The μPGV manual

Introduction

The Micro Parametric Guitar Vocoder, or shortly **μPGV** is a guitar synthesizer that fits in a typical guitar pickup slot. Both typical single coil and humbucker size formats are available. The main function is the vocoder, but it also has synthesizer modes and effects that work without a vocal microphone. These include FM synthesis, harmonic generator, vibrato, pitch bend, and reverb. Also included is an artificial chord sustain effect for playing long lasting chords in any synthesis mode. **Figure 1** shows the two size variants.

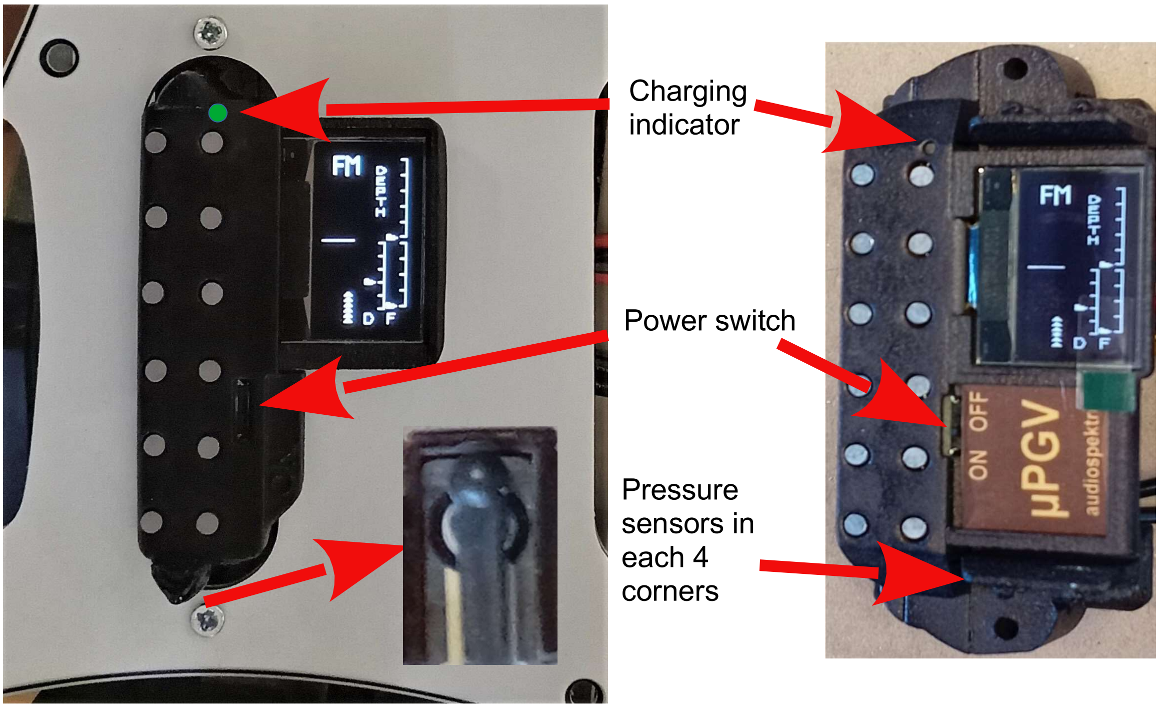


Figure 1: Front panel images of the two size variants of the μPGV. The user interface consists of a small OLED display and four touch sensors for selecting the different synthesis modes and adjusting parameters. The power switch is also on the front panel. The battery power status is displayed at power-on. The thin OLED display of the single coil sized version extends over the pickguard surface. No additional cutouts are needed, though. The four touch sensors are operated by pressing the small bumps, see the detail image. The humbucker-size variant is electrically and functionally identical, but the larger slot allows less tightly packed setup for the touch sensors. It also sits fully inside the slot opening, allowing deeper positioning, if the pickguard to string -distance is short.

An important feature of the **μPGV** is that it has separate sensors for each of the six guitar strings. This allows its DSP processors to run 6 independent low latency digital synthesis channels, one for each string. Typical stompbox effect pedals have to rely on the 6 string composite guitar signal, therefore it is natural that they have longer latency if trying to access the individual string signals like the µPGV does.

The main difference of the vocoder mode when compared to conventional guitar vocoders is that the µPGV measures the individual pitch and amplitude of the 6 strings. Based on that data, the µPGV performs independent synthesis for all the string signals using the vocal spectrum, allowing controlled modification of the analysed parameters. Conventional guitar vocoders only modulate the composite raw guitar signal with the vocal spectrum.

