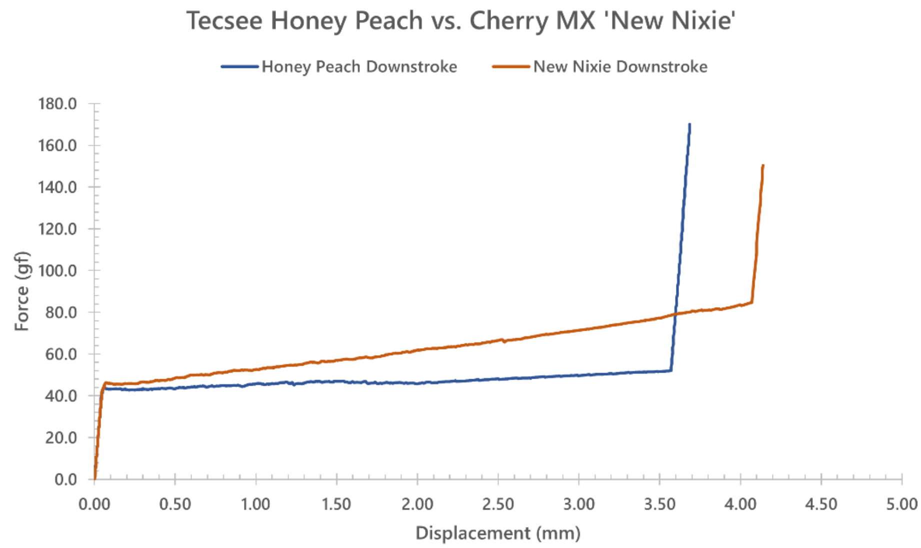


Figure 2: Isolated downstroke force curves for Tecsee Honey Peach and Cherry MX 'New Nixie' switches.

To be entirely fair, just looking at the downstroke force curves for the Tecsee Honey Peach and Cherry MX ‘New Nixie’ switches, you’d be hard pressed to think that these two switches are similar at all. While they both definitely are linear switches and are largely comprised of a single straight line in force from the beginning to the end of the stroke, the slopes – or change in force per unit displacement – of these curves are actually quite a bit different from each other. Whereas both switches start around 42-45 grams of force at the start of their downstroke, the Honey Peaches only go up to about 52 grams in 3.57 mm of total travel distance whereas the New Nixies reach all the way up to about 85 grams of force at 4.07 mm of travel. Really cranking out the napkin math here, we can see that this results in a slope somewhere between 2-3 grams per millimeter of travel (gf/mm) for the Honey Peaches and a *much* larger value of between 9-10 gf/mm for the New Nixies. However, this isn’t the only difference that there is to be seen between these two switches if you’re nearly as pedantic as I am.

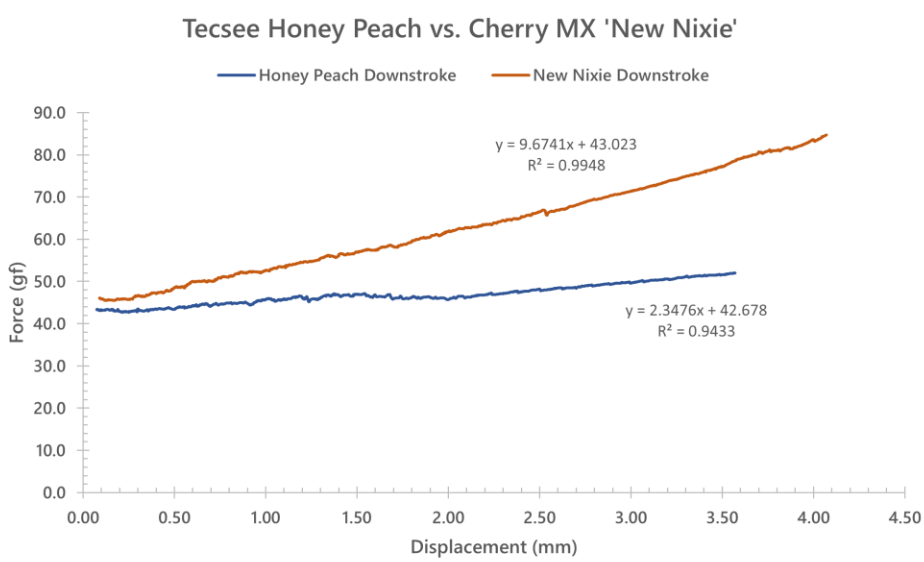


Figure 3: Isolated linear region of downstroke force curves for Tecsee Honey Peach and Cherry MX 'New Nixie' switches with equations for line of best fit through each curve.

Stripping away the beginning and ending parts of these force curves to isolate just the linear part of the stroke that is felt when pressing each of these switches in, we see that they aren't quite as linear as what they may have looked like in Figure 2, above. While these are both *linear-ish* in nature, we can see quite a few peaks and dips in force in both switches – especially those between 1.00 and 2.00 mm in the Honey Peaches and around 2.60 mm in the New Nixies. Using the simple linear regression model built into Excel and everyone's favorite coefficient of determination in R^2 – which is a number ranging from 0 (not at all linear) to 1 (perfectly linear) that represents how well a set of points of data lie in a straight line – we can see that these two switches definitely are not equally straight. As you might have already been able to tell just from how the curves look qualitatively, the Honey Peach's stroke is a bit more wavy and less straight than that of the New Nixies, making now two differences between these two switches that have "very similar push feelings to each other".

