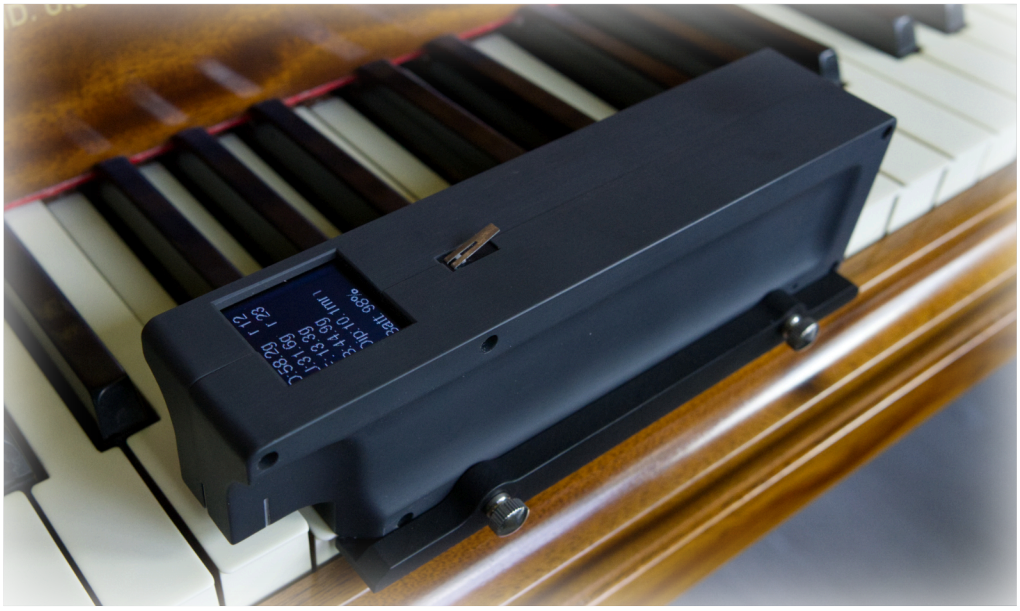
Key Measuring Device (KMD)



User Manual

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Patent Pending

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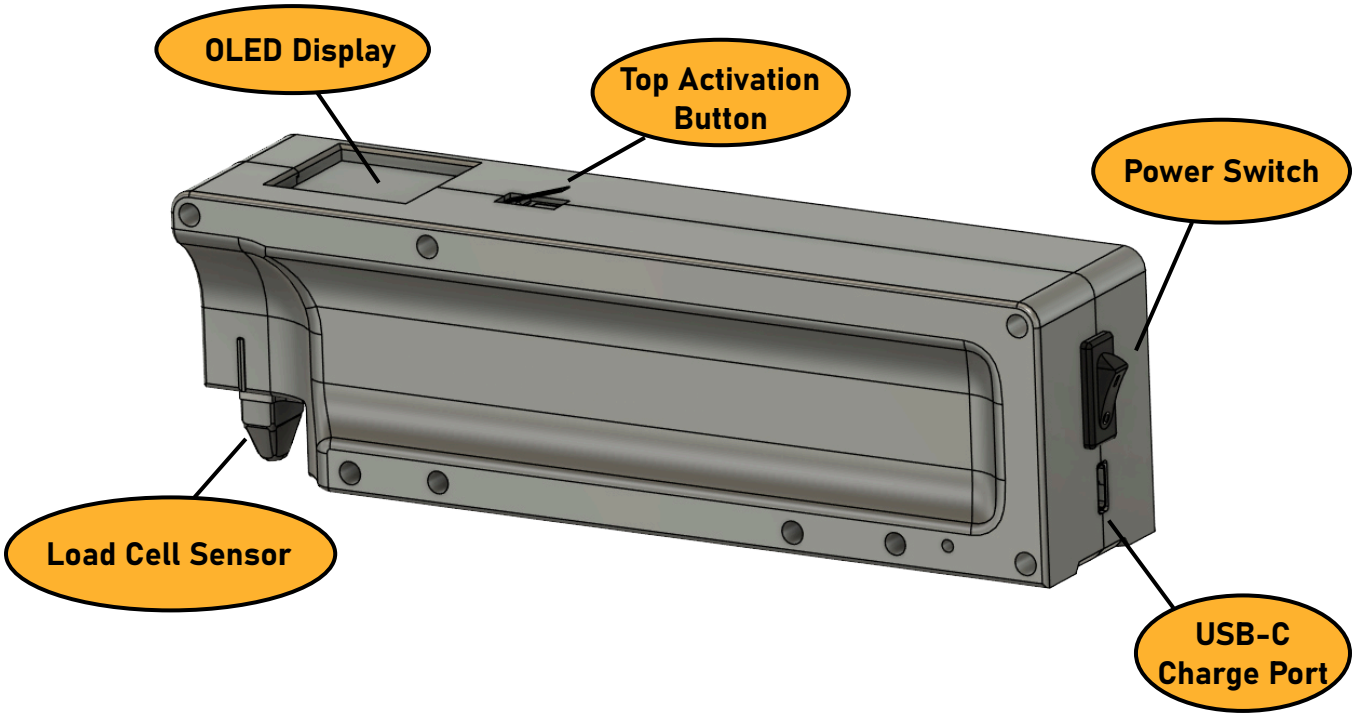
Overview