The connections

The µPGV needs two additional connectors compared to a typical guitar setup. A vocal mic mini-XLR connector, and a USB-C charger connector for charging the Li-ion battery. **Figure 2** shows this setup assembled to a typical pickguard panel.

Figure 2: The pickguard modified for use with the µPGV in the case of the single coil -sized variant. Additional vocal microphone mini XLR connector and a USB-C charger jack are needed. The hole of the removed second tone knob is used for the USB-C charger jack. The volume and the other passive pickup tone knobs stay at their normal positions.

A hands-free headset microphone is most useful when simultaneously playing and singing. The microphone has to be an electret-type mic, no dynamic microphones are supported at this time. Several models work well, e.g. Behringer BC444, AKG C 555 L, and t.bone HC-444 TWS. See the pin-out and biasing details in the "Assembly instructions" -section if you use improvised setups.

The output of the µPGV is a low impedance amplified signal that can be connected to the guitar volume knob through its selector switch simply replacing the removed pickup in the selector. **Figure 3** shows the corresponding pickguard setup for a humbucker -sized variant.

Figure 3: The pickguard modified for use with the humbucker -sized variant. The vocal microphone and the USB-C charger are also shown connected. The selector switch now has only two positions, either for the µPGV or for the remaining bridge pickup.

Power

The µPGV uses 5 volts, and takes 130mA of current. The rechargeable 3.7V Li-ion battery uses a standard USB-C connector. The later section "Assembly instructions" shows the powering options.   E.g. a small 1500mAh battery is sufficient for about 10h of playing time. A 3.7V Li-ion battery has to be used, e.g. the most common round 18mm diameter battery, see the "Assembly instructions" in a later section. **Do not use any LiFePO4 batteries**: they have lower voltage, 3.2V - 3.65V, thus will be overheated when charging using the µPGV electronics. The USB-C connector is limited to a 500mA charging current to prevent overheating the battery. The µPGV can also be used while charging.

The controls

The µPGV has four touch pressure sensors for selecting the different operation modes and controlling the synthesis parameters, as shown in **Figure 4**. Each sensor has both a solo function when pressed alone, and a function when pressed together with another touch sensor. The solo functions include adjustment of the parameters for the active synthesis mode, i.e. the lower left side (B1) decreases the value, and the lower right side sensor (B2) increases it. The small arrow on the upper right side of the OLED display panel gauge shows the current value. The upper side sensor functions depend on the selected mode of synthesis, as described in the following sections.