As I noted the differences in both the slope and straightness of the force curves for these two switches in a desperate attempt to fend off the claim that 'all linear switches are basically the same', I couldn't help but feel like I had stumbled onto something a bit bigger than just these two switches. We as a community have come up with all manner of ways to describe different tactile bumps and all sorts of strange, zoomer-like onomatopoeias to describe how switches sound, and yet we're all just resigned to claiming that all linear switches are the same as one another. Now armed with force curves for well over 600 different linear switches that I've collected in my Force Curve Repository to date, I think it's time we begin adding a bit more nuance to our discussions about linear switches…

A Proposed Change

In addition to describing linear switches based on all of the qualities that we've come to agree on as a community over the years, I believe we should begin using two new phrases to help better articulate otherwise undiscussed differences between linear switches:

Slope – This effectively describes the rate of change of force of the linear portion of a switch's downstroke and is measured in grams per millimeter (or gf/mm). The linear portion of the downstroke is defined as the flat line, increasing force region that occurs in linear switches between the initial spike in force as a switch begins being pressed and the spike in force due to bottoming out. Slope also can be described on a qualitative scale of Flat (low gf/mm) to Steep (high gf/mm).

Linearity – This effectively describes how straight the linear portion of the downstroke of a switch is. Measured by using the coefficient of determination from a linear regression model, it is quantified by the value R^2 and runs on a scale from 0 (not at all straight) to 1.000 (perfectly straight). Linearity also can be described on a qualitative scale from Wavy (R^2 ≈ 0) to Straight (R^2 ≈ 1.000).

In order to better demonstrate *why* I think that Slope and Linearity will be particularly useful tools to help describe differences between linear switches, consider the following pair of graphs which highlights extreme differences in Slope and Linearity from force curves I've collected to date. In these force curves, the spikes in force from the start of the downstroke as well as bottoming out have been removed. (As well, repeating displacement data points have been removed via Excel to produce roughly similar packing of data points per millimeter travel distance across all switches.)

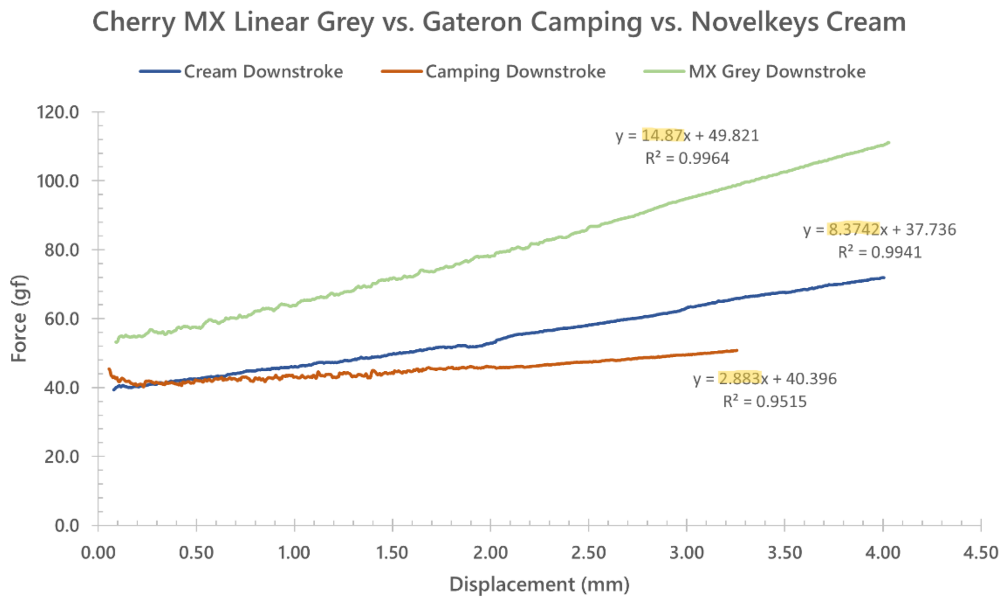


Figure 1: Comparison of slopes of the linear region for three different switches with equations for line of best included. Note that the highlighted values correspond to the 'Slope' discussed above.

As can be seen above in Figure 4, these three linear switches have drastically different slope values between one another. While many people would likely be able to discern the differences between Cherry MX Linear Greys and Novelkeys Creams based on differences in their weightings and housing materials, I doubt differences in the rate of change of force, or slope, of these two switches would be as easily identifiable without being prompted about it first.

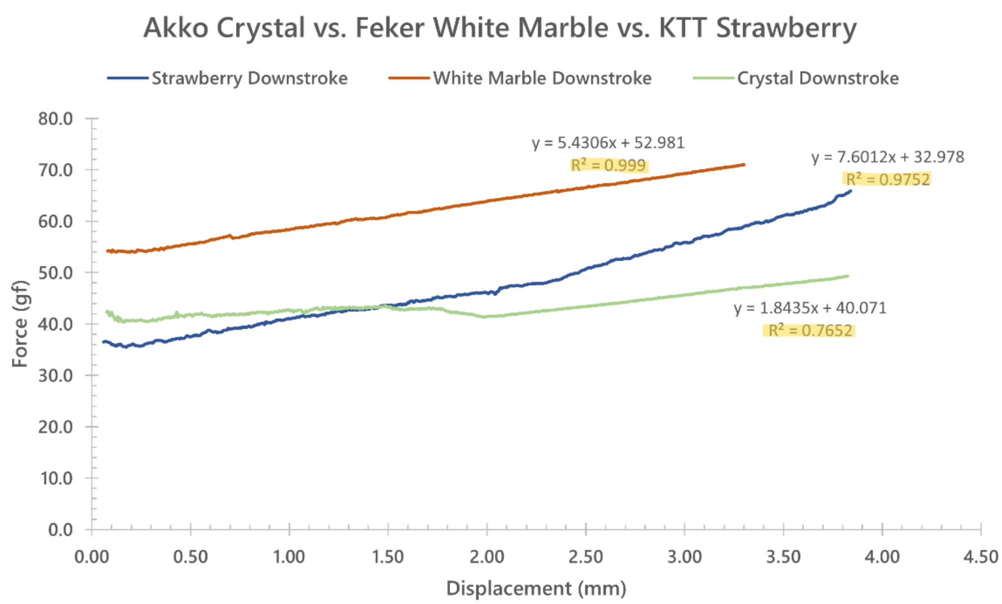


Figure 5: Comparison of flatness of the linear region for three different switches with equations for line of best fit included. Note that the highlighted values correspond to the 'Linearity' discussed above.