The Key Measuring Device (KMD) uses a precise load cell sensor (plunger) coupled to a mechanical actuator to measure the touchweight forces acting on a piano key. Upon activation, the load cell moves at a constant rate depressing the key until a specified stop weight is achieved. At that point, it reverses direction until the sensor disengages from the key. The KMD directly measures upweight, downweight and keydip; and then calculates balance weight and friction.

Using the KMD

Charging the KMD

The KMD battery is charged with a typical 5V USB C charger and the port is located on the rear of the device below the power switch. The charge rate is such that it can be done from any port that conforms to USB 1.0 or greater standards. The KMD should arrive with at least 50% battery charge but may need to be charged before the first use.

Turning on/off the KMD

The KMD is powered on and off via a rocker switch at the rear of the device. It is important to place the KMD upright on a level surface with no movement during startup. This ensures that the internal force sensor is tared properly. Treat it like starting up a precise digital scale.

Power saving mode

If the KMD is left on and idle for an extended period of time it will put itself into a power saving mode to protect the battery. Turn the KMD off and then on again to exit this power saving mode and resume normal operation.

Taking a measurement

To take a measurement, push the KMD firmly on the keys aligning the force sensor over the desired key to be measured. Make sure that the keys supporting the KMD are fully bottomed out. Then press the top activation button being careful not move the KMD during the measurement cycle. Any movement will affect the accuracy of the results. Once the plunger stops moving and the key information is displayed on the screen you can move to the next key.

Using the 13 mm spacer

In order to achieve the most consistent results, a 13mm spacer is provided with the KMD. The thumbscrews on the spacer attach directly to threaded inserts along the bottom edge of the KMD. The spacer is symmetrical and can attach to either side of the KMD.

Display

The KMD uses a low power consumption, high contrast, high viewing angle OLED (Organic Light Emitting Diode) display. After a successful measurement, the following will be displayed:

- **"D" - Downweight:** The amount of force required to depress the key downward. The KMD takes an average of touchweight values within a specified window of the downstroke to calculate this value.
- **"U" - Upweight:** The amount of force required to lift the key upward. The KMD takes an average of touchweight values within a specified window of the upstroke to calculate this value.
- **"F" - Friction:** The amount of mechanical drag in the system, calculated by:

$$\frac{\text{(Downweight - Upweight)}}{2}$$

- **"B" - Balance Weight:** The amount of force required to hold the key in static equilibrium in mid stroke, calculated by:

$$\frac{\text{(Downweight + Upweight)}}{2}$$

- **"Dip" - Keydip:** The distance the key travels during normal operation. The KMD measures the keydip on the downstroke and the upstroke of the key press. It uses the upstroke value for the keydip to eliminate the effect of gear backlash in the

mechanism. The downstroke keydip is used for error detection. (see Measurement Error)

- **“Batt” - Battery:** The charge state of the internal battery
- **“r” - Range:** This is a sanity check for the upweight and downweight. Within the windows in which those measurements are averaged there is a variance. The range is simply the largest value minus the smallest value within that window. A large value may indicate that letoff or added damper weight may be included in touchweight average skewing the results.

Measurement error detection

The KMD has basic error detection to prevent inaccurate readings. If any of the following conditions are met, the KMD will display “Error” and discard the results:

- **|keydip(upstroke) - keydip(downstroke)| > 1.0 mm**
- **range(downweight) > 99 grams**
- **range(upweight) > 99 grams**
- **keydip < 3.0 mm**
- **keydip > 13.0 mm**

The most common cause for an error message is the first item above which can be caused by sticky keys. If you come across a key that consistently gives an error message, watch the keystroke closely to verify a smooth downward and upward motion.