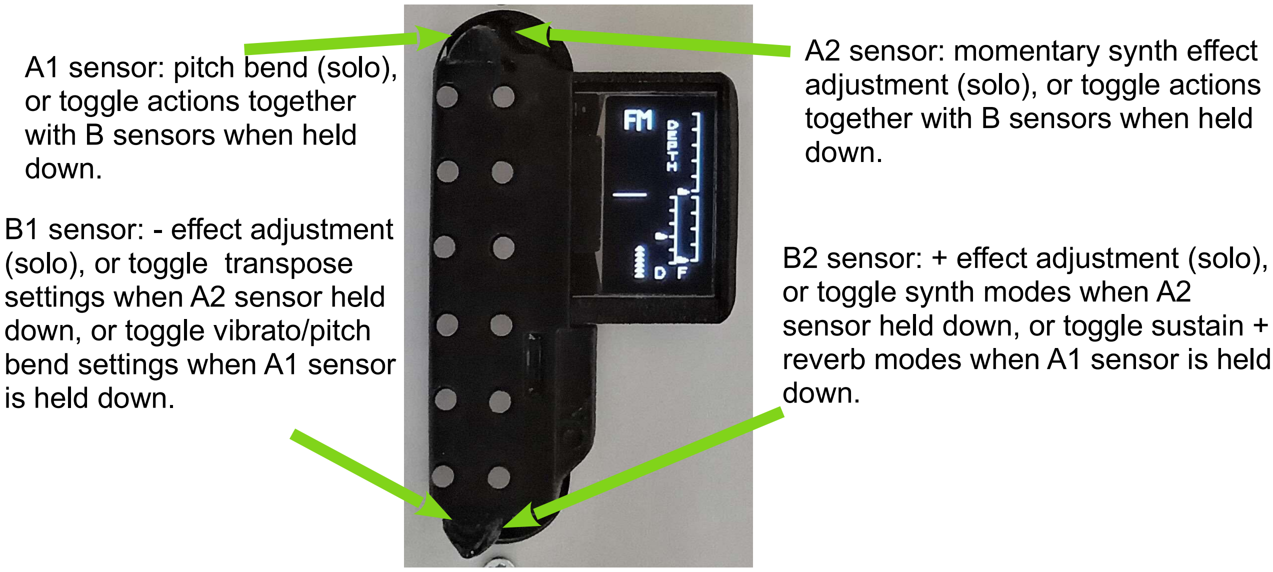


Figure 4: The front panel controls and their functions when used alone and with some other sensor.

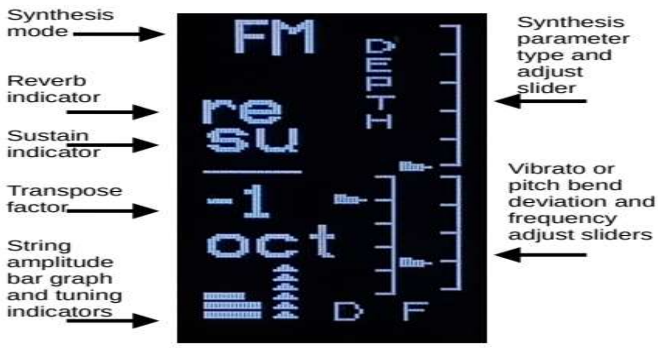


Figure 5: The OLED display fields

Synthesis mode selection

When the A2 sensor is held down, the user can scan through the various synthesis modes by toggling the B2 sensor. When cycling through, the mode order is as follows: FM synth (FM), Vocoder 1 (VOC 1), Vocoder 2 (VOC 2), Vocoder spectrum freeze (VOC frz), Vocoder noise control, (VOC nz) and Harmonic Generator (HG). Each mode is described later in detail.

The OLED display panel shows the selections made: The current synthesis mode is written on the upper left corner of the panel (e.g. “FM” is the default mode at startup), and on the upper right side a half display length linear gauge shows the adjustable parameter of the current mode. The type of the parameter is written on the left side of the gauge (e.g.”depth” for FM synthesis, i.e. the modulation depth).

Transpose selection

When the A2 sensor is held down, the user can toggle through several possible transposition values using the B1 sensor. The order is: none, -1 octave, -2 octave, +1 octave, -4th, +4th, -5th, or +5th. The current selection is shown on the left side, just below the center line of the OLED display.

Sustain and/or reverb selection

When the A1 sensor is held down, the user can scan through the four possible alternative modes by toggling the B2 sensor in the order: none, sustain (su), reverb (re), or both sustain and reverb (re over su). The current selection is shown on the left side, just over the center line of the display. These selections have no adjustable parameters. The vocoder synthesis modes do not support reverb, therefore the toggle sequence in those modes is only sustain – none.

Vibrato/pitch bend

When the A1 sensor is held down, the user can activate vibrato or pitch bend adjustment by toggling the B1 sensor. The three options are: 1. pitch bend, 2. vibrato with pitch bend deviation adjustment, and 3. vibrato with frequency adjustment. The active mode is indicated by a small triangle pointer next to either to the F or D letter, or no triangle for pitch bend.

The current vibrato frequency and vibrato/pitch bend depth are shown with the two gauges on the lower right side of the OLED display. The left one shows the deviation or depth of the vibrato or pitch bend (letter “D” below the gauge), and the right one the frequency of the vibrato (letter “F”). When the triangle points to the “F” gauge, the player can toggle through 4 different frequencies of vibrato using the A1 sensor alone: 1.75Hz, 3.5Hz, 7Hz, and 14Hz (Hint: the Hammond organ -type vibrato frequency is 7Hz).

Correspondingly, when the small triangle pointer is next to the “D” gauge, use only the A1 sensor alone to toggle through 6 possible deviation values from 1 to 6 semitones. Deviation is the distance between the extrema, i.e. for a 1 semitone deviation, the note frequency sinusoidally goes from -1/2 semitone to + 1/2 semitone around the nominal pitch, etc.

The third alternative selected by the A1 + B1 is pitch bend, in this case there is no triangle under the

D or F gauges. This is also the situation on power-up. Now the previously adjusted D value shows the maximum pitch bend deviation achieved when pressing the A1 sensor alone. The actual pitch bend is dependent on the pressure applied. The default maximum at power-up is two semitones, and only pitch bend is active.