As can be seen above in Figure 5, these three linear switches have drastically different linearities to their stroke. Now while people may have stood a chance at identifying differences in slope between the last set of three switches when blindfolded, I absolutely do not believe that people would have been able to tell whether a KTT Strawberry or Akko Crystal switch is 'more straight' in hand. While that may seem to defeat the usefulness of this metric, consider that just by looking briefly at the numbers highlighted in the image above that you have a much better understanding of if that linear switch may have some variability in its feeling or inconsistencies in force throughout the stroke that may actually translate to a different feeling underneath your fingers. Switches with lower R^2 values are thus less straight and less consistent throughout their stroke!

Now, that is not to say that this proposed change is something I'm pitching out there without any sort of backup on my end. Given that quantifiable differences between linear switches is an idea that has vaguely floated around in my head for quite a while now, and has only continued to grow in intensity as I've collected more and more force curves, I fully well intend to work this into my reviews of linear switches moving forward. So, let's go ahead and discuss how I intend to work this into my current, existing structure of content.

How I Plan to Use This

Much like with how I've expanded the comparison sections of my full length reviews to include force curve comparisons between all switches in addition to descriptive, qualitative differences between them, I think that a comparison of the absolute and relative Slope and Linearity values for comparison sections with linear switches will be invaluable for furthering the comparison and contrast. This process will take place moving forward and will likely *not* be carried out retroactively for reviews of linear switches written prior to the date of release of this article. In order to begin integrating this into my full length reviews, the following are the changes that have taken place and will continue to develop in the coming weeks and months:

- To start off with a sizable data set of Slope and Linearity values for relative comparisons, I've already computed these values for just under 1/3rd of all linear force curves I've collected to date, totaling 204 out of 670 total force curves as of the time of writing this review. I will continue filling out this data set in a similar fashion to the other repositories and measurement sheets which I currently maintain.

- These values, as well as all Slope and Linearity values moving forward, will be tracked in an Excel sheet titled '1-Slope and Linearity' which will be stored both in my Measurements folder on Google Drive as well as in the main tree of the Force Curve Repository on GitHub.

- Excel sheets that have the calculations for Slope and Linearity for all switches will be uploaded to their respective switch's folder on GitHub.

- Given that Slope and Linearity are mutually exclusive descriptions and are not based in one another, I've chosen to visually represent the Slope and Linearity of linear switches in an X-Y grid for relative comparisons in addition to numerically in a table for absolute comparisons. Blank versions of what will be appended to comparison sections for linear switches moving forward may be found below:

Linearity and Slope Chart Values		
Regular Values	**Slope**	**R^2**
Switch Being Reviewed		
Comparison Switch #1		
Comparison Switch #2		
Comparison Switch #3		
Comparison Switch #4		
Comparison Switch #5		
Comparison Switch #6		
Normalized to Avg. Values	**Slope**	**R^2**
Switch Being Reviewed		
Comparison Switch #1		
Comparison Switch #2		
Comparison Switch #3		
Comparison Switch #4		
Comparison Switch #5		
Comparison Switch #6		
Number of Data Points in Avg.		**XXX**

Figure 2: Blank numerical Linearity and Slope Chart Values table to be added to future full length reviews of linear switches.

The upper case of this table will contain the absolute, as calculated slope and R^2 values for the switch being considered in the full length review as well as each of the standard six comparison switches following them. In the lower case, these values will have been normalized to the average slope and R^2 values *of all linear switches that have had their slope and linearity calculated to date*. The number of calculations which have been used to develop the average slope and R^2 can be found beneath the table.

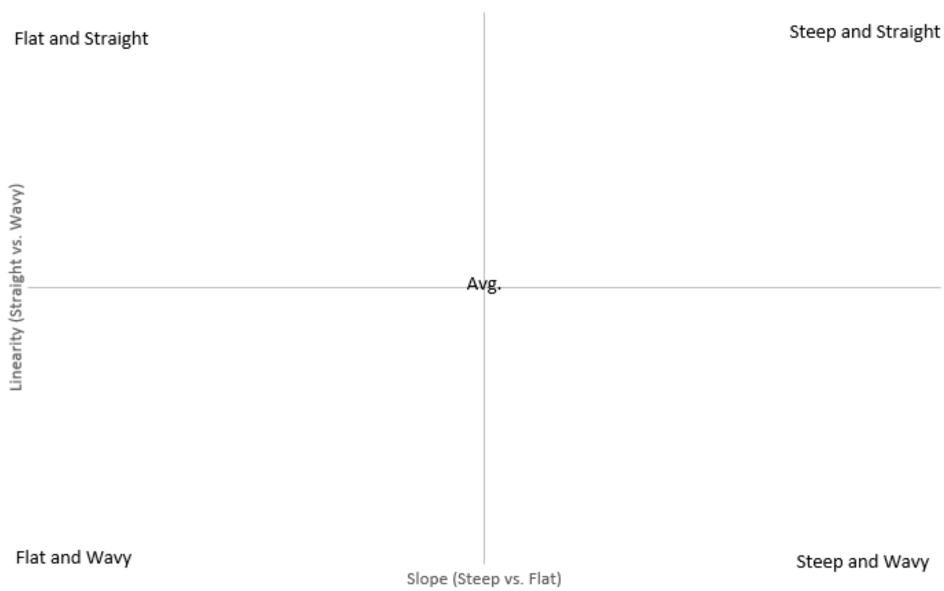


Figure 7: Blank qualitative Linearity and Slope comparison graph to be added to future full length reviews of linear switches.

In order to help visually demonstrate the qualitative differences between each of the switches in the comparison list, a plot of Linearity (Y-Axis) versus Slope (X-Axis) is taken with the origin represented by the average slope and R^2 value of all switches processed to date. The normalized values from the lower case of the table in Figure 6, above, will then be plotted and labeled to provide a sense of comparison between these switches. As well, note that each quadrant of the plot has been labeled with Steep/Flat and Straight/Wavy in order to help orient viewers as to what the relative location of each switch's point means. Like with all normalized data, note that the further away from the origin any given point is, the more extremely different from the average that it is.