Device menu items

Accessing the menu

The KMD has several modes/parameters that can be accessed/modified using the menu system. This system is accessed by holding the activation button while powering on the device. The menu items in order are:

Menu items

1. **WiFi mode:** The KMD broadcasts a WiFi access point which the user can connect to using any WiFi enabled device with a modern web browser. (see Graphical user interface (GUI) AKA: nerd mode). This mode consumes a lot of power and reduces battery life so it is not enabled by default.
2. **Calibrate:** Sends the KMD into it’s calibration mode. (see Calibration Mode)

3. **Touchweight window low:** Sets the lower bounds for the touchweight window in millimeters along the keystroke used to calculate upweight, downweight, balance weight, and friction. Default: 2.0 mm

4. **Touchweight window high:** Sets the upper bounds for the touchweight window in millimeters along the keystroke used to calculate upweight, downweight, balance weight, and friction. Default: 4.0 mm

5. **Stop weight:** Sets the maximum force the KMD will impart on the key during the keystroke. This should occur when the key bottoms out on the downstroke and signals the KMD to start the upstroke. Default: 250 grams

6. **Exit:** Exits the menu and starts the KMD up normally in the default standalone mode.

Each time you power cycle the KMD while holding the activation button, the next menu item will be available to select. To select a menu item, release the activation button. Starting up the KMD without holding the activation button will start it in normal standalone mode and will reset the menu list position.

Adjusting stop weight example: With the KMD off, hold down the top activation button. Power cycle the KMD five times while still pressing the activation button. Each time you power cycle it you will see the next menu list item on the screen. On the 5th power cycle, “stop weight” will be displayed. Release the activation button to enter the stop weight adjustment mode. Now, press the activation button to cycle through different values for stop weight. Once the desired value is achieved, power cycle the device without pressing the activation button. Now you are in standalone mode with the changes to stop weight saved to nonvolatile memory.

Graphical user interface (GUI) AKA: nerd mode

GUI overview

The GUI (nerd mode) is where you really can see what’s going on with keys you are measuring. It’s a web based application that is served by the KMD itself and can be opened with any modern web browser. With it, you can see the touchweight curves for individual keys or the touchweight parameters for all the keys. The data can be exported to CSV format for further analysis.

Accessing the GUI

Accessing the GUI begins with starting up the KMD in WiFi mode (see Accessing the menu: 1. WiFi mode). This will broadcast a WiFi network with an SSID that matches your KMD serial number (i.e. KMD-0001). From a WiFi enabled device like a laptop or tablet, connect to this wireless network using “password” as the password. It is important to make sure the device you are using does not have “connect automatically” selected for any other WiFi networks. If

it does, you will likely lose connection to the KMD when your device finds out there's no Internet access through the KMD and it decides it would rather be connected to something with Internet access.