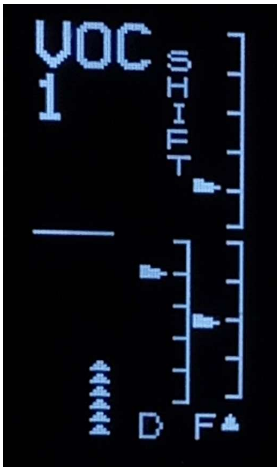


Figure 6. The situation with vibrato active (triangle pointer present), vibrato frequency adjustment active (triangle pointer next to "F"), frequency adjusted to 3.5Hz, and vibrato deviation previously adjusted to 5 semitones. The synthesis mode is VOC 1, with the spectrum shift adjustment active.

Tuning

The OLED panel also shows individual tuning aids for the 6 strings. They can be seen at the lower left corner. There are separate amplitude bar graphs for the strings, in the typical order e, a, d, g, b, and e. See Figure 5 for 3 active bars showing the amplitude of the corresponding strings. At the right sides of each bar, there are typical tuning indicators >, <, or •. The tuning aids are only applicable for the free string frequencies of a guitar in the standard tuning setting.

The synthesis modes explained

FM

At power-up the default synthesis mode is **Frequency Modulation (FM)**, familiar from many notable synthesizers since the 80's. Strictly speaking, in our case it is phase modulation, because the modulating frequency is equal to the actual note frequency. This is a convenient mode to start playing to test the synth and guitar tuning because no microphone is needed. With increasing modulation strength, the signal spectrum spreads to higher frequencies. There are two control inputs:

1. Amplitude dependent modulation sensitivity is adjusted by the bottom + and - pressure sensors. The individual string amplitudes increase the modulation strengths of the corresponding synthesized signals.

2. Amplitude independent momentary modulation sensitivity that only responds to the pressure applied to the top right sensor. This effect works globally to all the strings.

Both methods can be used simultaneously.

The vocoder modes

Modes 2 - 5 are all vocoder modes and therefore require a microphone to be connected to the mini XLR connector. As noted, the main difference of the µPGV when compared to conventional guitar vocoders is that the µPGV measures the individual pitch frequencies and amplitudes of the 6 strings. Based on that data, the µPGV performs independent synthesis for all the 6 string signals using the vocal spectrum as the signal spectrum for each of the 6 channels independently. Conventional vocoders only modulate the composite raw guitar signal with the vocal spectrum. In the case of VOC 2 mode, the applied spectra can even be different for all the 6 channels.

Mode “VOC 1”

The µPGV's software allows the user to modify the analysed vocal spectrum. In mode VOC 1, the user can shift the spectrum upwards or downwards with the + and - pressure sensors, the central position being neutral without any spectral shift. When the shift is at minimum, the spectrum is compressed and shifted towards the lower frequencies, resulting in a timbre/voice resembling a "giant" speaker. Correspondingly, when the shift is at maximum, the spectrum is shifted and expanded towards the higher frequencies, resulting in a timbre/voice resembling a tiny or "baby" speaker.

Mode “VOC 2”

In mode VOC 2, the + and - pressure sensors are used to shift the vocal spectrum upwards or downwards similar to modes 1 and 2 except for one key difference. In this mode the shift affects each guitar string differently. When adjustment is at the default middle position (seen at the top right gauge pointer) the spectrum is neutral without spectral shift. When adjusted downwards in the gauge, the spectra of strings 1-3 (the lower three strings) are compressed and shifted towards the lower frequencies, resulting in a timbre/voice resembling a "giant" speaker. Simultaneously, the spectra of strings 4-6 (the higher strings) are shifted and expanded towards the higher frequencies, resulting in a timbre/voice resembling a tiny or "baby" speaker. Inversely, when the + pressure sensor is used towards the maximum as seen in the gauge, the lower three strings are now expanded and the higher strings compressed, giving the opposite spectral shift/timbre results. The spectrum compression or expansion magnitude order is 1>2>3 and 6>5>4, meaning that the two middle strings (D and G) will always remain closer to neutral spectral shift and the highest and lowest strings will be the most shifted.