And now, to get a better sense of what this will look like when fully implemented while padding the word count for this article, below you will find a reimagined comparison section from the Tecsee Honey Peach Switch Review featuring these changes and new ways of differentiating linear switches:

Comparison Notes to Other Notable Linear Switches

Note – These are not aimed at being comprehensive comparisons between all factors of these switches as this would simply be too long for this writeup. These are little notes of interest I generated when comparing these switches to the Tecsee Honey Peach switches side by side.

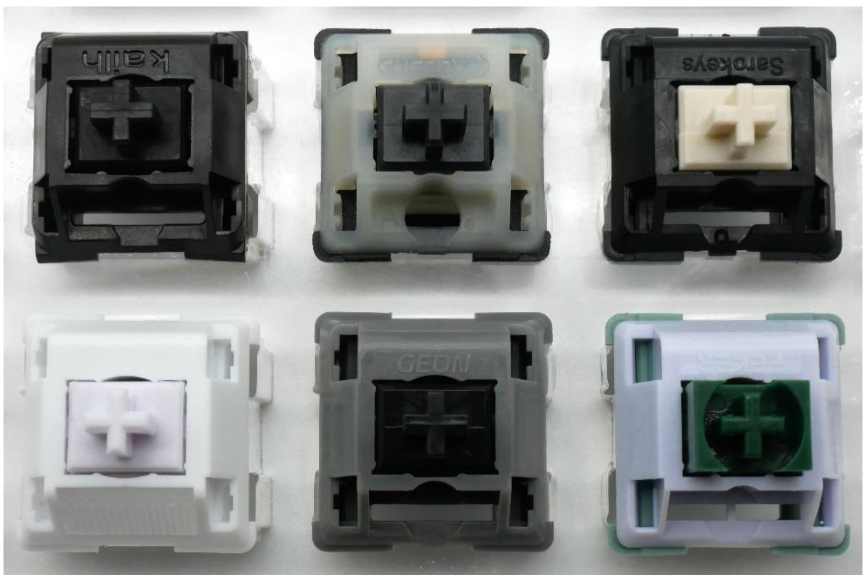
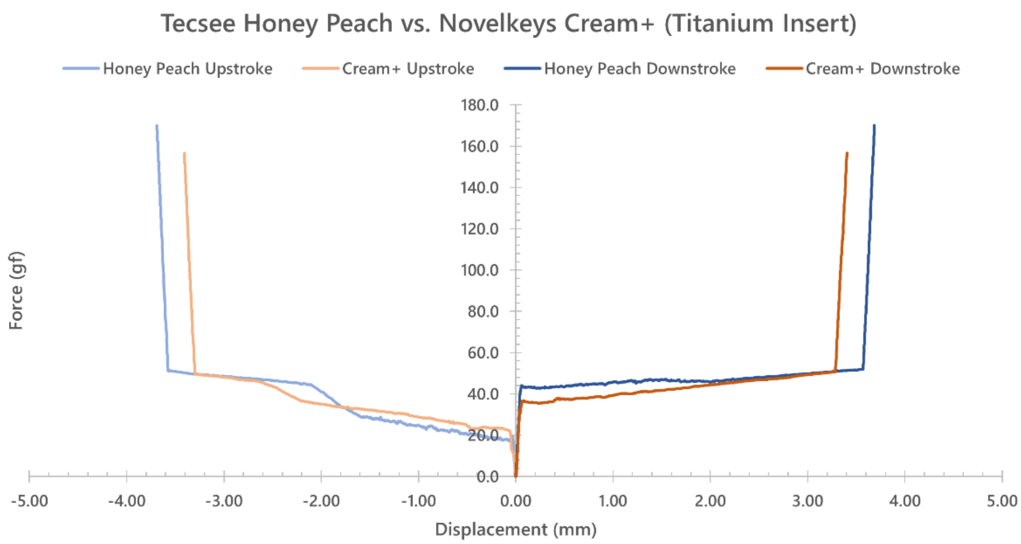


Figure 8: Switches for comparison. (L-R, Top-Bot: Novelkeys Cream+ (Titanium Insert), Cherry MX 'New Nixie', Sarokeys BCP, Wuque Studio Morandi, Lubed Black Geon Switch, and Feker Emerald Cabbage)

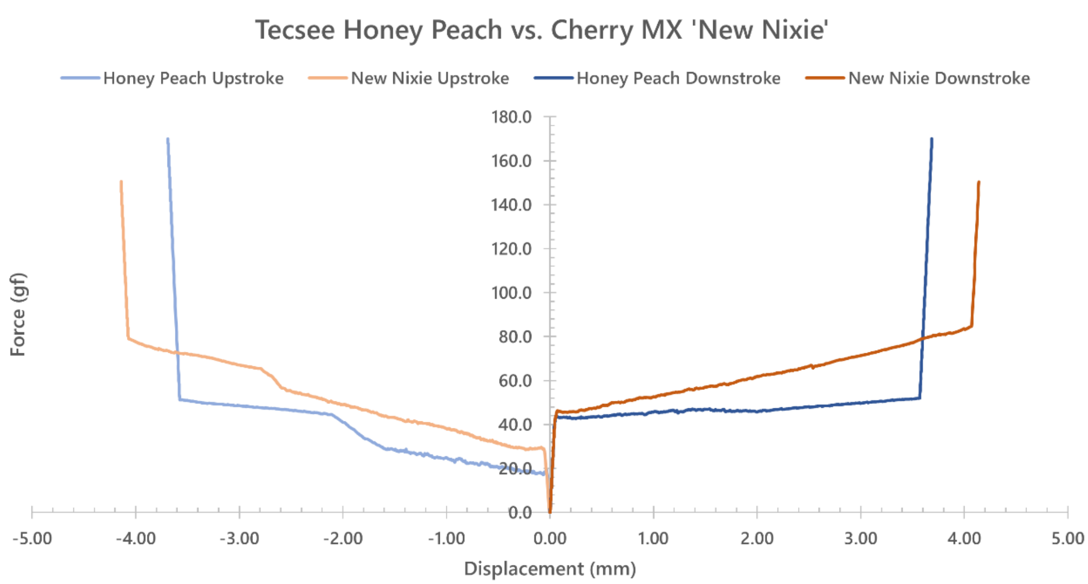
<u>Novelkeys Cream+ (Titanium Insert)</u>