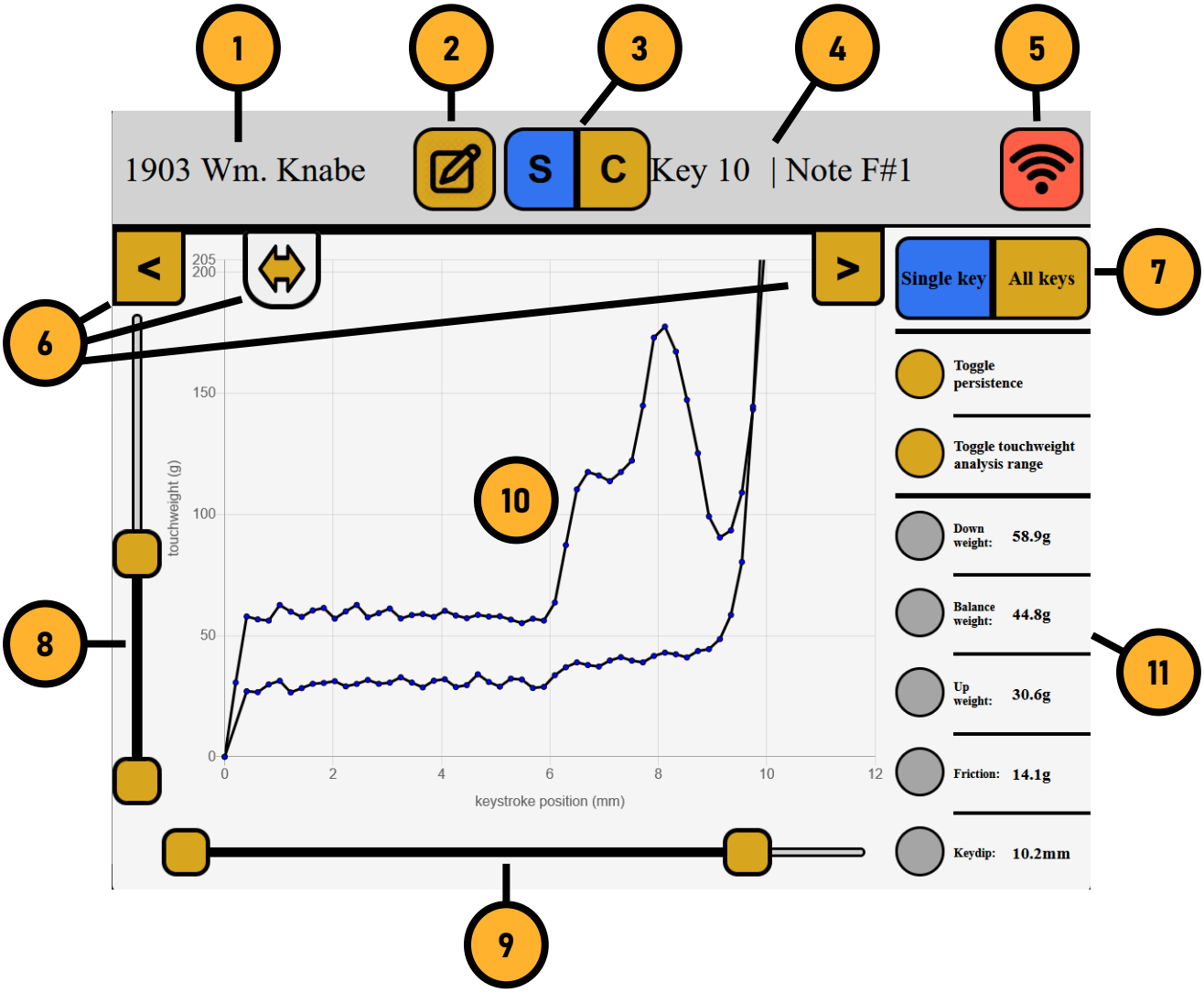
After your device is connected to the KMD, open a web browser and type the following address in the address bar and hit "enter" on the keyboard:

192.168.1.67

Make sure there is no "http://" in the address. Sometimes your browser will add that automatically especially if you attempt to access the above address without the KMD connected via WiFi.

If all goes well, you should now have the GUI displayed in your browser.

GUI layout



1. **Project title:** Shows the current working project. When you export data, the filename will incorporate the project title. It is modified in the File > Edit menu.

2. **File menu:** Contains the following sub-menus:

   New: Reloads the GUI webpage wiping all the key data.

   Open: Launches a system "File Open" dialog window where you can select and load a saved project JSON file.

   Edit: Opens a window where you can modify parameters pertaining to the project itself. Within it you establish the project name, number of keys in the piano being measured as well as the starting note.

   Save: Launches a system "File Save" dialog window where you can save the currently loaded project into a JSON file that can be loaded later.

   Export CSV: Allows you to export key data in CSV format. You can either export the detailed touchweight curve for a single key or the complete overview with values of downweight, upweight, balance weight, friction, and keydip for all the keys measure. The CSV files can then be opened by your preferred spreadsheet software.

   Settings: Opens a window where you can modify parameters pertaining to KMD operation. Within it you can alter calibration weight, touchweight window low, touchweight window high, and stopweight. You can also force the KMD into calibration mode or restore factory defaults. The KMD must be calibrated after restoring factory defaults.

3. **Measurement mode selector:** Selecting "S" will put the KMD GUI in "single" key mode. With it enabled, the key being measured doesn't change after a measurement is performed. This is useful when taking multiple measurements of a single or specific key successively.

   Selecting "C" will put the KMD GUI into "continuous" mode. With it enabled, after each successful measurement, the GUI will increment the selected key automatically. This is useful when measuring an entire keyboard starting at bass and working toward the treble.