Mode "VOC frz"

In this mode, the instantaneous vocal spectrum can be "frozen". When the microphone input signal exceeds the -6dB level, the µPGV captures, or "freezes" the vocal spectrum and the corresponding vocal amplitude remains fixed. Now the user may play the µPGV using that frozen vocal spectrum of the vowel. The user may also change the frozen vowel at will while playing by again raising his/her voice. The lower pressure sensors adjust the spectra the same way as in the mode VOC 1.

Mode "VOC nz"

In mode VOC nz the lower pressure sensors control noise modulation for the spectral peaks. The modulation range extends from very light, whispering type of sound all the way to a full noise heavy sound, while following the singer spectrum. In addition to the heavily modulated applications that the mode offers, the user may find the noise effect a useful nuance when going for a more "natural" sound with the vocoder because a human voice always has some random phase variations that otherwise are usually lost with vocoders. Note that the noise is not simply added over the spectrum, but appears as gradually smearing the frequency peaks in the spectrum.

Mode "HG", the second non-vocoder mode

Mode HG is a harmonic generator featuring harmonics 1-10. The harmonic frequencies above the fundamental are amplitude modulated with a sinusoidal waveform. The modulation is cyclical, so with a continuously increasing or decreasing modulation amplitude, the harmonics' amplitudes vary cyclically between the maximum and zero. The modulating signals of successive harmonics are phase shifted, so that the minima and maxima occur at different levels of the modulating signal. In the same way as for the FM, there are two controls for the modulating signal: the bottom + and – pressure sensors control the sensitivity of the modulation to the amplitude of the corresponding string, while the A1 sensor adds amplitude independent modulation, depending on the applied pressure to the sensor. The amplitude independent sensor has high gain, so that a strong force on it results in very drastic amplitude modulation of the harmonics.

Hint: if you adjust vibrato frequency to 7Hz, and try slight HG modulation, the effect is close to a notable Hammond organ effect.

Additional common effects

Reverb

The reverb effect can be added to any of the previously listed synthesizer modes, except not for the vocoder modes. It has no adjustable parameters. The display indicator is “re”.

Sustain

Usually high pitch notes fade away much faster than low pitch notes in guitar chords. Activation of the sustain effect “su” adds artificial sustain to any selected synthesis mode with the added advantage of being able to play long lasting chords where all the notes last the same amount of time.

This artificial chord sustain only follows the total sum of all the 6 guitar strings. For example, by simultaneously picking a high E string note and low E string note, the high note will play as long as the lower string note has some amplitude left even though acoustically the higher string has audibly faded away. However, if the faded string is picked again, its pitch is updated as soon as its real amplitude reaches a set percentage of the artificially sustained amplitude, and the sustained amplitude is updated when the real amplitude reaches it. This effect requires a bit of getting used to, and perhaps a playing style where all the strings may need to be dampened simultaneously frequently for stopping the current chord.

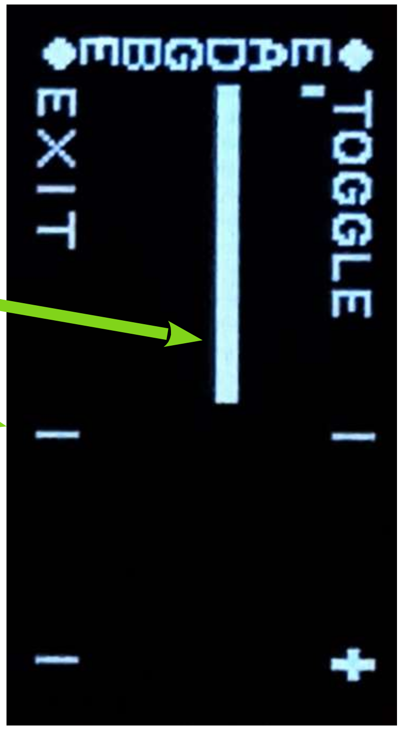
There is a fixed low threshold for the total measured amplitude that keeps the artificial chord sustain active. If there is a situation where only one high pitch string is picked, the sustain only lasts as long as this single note stays above this certain threshold. Because high pitch strings fade away fast anyway, the only effect for this situation is that the note stays artificially louder until the real measured amplitude reaches the low threshold and stops the artificial sustain quickly. However, even a very faint new picking of the string or any other string keeps the note sustained.