- Of these two switches, the Cream+ switches with the Titanium insert provide the more distinctively metallic finish at the point of bottom out, hitting with a flat, clap that is a bit more sharp and less forceful than that of the Tecsee Honey Peaches.
- In terms of factory smoothness, the best example of both of these switches are pretty comparably smooth. That being said, though, there is a lot less switch to switch variation in the batch of Cream+ switches I received than the Honey Peach switches.
- Whereas my batch of Tecsee Honey Peaches had quite a few extraneous sounds to them, the Titanium insert Cream+ switches had a singular sound profile to them which revolved entirely around the medium pitched, slightly metallic bottoming out sound. In terms of overall volume, these two switches are comparable, though the Cream+ switches are perhaps just a touch more subdued.



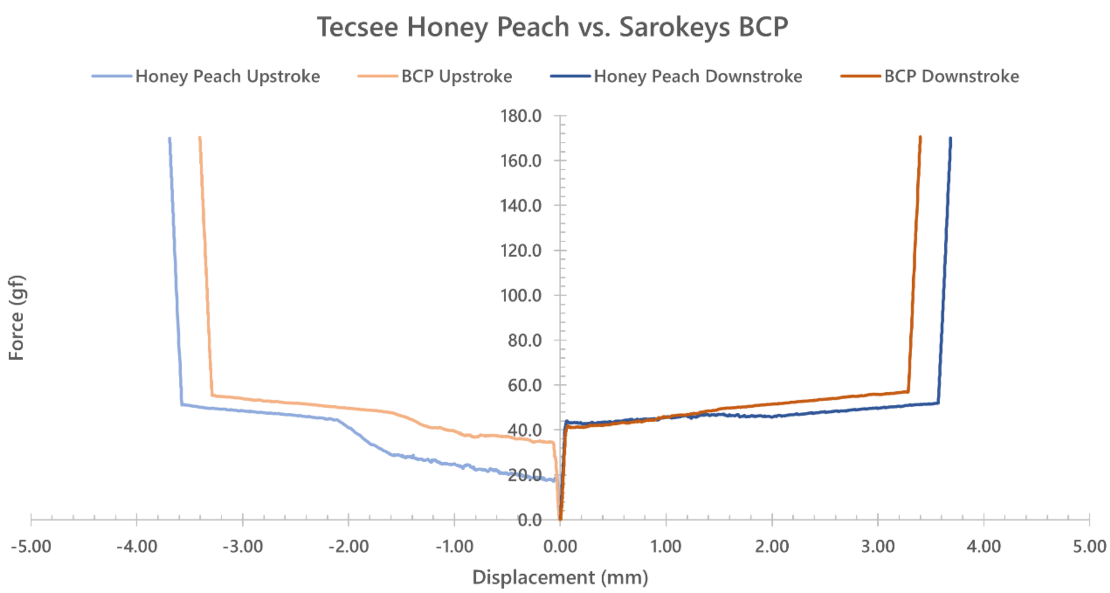
<u>Cherry MX ‘New Nixie’</u>

- ~~For how different these two switches are in terms of their construction and marketing points, they have fairly similar overall sound profiles and feelings as each other.~~ Whereas the Tecsee Honey Peaches have a bit more inconsistency and some more pointy metallic bottom outs and the Cherry MX ‘New Nixies’ have a bit more scratch to their stroke and depth to their housing collisions, these feel a lot closer to each other than one might expect upon initial guess.
- The Cherry MX ‘New Nixie’ switches have quite a bit less stem wobble than the Honey Peach switches in both the N/S and E/W directions. (Note that this is pretty unusual for a comparison between a switch made by Cherry and one made by another manufacturer.)
- In terms of their overall sound profiles, the ‘New Nixies’ are quite a bit more subdued, bass heavy, and have a larger amount of their sound profile eaten up by scratch than the comparatively higher pitched, sharper, and thinner sounding Honey Peaches.