4. **Key/note indicator:** Shows which key is currently selected which correlates to the graph data displayed. If "continuous" mode is selected, this indicator will also show which key the next measurement will be for. After manually selecting a key with the key selection slider, the next key will be the same as the current key and will increment normally after the first successful measurement.

5. **Connection status:** Shows whether or not the KMD has an active WiFi connection with GUI. Green indicates there is a connection and red indicates there is no connection.

6. **Key selection slider:** Allows you to manually select a key to view or measure. The slider

is proportional from the starting to the ending key (middle of slider would be key 44 on 88 note keyboard). The buttons on the end will increment or decrement the selected key. It's generally easiest to use the slider to get close to the desired key and finish with the buttons.

7. **Graph mode selector:** Selecting "Single key" will show the touchweight curve for the current key in the graph canvas. Selecting "All keys" will show the key parameters for all the keys. The data in the graph canvas correlates to the data that can be exported to CSV in the File > Export CSV menu.

8. **Y-axis scale slider:** Adjusts the upper and lower bounds of the graph y-axis.

9. **X-axis scale slider:** Adjusts the upper and lower bounds of the graph x-axis.

10. **Graph canvas:** The area where the graph data is displayed.

11. **Graph options/info:** With "Single key" selected, you can select "Toggle persistence" and "Toggle touchweight analysis range". "Toggle persistence" will show a grayed out curve of the previous key selected. This is useful when comparing two separate keys or a single key with itself (i.e. with and without dampers raised). "Toggle touchweight analysis range" highlights in blue the region of the curve where the touchweight numbers are being averaged. It is the touchweight window that is set using the "touchweight window low" and "touchweight window high" parameters.

    With "All keys" selected, you can select which key parameters are visible in the graph canvas. It also shows you the values for the current key selected. In the graph canvas, the dots corresponding to the current key are enlarged.

Calibration Mode

Your KMD is calibrated at the factory and should not need further calibration. If you do decide to follow the steps below, please exercise caution.

To enter calibration mode, access it through the menu system or web based GUI and place the KMD on a hard flat level surface. The KMD will display "click to check current calibration". After pressing the activation button, the KMD will push the force sensor all the way out lifting the front of the KMD off the surface. It will display the current reading real time. This value should be very close to the calibration value that can be set within the GUI. Below the current reading will be a couple more numbers, the offset and calibration factor. The offset is the zero offset and is reset every time the KMD starts up. It is equivalent to tare on a scale. The calibration factor is what gets changed during the calibration procedure.

To fully check the calibration, prop up the back of the KMD and place the sensor on a digital scale in such a way that only the sensor is touching the scale (preferably in the center of the

platform). The number on the KMD should match the number from the scale. It is normal for the number to jump around quite a bit on the KMD as the number displayed does not have any averaging applied. When propping the KMD, try to make it as level as possible.

If the numbers are satisfactory, power cycle the device to resume normal operation. Otherwise, press the activation button to continue the calibration procedure. The sensor will retract and the KMD will display “click to perform calibration”. Place the KMD on a hard flat level surface and press the activation button to continue. The KMD will then perform a two point calibration. The first point is the zero point with the sensor hanging in free air. The second point is when the KMD lifts itself off the surface with the sensor and is at the calibration weight. After it performs this, the KMD will display the zero offset and calibration factor. If you do not want to use these values, power cycle the device to cancel the calibration procedure. If you do want to use these values, press the activation button to commit them to nonvolatile memory.

Measuring a keyboard workflow

1. Turn on KMD in WiFi mode.
2. Connect to KMD via tablet or laptop and open the GUI (SSID: KMD-xxxx, password: password, IP address: 192.168.1.67).
3. Enter project information in File > Edit sub-menu.
4. Set measurement selector mode “C”.
5. Attach 13 mm spacer (optional).
6. Measure entire keyboard starting at key 1 and moving up sequentially. Periodically check to make sure the key on the GUI is still matched up with the key you are measuring. It is also a good idea to periodically save the project in the File > Save sub-menu. Towards the upper register it will be necessary to attach the 13 mm spacer to the opposite side of the KMD.
7. Export key data to CSV using the File > Export sub-menu.
8. Analyze results, regulate keys, repeat measurements as necessary.

Support contact info

If you have issues with your KMD or questions on its operation, please contact support at:

keymeasuringdevice@gmail.com