String amplitude calibration

The µPGV has efficient separate amplifiers for the 6 string signals, so the signal levels are easily kept strong enough. However, in order to avoid interference from the neighboring strings, it is essential that the pickup is installed as close to the strings as possible, but without the strings touching the pickup. Strings with different thickness generate very different signal amplitudes in the electronics. The µPGV is factory calibrated for a typical 10-46 string set, but each setup may still result in too much variation from string to string. Therefore the amplitudes can be re-calibrated according to the following instructions.

Push firmly both the B1 and B2 pressure sensors when turning the µPGV on. Keep the sensors continuously pushed until you see the OLED display showing the calibration display as shown in **Figure 7**.

Figure 7. The string amplitude calibration display shown during the D string adjustment phase.



The calibration display shows the 6 strings listed at the top of the display as EADGBE. Start by picking the low E string. You see a bar graph below the first E letter to the right, showing the momentary amplitude of the low E string. The activated mode is fixed FM, and you can listen how the correction modifies the amplitude when picking. Because in FM the modulation depth is amplitude dependent, you can also hear the effects of the amplitude gain modifications through the spectrum variations.

There are also two horizontal bars, about midway on the sides of the display. They show the absolute maximum level to which the amplitude of the string can reach. Now you can adjust the gain using the bottom B1 and B2 , or + - pressure sensors. The vertical amplitude bar reflects the gain adjustments, and you can hear the changes while picking and adjusting.

When increasing the gain, you will see that the bar can actually overcome the maximum level markers. Naturally the output amplitude cannot go beyond the maximum, but the excess gain can still be utilized by making a sharper attack, and/or cutting away the peaking part of the signal, or extending the sustaining string note duration. However, you can also hear that the amplitude dependent FM modulation remains constant as long as the amplitude exceeds the limit. This limiter does not distort the signal, because the amplitude value is just another number sent to the synthesis part, but a constant signal without any amplitude dependent variation is quite dull, so it may not be a good idea to adjust the gain much over the limit level bars.

In the display you can also see the words “EXIT” and “TOGGLE” that correspond to the A1 and A2 pressure sensors. Press the A2 = TOGGLE sensor. Now the A string bar activates and its amplitude can be calibrated the same way as was done for the E string.

Repeat the operations for all the remaining strings and compare the loudness differences. After the final E, you can also go back to the beginning by again hitting the TOGGLE sensor, if additional adjustments are needed to any string. The previous settings will stay unless you use the + and – adjustments again.

After you have calibrated all the strings, you need to push the EXIT sensor A1 to burn the new gain settings to the nonvolatile flash memory. Then the program returns to the normal operation and display mode.

Assembly instructions

The µPGV setup consists of the components shown in **Figure 8**. There are four cables interfacing to the external units: the rechargeable battery, the USB-C charging adapter, the mini-XLR microphone connector, and the signal output. The signal output has no connector, only bare leads, because it has to be soldered to the guitar selector switch, to replace the output cable of the removed conventional pickup. **NOTE: Only use such a selector switch that does not connect the µPGV output to any outputs of the remaining analog pickups.** There is a danger of getting high voltage spikes from the large inductance of the analog pickups, and on the other hand, the µPGV output is short circuited to ground when shut off, and when turned on, the analog pickup almost mutes the µPGV. If this is not possible, you need to use an extra selector switch to select either the µPGV or the output of the old selector to be connected to the volume potentiometer. Also check that no tone pots are connected to the µPGV output.

The vocal microphone mini-XLR connector is directly soldered to its cable, because it can be mounted from behind to the pickguard. The USB-C charger adapter, however has a removable JST SYR/SYP -02 -type connector, because the adapter has to be mounted from the front side of the pickguard. The battery cable also has a connector that is compatible with the JST SYR- 02T that can be found in some compatible batteries. Only one additional hole needs to be drilled to the pickguard, because the other tone potentiometer can be removed, and its hole utilized either for the mini-XLR or the USB-C charger adapter. Both need an 11mm diameter hole