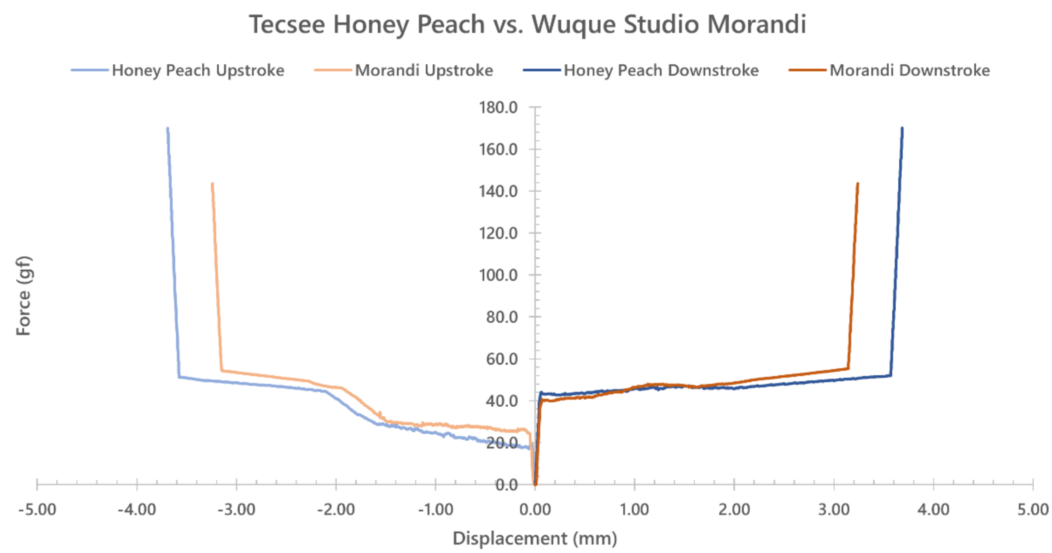
Sarokeys BCP

- Of all of the linear switches on this comparison list, the Sarokeys BCPs are the ones that feel the most different from the Tecsee Honey Peaches. In stark contrast to the Honey Peach's metal stem bottoming out and polycarbonate housings, the Sarokeys BCPs feel rather muted and compacted, with tough, firm housing collisions on either end of a decently scratchy stroke.
- In terms of stem wobble, the average Tecsee Honey Peach is pretty much in line with the average Sarokeys BCP switch. That being said, though, there is still a touch more variability in the batch of Hony Peaches that I received than the Sarokeys BCPs.
- Much like with the push feeling notes above, the sound profile of these switches is also pretty far apart. While the Tecsee Honey Peaches are only a slight bit louder than the Sarokeys BCPs, they have more clear, higher pitched, and metallic tones to their sound as opposed to the bass heavy, subtle, and muted tones of the BCPs.



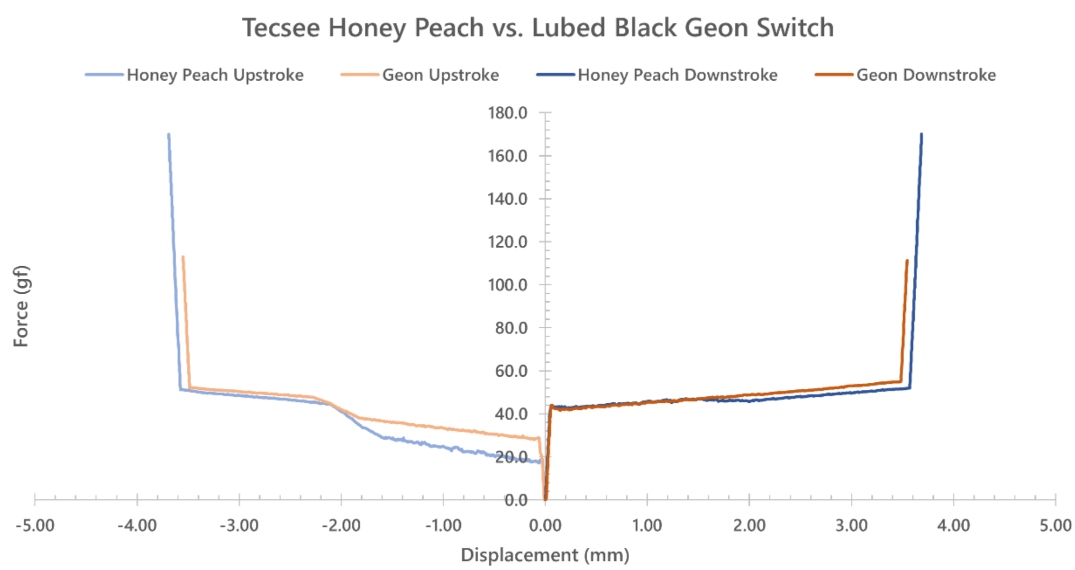
Wuque Studio Morandi

- In a rather surprising fashion, even though the Wuque Studio Morandi and Tecsee Honey Peach switches are rated to have fairly similar bottom out weights at 55 grams and 52 grams, respectively, the Morandi bottom outs feel *significantly* heavier in hand. This very well could be a result of the more stunted travel distance of the Morandi switches making their housing collisions feel more abrupt and sudden, though I would have initially guessed that the opposite would have been true here.
- The Wuque Studio Morandi have less stem wobble in both the N/S and E/W directions than the Tecsee Honey Peach switches.
- In terms of their factory smoothness, there is hardly any competition to be had here as the Morandi switches are far and away the more smooth and more consistently smooth of these two switches.



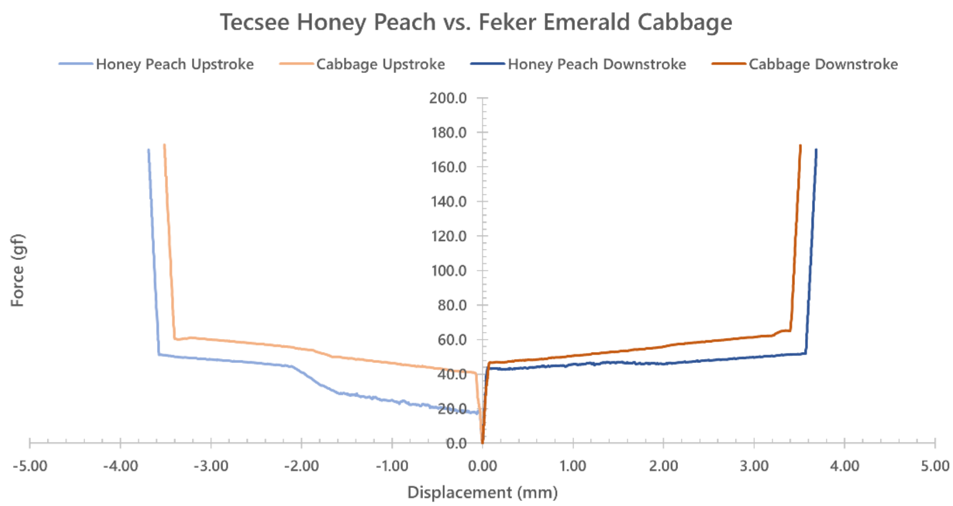
<u>Lubed Black Geon Switch</u>

- While there is a bit more of a metallic ‘twang’ to the bottom out of the Honey Peach switches, the general firmness of the bottoming out of these two switches is rather comparable to each other.
- Considering just the average switch, the Lubed Black Geon switches and the Tecsee Honey Peaches are fairly similar in terms of their smoothness throughout the stroke. Though, it needs mentioning yet once again, that the Honey Peach switches in the batch that I received had quite a bit more variation on this point than the boxes of Lubed Black Geon switches that I have tried.
- Of all of the switches in this comparison list, the Lubed Black Geon switches might be the only ones that have marginally more stem wobble in both N/S and E/W directions than the Tecsee Honey Peach switches.



Feker Emerald Cabbage

- Metallic stem poles be damned – the bottoming outs of the Feker Emerald Cabbage switches punch *much* harder and more firmly than the bottom outs of the Tecsee Honey Peach switches. This is even further surprising given that the bottom housings of the Emerald Cabbage switches are reported to be made of nylon whereas the Honey Peaches both have metal stem poles *and* bottom housings made out of traditionally thinner, sharper feeling polycarbonate.
- In terms of their stem wobble, the Feker Emerald Cabbages have a bit less N/S and E/W direction stem wobble. It's not likely enough of a difference to matter to most, but it is something that I definitely recognized when testing them outside by side.
- Considering their factory smoothness, the Feker Emerald Cabbages stand out as noticeably more smooth than the Tecsee Honey Peaches. Surprisingly, even this up and coming budget brand managed to produce switches that were more consistently smooth than a well-established manufacturer like Tecsee.



Linearity

Linearity and Slope Chart Values		
Regular Values	**Slope**	**R^2**
Tecsee Honey Peach	2.3350	0.9409
Novelkeys Cream+ (Titanium Insert)	4.8270	0.9963
Cherry MX 'New Nixie'	9.7002	0.9941
Sarokeys BCP	5.2709	0.9908
Wuque Studio Morandi	4.6732	0.9588
Lubed Black Geon Switch	3.8205	0.9959
Feker Emerald Cabbage	5.4819	0.9934
Normalized to Avg. Values	**Slope**	**R^2**
Tecsee Honey Peach	-3.6010	-0.0395
Novelkeys Cream+ (Titanium Insert)	-1.1090	0.0159
Cherry MX 'New Nixie'	3.7642	0.0137
Sarokeys BCP	-0.6651	0.0104
Wuque Studio Morandi	-1.2628	-0.0216
Lubed Black Geon Switch	-2.1155	0.0155
Feker Emerald Cabbage	-0.4541	0.0130
Number of Data Points in Avg.		**204**

Figure 15: Absolute and relative Linearity and Slope values for each switch in this comparison section.

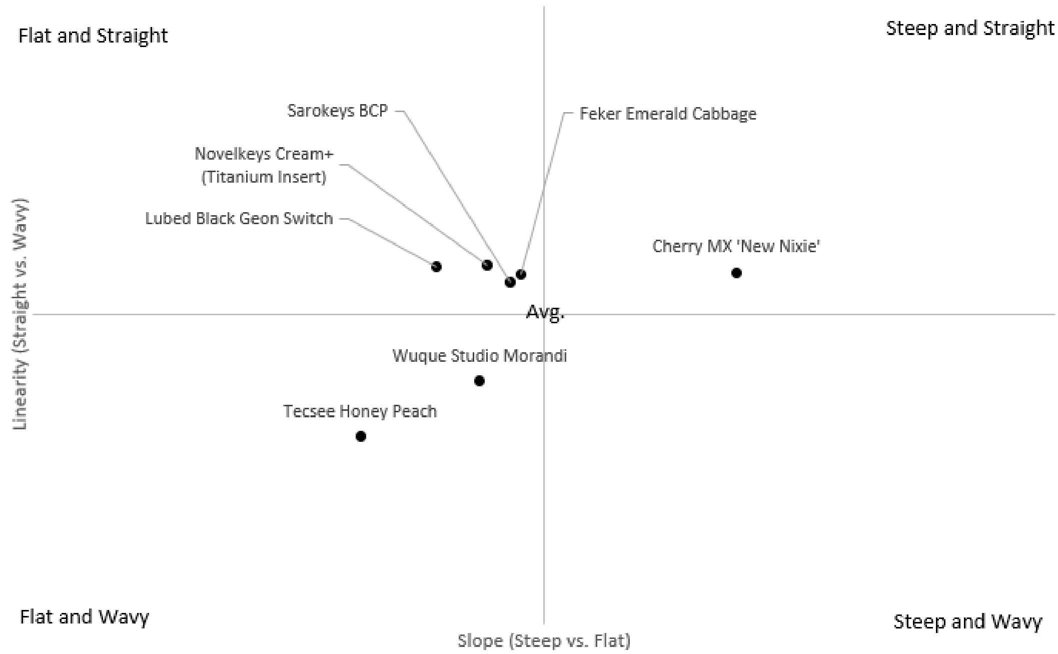


Figure 16: Qualitative comparison of the normalized Linearity and Slope for each switch in this comparison section.

If you are just now seeing this section for the first time and are a bit confused as to what I am talking about when discussing 'Slope' and 'Linearity', I highly suggest checking out my article titled 'On Differences in Linear Switches' where I explain what this section is for and how it came to be! For a bit of a shorter answer, know that this is part of my ongoing attempt to better quantify and articulate differences between linear switches which have historically not been captured in discussions about them.