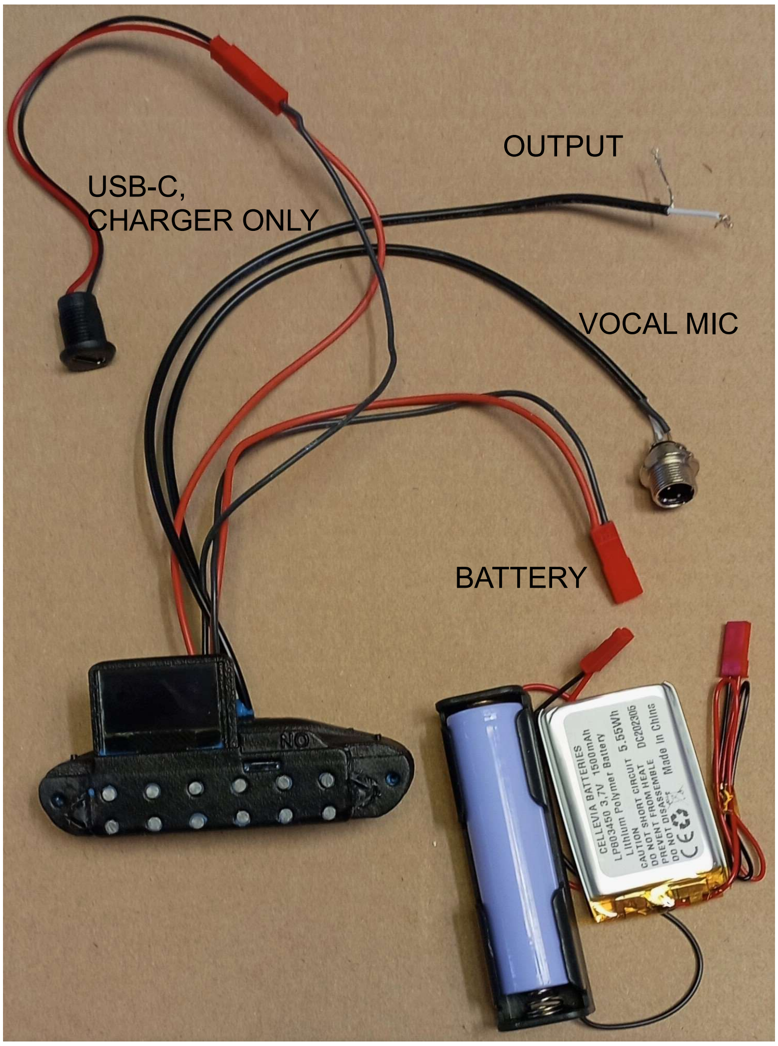


Figure 8. The µPGV assembly setup wiring with two alternative, different battery sizes (batteries sold separately).

Due to air freight limitations for Li-Ion batteries, there are some options to consider in the assembly, when installing batteries that are not included in the package. These options are addressed in the following.

The default power solution is to use a 3.7V Li-ion battery that fits behind a typical pickguard. **Do not use any LiFePO4 batteries**: they have lower voltage, 3.2V - 3.65V, thus will be overheated when charging using the µPGV electronics.

The most common small rechargeable Li Ion battery size is the 18650 for a 65mm long, 18mm diameter battery. The setup has a holder for that size of a battery, with a JST SYR- 02T compatible socket. These batteries with sufficient capacity can be found on every continent. Unfortunately the 18mm thickness is too large for many guitar bodies, therefore at least in Europe and China it is easy to find a flat battery, e.g. the LP803450 model by Cellevia with a size of 8mm x 34mm x 50mm. It also has the compatible plug. It has 1500mAh capacity, which is sufficient for about 10 hours of playing. It fits behind most pickguards, and can be found e.g. from www.tme.eu.

The µPGV can also be run using only the USB-C charger connected without a battery. The charger is not included in the setup. In that case it is best to obtain a long charger-only cable that has a 90 degree kinked end, so the cable does not obstruct playing.

Notes on the vocal microphone connections: There seems to be no standard for the use of the mini XLR jack in electret microphones. The tested microphones, Behringer BC444, AKG C 555 L, and t.bone HC-444 TWS have differences. All seem to use pin 1. of the XLR as the GND/shield terminal. Behringer BC444 uses pin number 3 as the bias voltage input, and its internal resistance against the signal output pin 2 is 2.2 kohms. The AKG and t.bone seem to have the pins 2. and 3. short circuited, therefore serving for both as the signal output and bias voltage input. In order to be able to use all these microphones, the µPGV has an internal 2.2 kohm series resistor for the 1.5V bias voltage, and the bias and signal lines are already connected together. Note that the 1.5V bias voltage is lower than the typical requirement for some microphones! As a matter of fact, only the Behringer BC444 from the above mentioned microphones is specified for that low bias, but the others mentioned are found to work well, too. However, some other tested microphones that seemed to require a higher bias voltage, had too weak output volume for µPGV, so only the three above mentioned are recommended.