Final Conclusions

For once, it feels like there's not many more words that I can nor want to include at the end of an article that could speak to what was presented above better than how you read it. This idea of quantitatively differentiating linear switches is something that has been deeply stuck in my mind for many months now and is something I think is sorely missing from the discourse surrounding linear switches. While I do not expect everyone to agree with this nor adopt this in their own discussions about switches, as part of my ongoing attempt to be as objective and as rigorous as possible, I'm choosing to implement this as a part of my regular content work. My hope is that it will be as widely appreciated as the introduction of force curves and comparative force curves were when I chose to role those out as well. Regardless of how it is perceived, though, this also opens up a gigantic rabbit hole of data-driven switch discussions which I find incredibly fascinating just at first glance. For example – were you perhaps curious what the 204 switches I've measured thus far look like when all plotted on the same relative graph as seen above in Figure 16? Me too…

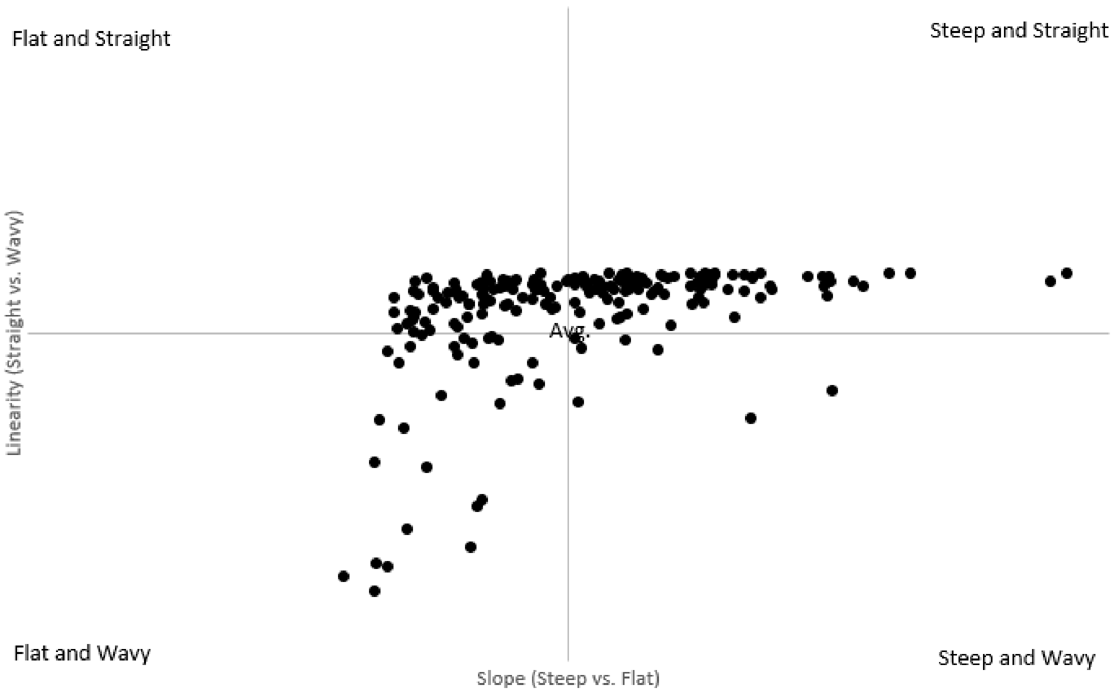


Figure 3: I certainly see quite a few odd features to look into with all of those plotted together...

Sponsors/Affiliates

Mechbox.co.uk

- A wonderful UK based operation which sells singles to switches that I've used above in my comparisons for collectors and the curious alike. Matt has gone out of his way to help me build out big parts of my collection, and buying something using this link supports him as well as my content!

KeebCats UK

- A switch peripheral company based out of the UK which sells everything switch adjacent you could ask for, they've been a huge help recently with my film and lube supply for personal builds, and they want to extend that help to you too. **Use code 'GOAT' for 10% off your order when you check them out!**

Proto[Typist] Keyboards

- An all-things keyboard vendor based out of the UK, proto[Typist] is a regular stocker of everything from switches to the latest keyboard and keycap groupbuys. While I've bought things from the many times in the past, they also are a sponsor of my work and allow me to get some of the great switches I write about!

Divinikey

- Not only do they stock just about everything related to keyboards and switches, but they're super friendly and ship out pretty quick too. Divinikey has been a huge help to me and my builds over the last year or two of doing reviews and they'll definitely hook you up. **Use code 'GOAT' for 5% off your order when you check them out!**

ZealPC

- Do they really need any introduction? Zeal and crew kicked off the custom switch scene many years ago with their iconic Zealios switches and the story of switches today couldn't be told without them. **Use code 'GOAT' (or click the link above) for 5% off your order when you check them out!**

MechMods UK

- A rising vendor based in the UK, Ryan and crew have been a pleasure to work with and have nearly everything you'd need to build your first or fourteenth keyboard. **Go build your latest or greatest one right now with them by using code 'GOAT' at checkout for a 5% discount!**

Dangkeebs

- A longtime supporter of the website and the collection, Dangkeebs has quite possibly the widest variety of switches of any vendor out there. Not only is their switch selection large, but it rotates and is constantly adding new stuff too. **You're going to need 5% off your order with my affiliate to save off the cost of all those switches!**

SwitchOddities

- The brainchild of one my most adventurous proxies, SwitchOddities is a place where you can try out all the fancy, strange, and eastern-exclusive switches that I flex on my maildays with. **Follow my affiliate code and use code 'GOAT' at checkout to save 5% on some of the most interesting switches you'll ever try!**

Cannonkeys

- Does anybody not know of Cannonkeys at this point? One of the largest vendors in North America with keyboards, switches, keycaps, and literally everything you could ever want for a keyboard always in stock and with an incredibly dedicated and loving crew. **Follow my affiliate link above in their name to support both them and I when you buy yourself some switches!**

Kinetic Labs

- One of the most well-rounded keyboard vendors out there, Christian and crew have been supporters of all my switch and switch-adjacent needs for some years now. **I'm honored to have them as an affiliate and think you should check them out using my affiliate link above to support both them and I when you check out their awesome products!**

Keebhut

- Want to try out some switch brands that fly under most vendor's radars? Keebhut is always seeking out that next latest and greatest and has been super helpful in hooking me up with new brands over the past year. **They are all about sharing that love as well, and want to give you 5% off your next order with them when you use code 'GOAT' at checkout!**